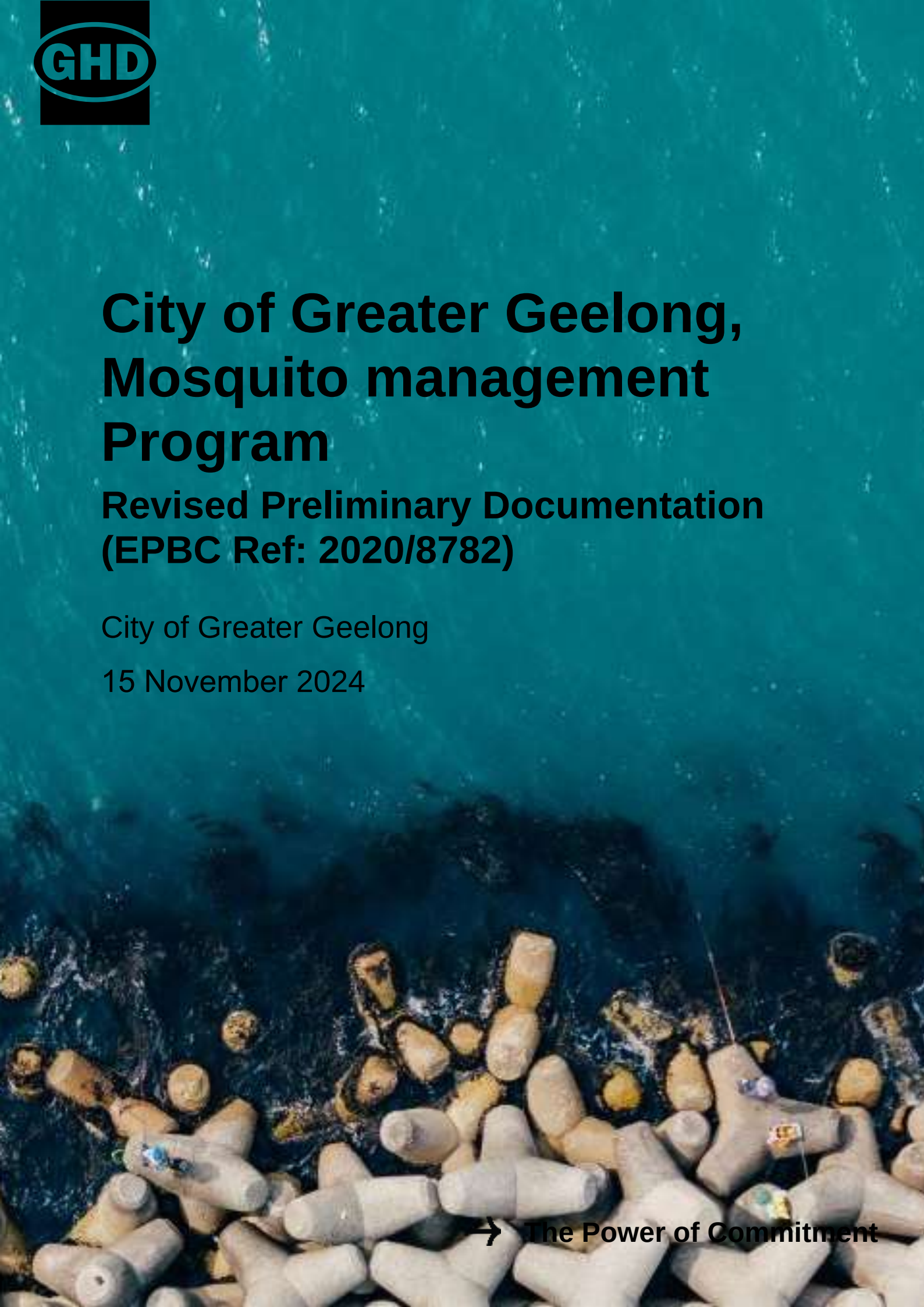
City of Greater Geelong, Mosquito management Program

Revised Preliminary Documentation (EPBC Ref: 2020/8782)

City of Greater Geelong

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The Power of Commitment

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Executive Summary

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the Report.

Proposed action

The City of Greater Geelong proposes to undertake a mosquito management program within the City of Greater Geelong municipality (the City) and in the bordering Borough of Queenscliffe and Surf Coast Shire. The proposal was referred to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) on 12 October 2020 and was deemed a controlled action on 12 November 2020.

The purpose of this report is to address the Preliminary Documentation information required by the Minister under section 95A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the assessment of the relevant impacts to the proposed action - City of Greater Geelong, Mosquito management Program (EPBC 2020/8782). This report enables interested stakeholders, the general public and the Minister to understand the expected environmental consequences of the proposed development on protected matters and any relevant social and economic considerations.

The proposed action is to apply larvicide (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) to mosquito breeding sites by ground-based and aerial application in the proposed action area, which includes portions of the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site. The City is required to provide mosquito management in the form of the proposed program to reduce mosquito numbers in the community. This minimises health risks associated with mosquito-borne diseases and reduces the impact of biting insects on the health and wellbeing of the community.

The City proposes to operate the six-year program from late 2024 through to late 2030. The program will continue the activities described for the current program (refer permit EPBC 2005/2132) including:

– Monitoring of adult and larvae mosquitos at breeding sites
– Review of monitoring results to determine the need for and type of treatment
– Treatment of up to 52 sites (9 ground-based and 43 aerial) over the course of the six-year program
– Ecological studies
– Annual reporting in line with current reporting requirements
– Community education

The aerial treatment program will operate from 15 August to 15 March each year and the ground-based treatment program will operate from 15 August through to 31 May each year. Generally, mosquito larvae numbers are low during the winter months and, as a result, monitoring and treatment during this period is minimal.

Relevant matters of national environmental significance

The following matters of national environmental significance (MNES) were found to be relevant to the proposed action and were assessed for potential impacts.

Listed threatened species and communities

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine.

Listed migratory species

– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Migratory, Marine.

Additional species

According to the likelihood of occurrence assessment (Appendix G), a further three species that are newly listed as threatened under the EPBC Act could also be impacted by the proposed action – these species were also assessed for potential impacts:

– Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable, terrestrial bird species
– Common Greenshank (*Tringa nebularia*) - Endangered, migratory shorebird
– Sharp-tailed Sandpiper (*Calidris acuminata*) - Vulnerable, migratory shorebird

Ramsar wetland

– Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.

Potential impacts and management

The identification of potential impacts and impact analysis was undertaken in a staged approach. A detailed review of existing information and literature was undertaken to firstly identify the potential impacts relevant to the proposed action. This included reviewing:

– Potential impacts described in the previous referral (2005/32) and DCCEEW's preliminary documentation request
– DCCEEW's referral database and other published information for other projects involving similar mosquito management programs
– The findings of a literature review of potential direct and indirect impacts on MNES from the use of *Bacillus thuringiensis israelensis* (Bti) and S-methoprene
– The City's desktop and survey reports for Migratory bird monitoring and seasonal behaviour and the Orange-bellied Parrot (completed by GHD between 2018 and 2020)

The impact analysis considered a variety of aspects and applied this knowledge to derive potential impacts on MNES, which were categorised into closely aligned fauna groups for a succinct analysis, with the exception of unique species such as the Orange-bellied Parrot, Blue-winged Parrot and Growling Grass Frog. Fauna groups considered were:

– Resident Shorebirds/seabirds: Eastern Hooded Plover, Fairy Tern
– Migratory Shorebirds: Eastern Curlew, Curlew Sandpiper, Greater Sand Plover, Great Knot, Lesser Sand Plover, Red Knot, Bar-tailed Godwit, Sharp-tailed Sandpiper, Red-necked Stint, Common Greenshank and Sharp-tailed Sandpiper
– Wetland Birds: Australasian Bittern and Australian Painted Snipe
– Fish: Australian Grayling and Yarra Pygmy Perch

The aspects that were considered in the impact assessment included:

– The potential impacts described in the previous referral (2005/2132)
– Measures outlined in the conditions of approval for the referral
– The nature of the proposed action, including treatment types, frequency and areas, and that it will not remove or modify any habitats for any species
– Field survey outcomes for the mosquito management program in relation to aerial treatment and potential impacts to MNES, particularly migratory shorebird species
– Outcomes of the literature review
– Occurrence of the species within the proposed action area, habitat requirements and foraging behavior

– EPBC Act Policy Statement Significant Impact Guidelines 1.1 - Matters of National Environmental Significance
– Recovery plans for species, where relevant
– Cumulative impacts on MNES from surrounding projects or activities that are planned, approved or currently in construction

The impact assessment and literature review found that there are no predicted long-term ecological impacts associated with the proposed action, however there will be some impacts. These include:

– Short term and temporary disturbance as a result of agricultural drone movements during aerial treatment
– Medium risk of exposure to larvicide products by four threatened species, although it is considered unlikely that any species would experience prolonged exposure given the short life of the larvicide products, time between seasonal treatments and the small area of habitat affected by treatment, compared to surrounding available untreated habitats in the local area
– Ongoing use of the two larvicide products resulting in potential indirect impacts to non-target invertebrate fauna beyond the life of the proposed program

The impact analysis of the proposed action against the 'impact criteria' of the Significant Impact Guidelines 1.1 indicates that significant impacts (direct and indirect) to MNES are unlikely. Despite this conclusion, the City will implement several mitigation measures, as outlined in section 5, to minimise potential impacts as far as practicable.

This will include monitoring for potential impacts, enabling mitigation measures and the mosquito management program to be adapted to avoid and further minimise impacts to MNES within the proposed action area. The measures aim to continue and build upon the avoidance and minimisation strategy implemented by the City as part of its former program under permit EPBC 2005/2132. The measures also provide a mechanism for the City to regularly monitor and report the progress of the proposed action throughout the proposed six-year mosquito management program and determine the effectiveness of the monitoring following independent review. The City has also incorporated an adaptive management approach to accommodate new information regarding MNES species, particularly the Orange-bellied Parrot and additional information arising from the proposed aquatic invertebrate monitoring program.

Residual impacts and offsets

With the implementation of the mitigation measures and mechanisms for adaptive management, the residual impacts on the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site, shorebirds/seabirds, migratory shorebirds, wetland birds, fish, the Orange-bellied Parrot, Blue-winged Parrot and the Growling Grass Frog are expected to be negligible and unlikely. As a result, the proposed action will not require an offset package to be developed.

Environmental outcome

This response to Preliminary Documentation Request for the proposed action is evidence of due process and careful consideration around the potential social and environmental trade-offs. Alternative options have also been considered. The impact assessment and social and economic considerations as detailed in this document demonstrate the implications of doing nothing.

The City will implement measures to mitigate risks and potential impacts from the main sources of threat to MNES posed by the proposed action, as far as practicable. The City aims to achieve a proposed environmental outcome where no significant impacts (direct or indirect) on MNES would occur from the proposed action.

The integration of environmental and social considerations is inherent in the overall purpose of the program and will be maintained through ongoing monitoring and risk-based prioritisation of mosquito-treatment sites.

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1. Introduction

1.1 Purpose of this report

The purpose of this report is to address the Preliminary Documentation information required by the Minister under section 95A of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the assessment of the relevant impacts to the proposed action – City of Greater Geelong, Mosquito Management Program (EPBC 2020/8782, previously called the Mosquito Control Program). The City of Greater Geelong (the City) proposes to apply mosquito larvicide within the City's municipality on lands managed by Parks Victoria, and in the bordering Borough of Queenscliffe and Surf Coast Shire. The application of larvicide will consist of two active constituents (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) into mosquito breeding sites by ground-based and aerial application which includes portions of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. The City's previous permit to apply larvicide within the Ramsar site has expired (EPBC 2005/2132) and the City is required to provide mosquito management in the form of ground and aerial treatments to reduce the impacts of arboviruses and nuisance from mosquitoes to the community.

The City most recently submitted a referral for the continuation of the mosquito management program (EPBC 2020/8782) using both aerial (by helicopter) and hand methods to deliver the mosquito management products to the treatment sites. This was determined to be a controlled action due to the potential impacts on Matters of National Environmental Significance (MNES). The relevant controlling provisions of the decision include:

– Ramsar wetlands (sections 16 & 17B)
– Listed threatened species and communities (sections 18 & 18A)
– Listed migratory species (sections 20 & 20A)

The City has recently reviewed its program, and particularly its delivery method, as the use of helicopters is no longer feasible due to their availability and cost. The City is now proposing the use of an agricultural drone to complete the aerial delivery of mosquito management product to treatment sites. Switching to the use of drones has brought about a rationalisation of treatment sites and treatment frequencies to better reflect the potential treatment area of the project, and to make projections with regard to the seasonal application rate of larvicide. The use of agricultural drones makes the program more efficient, flexible and effective at responding to potential future areas of mosquito breeding compared to the program described in the original referral. Most importantly, the use of agricultural drones to deliver targeted and smaller payloads of larvicides will reduce the overall volume of mosquito management product applied to the project area, including the Ramsar site and sites of value to listed threatened and migratory species.

The City also proposes that ecological studies are conducted in conjunction with the larvicide treatment program for up to six years, from late 2024 to late 2030. The ecological studies will be used to develop a self-assessment tool that the City can use to determine if application of larvicide and use of a drone in the Ramsar wetland has a significant impact on Matters of National Environmental Significance (MNES) found in these sites. This self-assessment tool will enable the City to determine whether the application of larvicides impacts a protected matter, and employ appropriate management strategies developed throughout the ecological studies.

Throughout this six-year period, the City may conduct activities such as:

– Monitoring of adult and larvae mosquitos at breeding sites
– Review of monitoring results to determine the need for and type of treatment
– Treatment of up to 52 sites (9 ground-based and 43 aerial) over the six-year period
– Ecological studies
– Annual reporting
– Community education

In the past, all ground-based and aerial mosquito treatment in this project area has occurred between 15 August and 15 March. The City has not undertaken aerial mosquito treatments in April to July of any year, due to the local seasonality of mosquitoes, and to comply with conditions of the previous EPBC approval (EPBC 2005/2132), which restricted treatments after 15 March due to the breeding pattern of the Orange-bellied Parrot.

In recent years, the City has documented a shift in the mosquito season, with mosquitoes now breeding through and beyond March, and therefore the City proposes to extend the ground-based treatment period to the end of May in order to better protect public health and reduce levels of mosquitoes and mosquito-borne diseases in the community. The City proposes only ground-based treatments to continue beyond 15 March through to 31 May, and only if mosquito triggers have been met via on-ground surveillance. In order to avoid impacts to the Orange-bellied Parrot and reduce the potential for impacts on other Matters of National Environmental Significance (MNES), aerial treatments would continue to only occur between 15 August and 15 March. Timeframes are further discussed in section 2.1.

The purpose of the preliminary documentation is to enable the Minister, the general public and interested stakeholders to understand the expected adverse environmental consequences of the proposed development on protected matters, and any relevant social and economic considerations.

The proposed action area and treatment sites, and a comparison between the previous and current referrals' action area and treatment sites are described in section 2.2 and 2.4.

1.2 Key term and definitions

The following key terms and definitions apply to the proposed action.

Action – comprises the City of Greater Geelong mosquito management program (the proposed program) within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire. The proposed action is to apply larvicide (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) to mosquito breeding sites by ground-based and aerial application in the proposed action area, including portions of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.

Aerial sites – defined as mosquito breeding sites that cannot be treated by ground-based application. These sites can only be accessed via drone. There are 43 aerial sites listed in the proposed action area and they include large natural wetland/waterbody areas away from residential areas. They are generally large areas that have no, or very limited, access for manual application. Most areas are too large and near impossible to treat effectively and efficiently by hand – it is generally cost prohibitive and would likely to take too long to be effective. Some aerial sites may be treated multiple times during a season, once during a season or occasionally (every 2-3 years) over the course of the six-year program.

Ground-based sites – defined as mosquito breeding sites that are not treated by drone application. These sites can be accessed manually using a vehicle or 'on foot.' There are nine of these sites listed in the Geelong region and they include roadside pits and drains, constructed wetlands and freshwater lakes/ponds/easements within residential areas. They are generally smaller areas within townships and are considered too close to roads, houses or power lines and infrastructure for safe aerial treatment. In addition, sometimes when only a small section of the larger site has high larvae numbers, it is more cost effective to treat those areas by ground-based methods. Some sites may be treated multiple times during a season, once during a season or occasionally (every 2-3 years) over the course of the six-year program.

Proposed action area – defined by the area of the nine ground-based sites and 43 aerial treatment sites within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire.

Program treatment area – defines the maximum extent of the area (ha) to be treated for each site over the course of the proposed six-year program.

Season – defines the annual operational period for the proposed program over the course of approximately 10 months. This is the period that the City proposes to apply larvicide to mosquito breeding sites, with consideration to the conditions of the approval. The City proposes to apply aerial treatments between 15 August and 15 March each year and ground-based treatments between 15 August and 31 May each year. Note: the start date for the 2024- 2025 season program will ultimately be determined by the approvals process.

Treatment – defined as the application of larvicide to a mosquito breeding site by hand or drone over the course of one day. A site is only ever treated once during a treatment period but may be treated multiple times during a season.

Treatment period – is the period encompassing the treatment of multiple sites by drone or hand over the course of one day. Treatment periods vary (e.g. 2 hours to 8 hours) depending on the number of sites requiring treatment during that day.

1.3 Scope and limitations

This report has been prepared by GHD for the City of Greater Geelong and may only be used and relied on by the City of Greater Geelong for the purpose agreed between GHD and the City of Greater Geelong.

GHD otherwise disclaims responsibility to any person other than the City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

This report is a draft document only.

1.4 Relevant matters of national environmental significance

From the information provided to date, the Department of Climate Change, Energy, the Environment and Water (DCCEEW) considers that the protected matters that may be significantly impacted by the proposed action include, but are not limited to:

Listed threatened species and communities

- Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
- Growling Grass Frog (*Litoria raniformis*) – Vulnerable
- Australian Grayling (*Prototroctes maraena*) – Vulnerable
- Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
- Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine

Listed migratory species

- Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
- Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
- Sharp-tailed Sandpiper (*Calidris acuminata*) – Migratory, Marine[1]

Additional species

According to the likelihood of occurrence assessment (Appendix G), a further three species that are newly listed as threatened under the EPBC Act could also be impacted by the proposed action:

- Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable, terrestrial bird species
- Common Greenshank (*Tringa nebularia*) - Endangered, migratory shorebird
- Sharp-tailed Sandpiper (*Calidris acuminata*) - Vulnerable, migratory shorebird

[1] Listed as Vulnerable under EPBC Act 5th January 2024

The ecological character of a declared Ramsar wetland

– Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site

A Protected Matters Search on 31 January 2024 was completed for the proposed action area (Appendix C). Further information regarding each MNES is provided in section 3.

1.5 Variations

Since the City's referral of the proposed action on 12 October 2020, two variations to the referred proposed action have occurred. These variations are described below and summarised in Table 1 and Table 2.

1.5.1 Variation 1

On 23 September 2021, the City provided DCCEEW with an updated project description as part of the preliminary documentation. Upon review, DCCEEW conveyed that the differences between the original referral and the updated project description are of a scale that warrants a formal variation under section 156A of the EPBC Act.

The City engaged GHD to prepare a formal variation, with the requested changes pertaining to an increase in the total area of the proposed treatment sites / project footprint by 2,274.36 hectares (ha). The variation did not alter the outcome of the assessment of the project against the significant impact criteria under the EPBC Act, as presented in the original EPBC referral.

Pursuant to section 156B of the EPBC Act, the character of the varied proposal was substantially the same as the character of the original referral, including in relation to changes to:

1. The nature of the activities proposed to be carried out in taking the action; and
2. The nature and extent of the impacts the action is likely to have on the matter protected by each provision of Part 3.

On 22 March 2022, DCCEEW accepted the variation to the proposal. This information is published on the DCCEEW's website.

Table 1 Variation 1 requested changes

Project aspect	Key change
Proposed action area	Additional 2,274.36 ha
Action	No change to the project concept or its core components of the project
Larvicide application rates	No projected significant increase in the application rate or type of larvicide product applied between the original referral and the revised referral.
Seasonal treatment frequency and area	No projected significant change in the seasonal treatment frequency between the original referral and the revised referral.
Timing of action	Reduced timelines
Impacts to MNES	No significant changes

1.5.2 Variation 2

Following further internal consideration, the City determined that using helicopters to deliver the application of mosquito larvicide was no longer plausible due to cost and availability factors. On 17 October 2023, the City provided an updated project description to DCCEEW to outline the proposed changes to the proposed action. DCCEEW determined that the proposed changes to the action were of a scale that warranted a formal variation under Section 156A of the EPBC Act.

Subsequently, the City re-engaged GHD to prepare a formal variation, which is currently being considered by DCCEEW. The variation request relates to a proposed change in the project's aerial delivery method (using a drone instead of a helicopter), the reduced project duration, and a reduction in the number of treatment sites as well as the total treatment area. These changes are detailed in Table 2.

Table 2 Variation 2 requested changes

Project aspect	Previous referral (20 October 2020)	Proposed variation (Variation 2)
Number of sites (ground and aerial)	72	52
Aerial delivery method	Helicopter	Drone
How many ground-sites went to aerial	-	9
Total treatment area (ha)	4,269.76	3,279.72
Total treatment area (ha) within or adjacent Ramsar site	4,161.01	3,208.91
Total cumulative treatment area (ha)	8,574.82	4,145.07
Maximum amount of product used (S-methoprene) (kg)	8,057.283	2,551.041
Maximum amount of product used (Bti) (kg)	48,553.588	24,829.549
Duration of program	10 years	6 years

Pursuant to section 156A of the EPBC Act, both variations were prepared to meet the requirements of the EPBC Regulations 2000 and included:

– Details of the proposed variation to the action
– The reasons for the proposed variation
– How the impacts of the proposed variation on matters of national environmental significance compare with those of the original proposal
– If applicable, the impacts of the proposed variation on Matters of National Environmental Significance (MNES) not considered in the referral or assessment of the original proposal
– If applicable, alternatives, mitigation measures and offsets to compensate for additional impacts on matters of national environmental significance

With the use of drones to deliver the product, there is a decrease in the total treatment area by ground and aerial delivery, both seasonally and cumulatively. This is in part due to an overall reduction in the total number of sites from 72 to 52, but also a significant reduction in the total treatment area of approximately 23% between the previous referral and the current proposed referral (variation 2). Aerial application by drone provides increased ease of access compared to a helicopter.

Table 3 summarises the previous and proposed seasonal and cumulative treatment areas, for each of the aerial treatment sites that are now included in the proposed action (note that where there is no data provided in Table 3, this is because the site was previously a ground-based treatment site). Across the total duration of the program, the area that is to be treated via aerial delivery is less than half of the total area calculated in the previous referral.

The largest reduction in scope is seen in the total amount of product to be used across the entire program for both S-methoprene (approximately 67% less) and Bti (approximately 48% less), when compared to the proposed action as defined in the previous referral. This is due to the refinement of treatment areas to match the capacities of an agricultural drone, and the change from a 10-year program to a six-year program.

Table 3 Summary comparison of all sites now to be conducted by aerial drone from previous proposal to new proposed action

Site no.	Site description	Previous seasonal treatment area (ha)	Proposed seasonal treatment area (ha)	Previous program cumulative treatment area (ha)	Proposed program cumulative treatment area (ha)
2.17	**SOUTHERN LAKE VICTORIA**	4.55	**4.55**	45.46	**27.27**
2.4	**COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK**	1.43	**1.43**	14.33	**8.60**

Site no.	Site description	Previous seasonal treatment area (ha)	Proposed seasonal treatment area (ha)	Previous program cumulative treatment area (ha)	Proposed program cumulative treatment area (ha)
2.5	**COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK**	3.79	**3.79**	37.90	**22.76**
2.7	**LONSDALE LAKES WILDLIFE RESERVE**	0	**13.64**	-	**81.82**
3.1	**OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER**	8.5	**8.5**	85.03	**51.02**
3.8	**OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK**	10.75	**10.75**	107.47	**64.48**
3.9	**WALLINGTON RD, WETLAND DRAINS LINGS RD**	8.47	**8.47**	84.68	**50.81**
3.10	**PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER**	14.58	**14.58**	145.78	**87.47**
3.11	**PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS**	31.22	**31.22**	312.16	**187.29**
3.12	**PACEY'S HILL WALLINGTON SWAMP**	5.43	**5.43**	54.32	**32.59**
3.13	**SALTWATER RIDGE (LAKE CONNEWARRE EAST)**	35.08	**35.08**	350.75	**210.45**
3.14	**WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY**	5.41	**5.41**	54.05	**32.43**
4.1	**MARSH BEHIND HOUSES CLIFF ST – LOWER BLUFF**	0	**11.35**	-	**68.12**
4.12	**SALT LAGOON IBBOTSON ST WEST SIDE**	0	**8.96**	-	**53.76**
4.6	**SWAN BAY NORTH, PT EDWARDS RESERVE**	21.17	**21.17**	211.70	**127.02**
5.1	**PT RICHARDS MARSH SWAMP FORESHORE**	0	**1.22**	-	**7.32**
5.3	**PITS AND PIPES SURVELLANCE (BOAT RD)**	0	**1.64**	-	**9.84**
7.1	**SWAN BAY NORTH, KNIGHTS RD**	42.47	**42.47**	424.67	**254.80**
7.2	**SWAN BAY – NYE RD WETLANDS**	2.91	**2.91**	29.05	**17.43**
7.3	**SWAN BAY – IBBOTSON ST**	17.68	**17.68**	176.82	**106.09**
7.5	**SWAN BAY JETTY NORTH AND SOUTH SIDE**	93.33	**93.33**	933.32	**559.99**
8.1	**BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT**	37.92	**37.92**	379.15	**227.49**
8.2	**REAR 90 CARR ST SALT MARSH AND DRAINS**	0	**48.84**	-	**293.04**
8.4	**REAR OF SCHOOL – LAKE MURTNAGHURT PERIPHERY**	21.90	**21.90**	219.03	**131.42**
8.7	**BARWON HEADS LEVY BANK & DRAINS & WETLANDS**	0.62	**0.62**	6.18	**3.71**
8.9	**JIRRALINGHA – PONDS AND WETLANDS**	0	**4.98**	-	**29.88**

Site no.	Site description	Previous seasonal treatment area (ha)	Proposed seasonal treatment area (ha)	Previous program cumulative treatment area (ha)	Proposed program cumulative treatment area (ha)
8.13	**LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)**	23.09	**14.84**	230.91	**89.07**
8.14	**LAKE CONNEWARRE, BACKWATERS**	10.77	**10.77**	107.70	**64.62**
8.18	**SALT SWAMP, BACK OF LAKE CONNEWARRE**	12.60	**12.60**	126.03	**75.62**
9.1	**BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)**	29.13	**29.13**	291.32	**174.79**
9.2	**BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)**	2.61	**2.61**	26.06	**15.64**
9.3	**BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)**	3.83	**3.83**	38.29	**22.97**
9.5	**BREAMLEA SALTMARSHES BLACKGATE RD**	20.67	**20.67**	206.75	**124.05**
10.7	**LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD**	6.35	**6.35**	63.50	**38.10**
10.8	**REEDY LAKE PERIPHERY**	65.64	**65.64**	656.35	**393.81**
11.2	**PT HENRY FORESHORE MARSH & PONDS WINDMILL RD**	1.82	**1.82**	18.24	**10.94**
11.6	**ALCOA WETLANDS – LAGOONS**	0	**3.88**	-	**23.28**
11.8	**DRAIN BEHIND ANIMAL HEALTH LAB**	0	**1.92**	-	**11.52**
14.1	**MURRAY ST DRAINS & MARSH NTH & STH OF RAIL**	0	**5.41**	-	**32.46**
14.3	**SWAN BAY BURNT PT END OF FELLOWS RD**	17.57	**17.57**	175.72	**105.43**
14.4	**SWAN BAY BURNT PT END OF FELLOWS RD**	9.59	**9.59**	95.87	**57.52**
14.8	**CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY**	0	**0.23**	-	**1.35**
15.8	**BREAMLEA TIDAL WETLAND LAKES (4 LARGE)**	16.45	**16.45**	164.55	**98.73**
	TOTALS	587.33 ha	**681.34 ha**	5,873.14 ha	**4,086.81 ha**

*The previous seasonal treatment area is a smaller value due to moving some ground sites to aerial in the current proposed action, as outlined in previous sections. The current proposed cumulative treatment area column shows the overall reduction of treated area for the duration of the program, with less than half the previous area needing to be treated.

2. Description of the action

2.1 The proposed action

The proposed action comprises the City of Greater Geelong mosquito management program (the proposed program) within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire.

The City proposes to operate the six-year program from 2024 through to the end of 2030. The program will continue the activities described for the current program (refer permit EPBC 2005/2132), including:

– Monitoring of adult and larvae mosquitos at breeding sites
– Review of monitoring results to determine the need for and type of treatment
– Treatment of up to 52 sites (9 ground-based and 43 aerial) over the course of the six-year program
– Ecological studies
– Annual reporting in line with current reporting requirements
– Community education

The proposed action area and treatment sites are described in sections 2.2 and 2.4.

The proposed program will operate in line with the Victorian Government's 2004 Framework for Mosquito Management in Victoria, as well as Australian and international best practice guidelines. It will consist of a combination of activities including monitoring of larvae abundance, ground-based (manual/applied by hand) treatments and aerial (drone) treatments of larvae in mosquito breeding sites.

The aerial treatment program will operate from 15 August to 15 March each year and the ground-based treatment program will operate from 15 August through to 31 May each year. Generally, mosquito larvae numbers are low during the winter months and, as a result, monitoring and treatment during this period is minimal.

The main mosquito species found in this region is *Aedes camptorhynchus*, a salt-water breeding mosquito that is capable of surviving a broad range of climatic conditions. Its breeding habitat includes the many regional salt marshes around the City. Another predominant mosquito species is *Aedes notoscriptus*. This species breeds in temporary ponds of stagnant fresh water, including domestic containers that fill with rainwater. Its presence often indicates household breeding sources like pot plant bases and blocked drains or gutters.

Mosquito breeding sites within the City will be monitored on a rotating basis. If larvae are found, staff will determine the most effective treatment method for the site (see section 2.4.4). Sites are either treated manually or recommended for aerial drone treatment. A 4WD vehicle may be used to access heavily vegetated breeding sites for manual treatment.

Monitoring will include setting light traps around the municipality to survey adult mosquito numbers. The AgriBio Centre at LaTrobe University will be engaged to determine the species and sex of adult mosquitoes and to test the mosquitoes for viruses. This helps to identify any emerging arbovirus issues and potential mosquito breeding sources.

The City will continue to use two mosquito control products for larval management, *Bacillus thuringiensis israelensis* (Bti) and S-methoprene. Both are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA). These products target specific aspects of the mosquito larvae biology. All forms of larvicide used for the proposed mosquito management program are delivered in non-liquid form (e.g. granules, sand, pellets or briquets).

Although the conditional requirements of EPBC 2005/2132 have formally expired, the proposed program will continue to follow the conditional requirements of the EPBC 2005/2132. In particular, to minimise impacts on Orange-bellied Parrot at the Swan Bay and Lake Connewarre treatment sites:

– No aerial treatment must occur at either site between 15 March and 15 August
– Low level (below 40 m) aerial treatment may occur between 16 August and 14 March at Lake Connewarre site

– Low level (below 40 m) aerial treatment may occur between 16 November and 14 March at Swan Bay
– Low level (below 40 m) aerial treatment may only be undertaken at the Swan Bay site between 16 August and 15 November if surveys taken 24 hours prior to treatment confirm the Orange-bellied Parrot is not present at this site

The proposed program does not involve the removal or modification of any native vegetation or fauna habitat.

2.2 Location, boundaries and size of the area that will be subject to larvicide application (proposed action area)

2.2.1 Purpose

Provide the location, boundaries and size (in hectares) of the area that will be subject to larvicide application, and any adjoining areas, including the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, which may be indirectly impacted by the proposed action, including mapping.

2.2.2 Location and size of the proposed action area

The extent of the proposed action area is defined by the area of the nine ground-based sites and 43 aerial treatment sites within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire. The combined area for these sites is 3,279.72 ha, consisting of 22.41 ha of ground-based treatment sites and 3,257.31 ha of aerial treatment sites.

The program treatment area is the area that will be subject to larvicide application and defines the maximum extent of the area for each site to be treated over the course of the six-year program. See section 2.4.7 for greater detail regarding the number and extent of treatment sites.

The majority of the proposed action area is within the Bellarine Peninsula and includes the following major towns: Geelong, Barwon Heads, Point Lonsdale, Queenscliff, Ocean Grove and Breamlea. The total area of the Bellarine Peninsula that incorporates the proposed action area is more than 55,000 ha. The proposed treatment area is less than six per cent of the total area of the Bellarine Peninsula, and less than 15% of the entire Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.

The total area of all the treatment sites is useful to understand the geographic extent of the sites and the potential total area that could be treated over time (i.e. six years). However, it is not an accurate representation of the area proposed for larvicide application for each treatment (i.e. each day), particularly for the sites subject to aerial treatments. The area of each site represents the entirety of the area that may be treated over the course of the six-year program, however each treatment tends to cover only a small portion of each site. For example, site 10.8 is Reedy Lake Periphery (c. 817.5 ha) – a large intermittent freshwater lake or swamp on the lower reaches of the Barwon River. Like the majority of aerial treatment sites, it includes areas unlikely to provide mosquito breeding habitat (i.e. not targeted for treatment). A very small portion of the site (65.64 ha or eight per cent of the site) will be treated each season and restricted to the margins of the site where the mosquito habitat occurs. The City may need to treat different locations with suitable mosquito habitat within the program treatment area over the course of the six-year program, and the proposed action area therefore includes all those areas that may receive treatment within this timeframe.

Due to the operational limitations of the drone, a buffer of 400 m from land has been used to calculate application areas for each site; this is because it is still unknown how far past 400 m an agricultural drone can extend and still maintain line of sight for the pilot at each aerial site. This has resulted in the reduction in larger sites such as Reedy Lake and Lake Connewarre but has also allowed previously proposed ground sites to become aerial sites due to ease of access.

Treatment sites within the Ramsar site and other reserves

A review of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Boundary was undertaken recently and closed on 17 of June 2022. This review will potentially result in the inclusion of more public land under the EPBC legislation. Therefore, the City has included these sites pre-emptively within the action area to ensure they are considered in the overall mosquito management program. The sites that are being included within the City's proposal based on the potential future inclusion within the Ramsar site boundary are:

– Site 2.7 – Lonsdale Lakes Wildlife Reserve
– Site 4.12 – Salt Lagoon Ibbotson Street West side
– Site 9.1 – Breamlea saltmarshes A (East side of Breamlea Road)
– Site 9.2 – Breamlea saltmarshes B (West side of Breamlea Road
– Site 9.3 – Breamlea saltmarshes C (South side close to town)
– Site 9.5 – Blackgate Road
– Site 15.8 – Tidal wetland lakes (4 large)

There are three ground treatment sites and 38 aerial treatment sites comprising approximately 3,208.91 ha located within or adjacent to the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. The Ramsar site occupies approximately 22,650 ha. Table 14 and Table 15 in section 2.4.7 list all proposed treatment sites within or adjacent to the Ramsar site.

In addition to the Ramsar site consideration, the proposed action will take place on state and private land tenures including the following nature/conservation reserves:

– Lake Connewarre Wildlife Reserve including Reedy Lake (within Ramsar site)
– Swan Bay including Swan Bay – Edwards Point Wildlife Reserve (within Ramsar site)
– Lake Murtnaghurt (eastern portion within Ramsar site)
– Point Lonsdale and Queenscliff Foreshore Reserves (partially within Ramsar site)
– Ocean Grove Nature Reserve
– Salt Lagoon/St Leonards Wildlife Reserve
– Breamlea Flora and Fauna Reserve, Breamlea Coastal Reserve and Breamlea Recreation Reserve
– Lonsdale Lakes Wildlife Reserve
– Lake Campagna
– Portarlington (Point Richard) Flora and Fauna Reserve

2.3 Project context

2.3.1 Purpose

Provide contextual information on the project, including its objectives and rationale, its relationship to statutory policies, plans and strategies, including the justification for need and selection of the project and implications of the project not proceeding.

2.3.2 Objectives and rationale

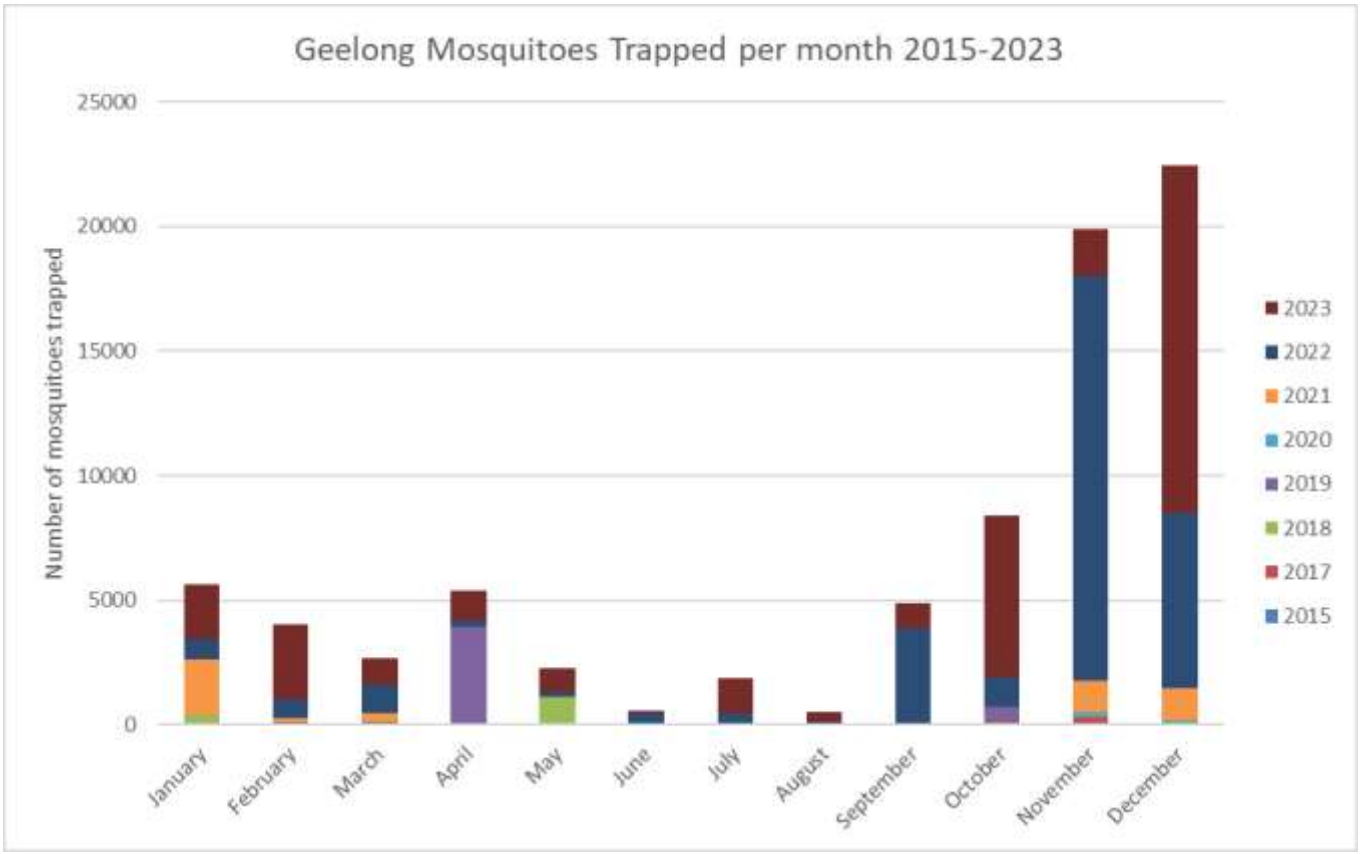
The objective of the proposed mosquito management program is to continue to reduce mosquito numbers in the community. This aims to minimise health risks associated with mosquito borne diseases and to reduce the impact of biting insects on the health and wellbeing of the community and the ability to enjoy the environment. The effective control of mosquitoes in the community is of considerable importance given their impact on public health in the form of diseases such as Ross River Virus (RRV), Barmah Forest Virus (BFV) and Murray Valley encephalitis (MVE) and the detrimental impact mosquitoes have on the community's outdoor lifestyle. The proposed program will operate in line with the Australian and Victorian Governments' best practice guidelines (*e.g. 2004 Framework for Mosquito Management in Victoria*) as well as international best practice.

The City of Greater Geelong is committed to reducing the risk of disease in, and the nuisance value of mosquitoes to, the community by implementing a mosquito management program. The proposed program would employ several control techniques to collectively contribute to the management of mosquitoes, and this program has been developed with consideration of environmental impact and cost effectiveness.

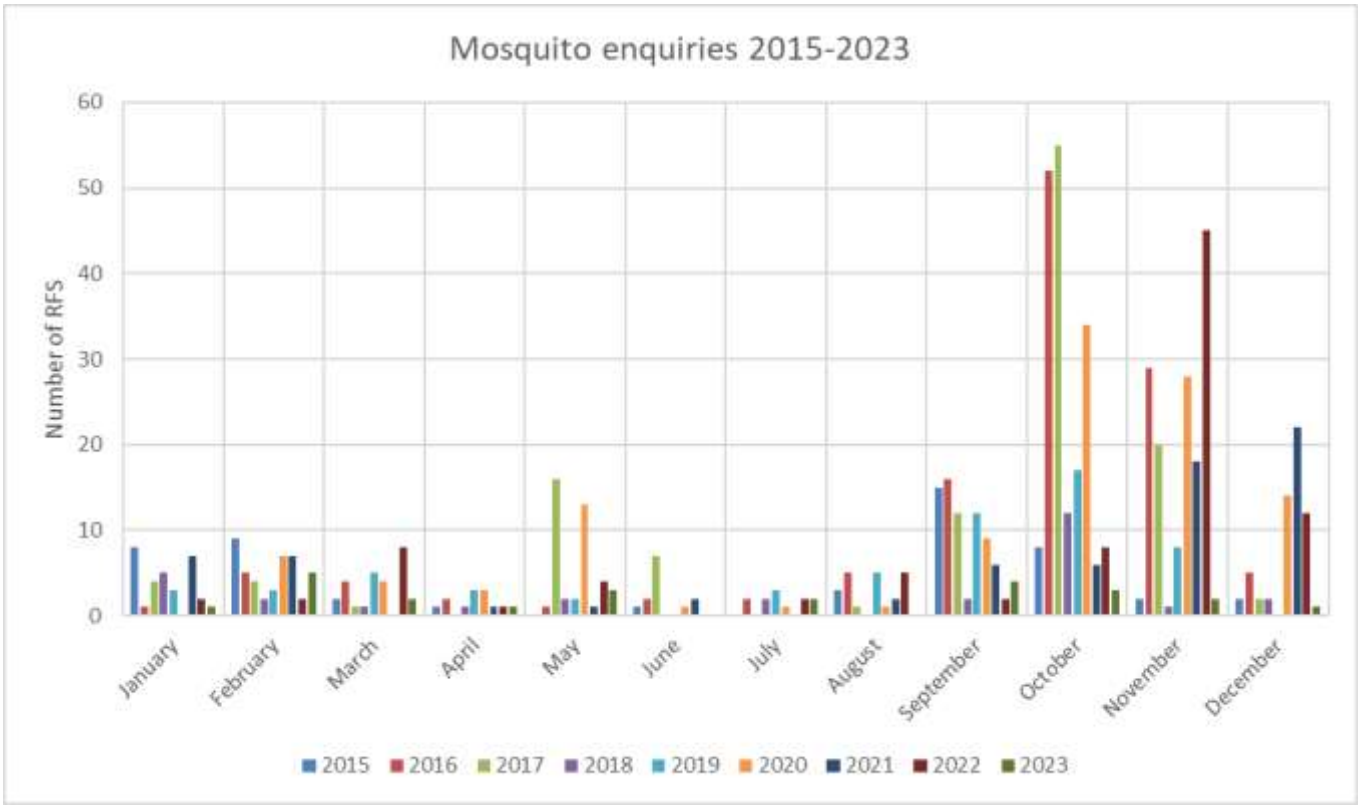
Since 1974, the Victorian Government has worked with other agencies including local governments to deliver an integrated mosquito management program. It is up to each Council to determine the measures best suited to their needs, with the focus on reducing the risk of spread of mosquito-borne diseases, including RRV and MVE.

In 2019, the City of Greater Geelong had its mosquito management program externally reviewed, with recommendations provided in relation to new approaches to managing mosquitoes in the Geelong area. The review noted that long-term climate change can influence mosquito management operations, especially when increased or unexpected mosquito activity occurs outside the normal mosquito season. Areas in NSW have seen increased activity of mosquitoes in early spring and late autumn. As such local authorities responsible for managing mosquitoes may need to consider expanding monitoring or control programs outside traditional periods. Many mosquito management programs, including the City of Greater Geelong's program, are undergoing critical analysis and considering what effect changing climate conditions may have on their programs, including the long-term effectiveness of the traditional operational schedule.

Historically, mosquito management operations in the City of Greater Geelong have occurred between August and March each year, when mosquitoes were in greatest numbers. The City of Greater Geelong has noticed a shift in the traditional mosquito season that may be attributed to changing weather patterns. While operating under the previous EPBC approval (2005-2020), the number of mosquito treatments required in August (at the start of the mosquito season) has reduced, with low larvae and adult mosquito numbers being detected during this time. Only two aerial treatments have been required during August since the 2014/2015 season. Additionally, high mosquito numbers have been detected at the opposite end of the mosquito season, with both increased numbers of adult mosquitoes trapped in light traps in Geelong (Graph 1) and increased numbers of mosquito-related enquiries made to the City in May each year since 2014 (Graph).



Graph 1 ***Number of mosquitoes trapped per month between 2015-2023 (all Geelong monitoring sites combined).***



Graph 2 ***Number of enquires each month between 2015-2023***

The City has not historically undertaken aerial mosquito treatments between April to July due to the conditions of the EPBC approval that restrict treatments after the 15 March. Given the shift in mosquito season, the City proposes to extend the treatment period for ground-based treatments to the end of May in order to protect public health and reduce levels of mosquitoes and mosquito-borne diseases in the community. The City proposes ground-based treatments to continue beyond the 15 March through to 31 May, if mosquito triggers have been met via on-ground surveillance. These triggers would include high larvae counts detected in monitoring points in Lake Connewarre and Swan Bay, and high adult mosquito counts in mosquito traps in residential locations near these wetlands. To continue to avoid impacts on the Orange-bellied Parrot, the City will not undertake aerial treatments between 15 March and 15 August.

2.3.3 Statutory policies, plans and strategies

The 2004 *Framework for mosquito management in Victoria* provides guidance for the development of mosquito management programs throughout the State. The framework provides information about legislation, risk management, mosquito management and developing a local management program.

The Victorian *Public Health and Wellbeing Act 2008* empowers the Department of Human Services and Councils as their agents to direct owners and occupiers of land to carry out measures to reduce the incidence of mosquito breeding to prevent mosquito-borne diseases. In practice, most mosquito management takes place on public land and Councils, including the City of Greater Geelong, implement mosquito management activities rather than directing other agencies to do so. Under section 24 of the Victorian *Public Health and Wellbeing Act 2008*, the function of every Council under this Act is to seek to protect, improve and promote public health and wellbeing within the municipal district through supporting, initiating, developing and facilitating organised programs.

On 14 December 2019, the Public Health and Wellbeing Regulations 2019 (the regulations) replaced the Public Health and Wellbeing Regulations 2009. The new regulations aimed to further reduce the risk of vector-borne diseases by broadening the scope of the existing regulations. They allow for the control of emerging and potential vector-borne disease risks. The changes include:

– Replacing ‘arbovirus infection control’ with ‘vector-borne infectious disease control’ and broadening the scope of infectious disease control regulation to include other disease vectors, not just mosquitoes

– Defining ‘disease vector’ so that an animal, including a bird or insect, can be the subject of infectious disease control
– Establishing obligations on owners and occupiers of premises to take reasonable steps to control mosquito breeding grounds and abate conditions conducive to their establishment
– Allowing an authorised officer to direct an owner or occupier of a premises to take steps to control any mosquito breeding ground and control the adult mosquito population on the premises
– Introducing a Chief Health Officer authority to issue a disease vector control notice to address a material public health risk caused by a disease vector
– Allowing an authorised officer to direct an owner or occupier of a premises to control a disease vector (as specified in a disease vector control notice)

The new obligation on owners and occupiers of premises to control breeding grounds or abate conditions conducive to their establishment is based on taking reasonable steps to reduce risk. This complements the existing non-regulatory measures to control mosquito breeding under the Victorian Arbovirus (mosquito-borne) Disease Control Program.

2.3.4 Implications of the project not proceeding

Mosquito management is a very important and effective public health intervention that has reduced the prevalence of mosquito-borne diseases, including RRV, in Australia (Tomerini, Dale and Sipe 2011). The absence of medical treatment or vaccines for RRV leaves vector control and personal mosquito bite prevention as the most important methods of preventing transmission (Russell 2002). Minimisation of nuisance biting and virus transmission prevention is the focus of all local mosquito management programs, including the proposed action.

Furthermore, under section 24 of the Victorian *Public Health and Wellbeing Act 2008*, the function of every Council under this Act is to seek to protect, improve and promote public health and wellbeing within the municipal district through supporting, initiating, developing and facilitating organised programs. In failing to undertake the proposed program, the majority of which takes place on public land, the City may be at risk of failing to protect, improve and promote public health and wellbeing as deemed appropriate under the Victorian *Public Health and Wellbeing Act 2008.*

2.4 Anticipated location, timing and duration of the larvicide applications

2.4.1 Purpose

Provide the anticipated location, timing and duration of the larvicide applications and other preliminary assessment surveys, including a summary table, which describes:

– *The number and size of all proposed treatment sites*
– *The product name, type (pellet, brick, liquid etc.), concentration of active(s) and all associated product documentation such, for example, proprietary names, container sizes, labels active and other listed ingredients, Safety Data Sheets, Technical information sheets, etc)*
– *The maximum intended application rate, frequency, and duration of in the proposed treatments over the life of the referral*
– *A description of triggers to be met to initiate treatment at a given site (for example, population levels, seasonal/lunar/weather conditions, etc.) that would initiate treatment at a given site*
– *A decision flow-chart which details the way decisions are made for the project, for example choice of treatment, location, height etc.*

2.4.2 Review and analysis of past treatments

To provide the anticipated location, timing and duration of the larvicide applications for the proposed action, the City completed a review of all sites treated historically in order to inform site selection and site treatment process for the proposed 2024-2030 program.

2.4.2.1 Historical data sources

The review included a focus on sites within or in close proximity to the Ramsar site and other areas (e.g. Breamlea Reserve) that support habitat for MNES. The information presented in this section has been summarised from the following information sources:

– City of Greater Geelong (2020), Proposed Mosquito Control Program for 2021-2030. Unpublished report
– City of Greater Geelong (2020), Summary of the aerial helicopter treatment data for the 2005-2018. Unpublished report.
– City of Greater Geelong (2020), City of Greater Geelong 2019-2020 Mosquito Program Annual Report
– City of Greater Geelong (2019), City of Greater Geelong 2018-2019 Mosquito Program Annual Report
– City of Greater Geelong (2018), City of Greater Geelong 2017-2018 Mosquito Program Annual Report
– City of Greater Geelong (2012), Aerial treatment data supplied by the helicopter contractor for four seasons (2020-2021, 2019-2020, 2018-2019 and 2017-2018) including dates, flight time (hours), site numbers treated, product and volume of product used at each site
– City of Greater Geelong (2021), Excel data sheet containing a summary of the aerial treatment site data between 2005 and 2021
– City of Greater Geelong (2021), Excel data sheet containing a summary of the aerial treatment sites (flight path data) between 2012 and 2021

2.4.2.2 Review process

Data from between 2005-2021 for each treatment site were reviewed to determine the following:

– *Site area* – defined as the total area of the site in hectares (e.g. 10 ha)
– *Type of treatment* – ground-based or aerial
– *Number of historical treatments* – defined as the number of treatments received by one site period reviewed (either aerial or hand)
– *Historical treatment area for aerial sites* – an approximate area (ha) was calculated from an analysis of the flight path (swaths) data of the helicopter over each treatment site for 9 seasons from 2012-2021 (see example Plate 1, Reedy Lake). The flight path data provided by the helicopter company was between 20-25 m wide, however to account for the dispersal area by the time the larvicide contacts the ground/water surface a 2.5 m buffer (extra 5 m) was added to calculate the dispersal area. This area was then used to calculate the average area treated for each site over the period (= total treatment area for all seasons combined (ha)/total number of treatments for all seasons combined) – Table 5. Figure 2, Appendix B display the aerial sites and treatment flight paths for each season for the period
– *Historical treatment area for ground-based sites* – an approximate area (ha) was calculated from discussions with City of Greater Geelong staff, and review of historical information by City of Greater Geelong staff. The City of Greater Geelong field staff and/or contractors that used to deploy larvicide by hand did not keep track logs or wear a GPS device to track movements within each site, therefore a qualitative approach was required based on a review of the site location, size of the site, availability of mosquito habitat and treatment application over the 2005-2021 period. As a result of the review the following approach was adopted:
    - Sites < 1 ha – Given the small area it was decided that the majority or entire site was most likely treated, therefore the treatment area was calculated as 100% of the site area (Table 6)
    - Sites > 1 ha – an area estimate was calculated for each site greater than 1 ha using the historical information and aerial imagery. It is very unlikely that the entire area of these larger sites was treated because of the absence of mosquito habitat for parts of the sites and other parts of the site may not be accessible for treatment (e.g. site 1.7 within Point Lonsdale; the majority (> 90%) of the site consists of residential housing with treatment focusing on pits and pipes outside the boundary of private properties). Therefore, an area estimate was calculated for each site (Table 5). Due to the lack of definitive historical information, a conservative approach was taken and calculations were rounded up to the nearest 5% increment (e.g. if approx. 16% of the site was deemed treatable then the area was calculated based on 20% of the site being treatable).

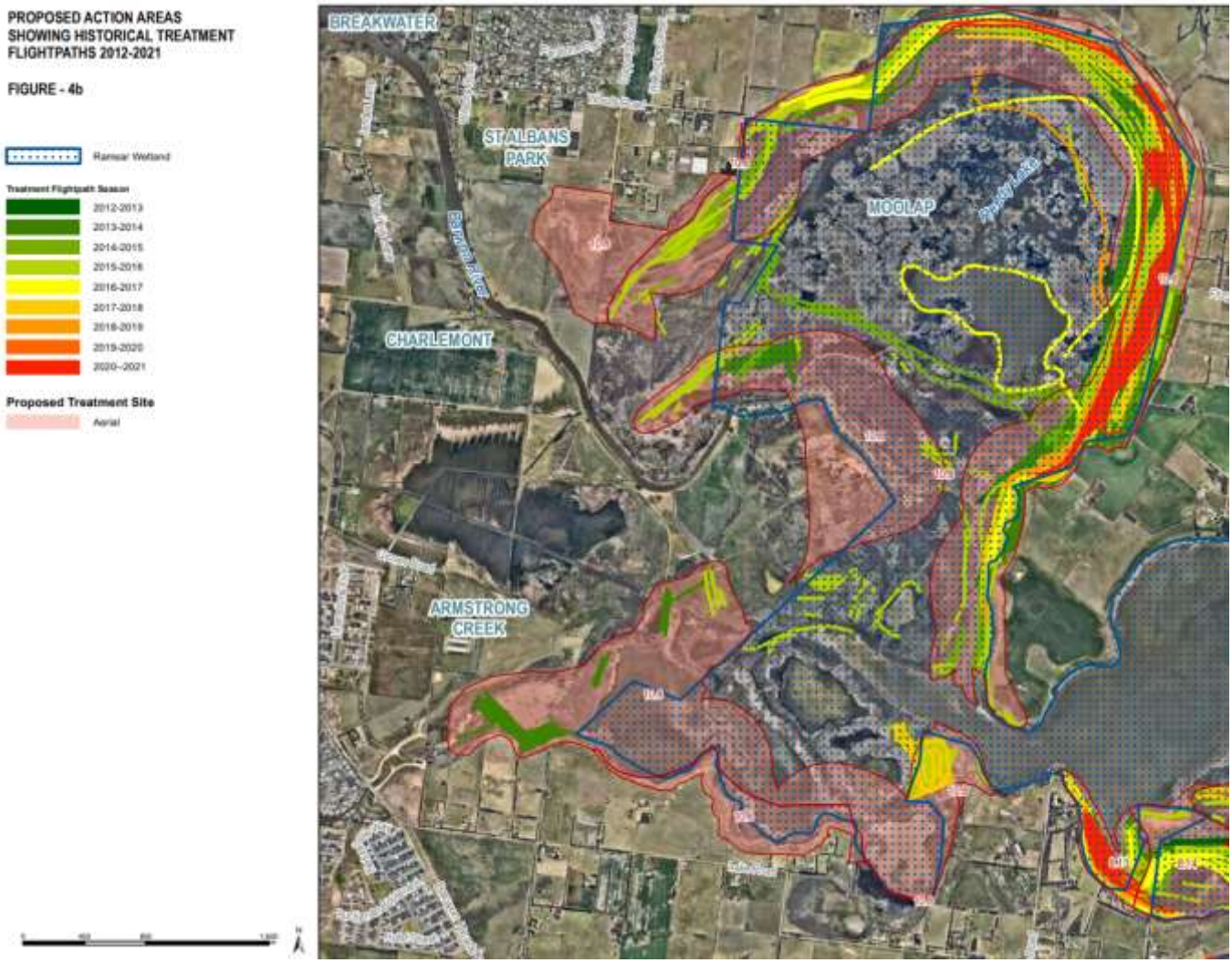


Plate 1 ***Interpretation of aerial treatment in Reedy Lake (site 10.8) from Appendix B. Different colours represent a flight path (swath) for each season from 2012-2021. Pink shaded area represents area of site. Blue dotted bounded area represents Ramsar site extent.***

2.4.2.3 Summary of historical data review

2.4.2.3.1 Aerial site treatments 2005 - 2021

Number, area and timing of historical treatments

The City of Greater Geelong has completed aerial treatments for 1475 breeding sites during 198 treatment periods (separate dates) between 15 August 2005 and 15 March 2021 (16 seasons). An average of 92.2 sites were treated each season, or 7.76 sites per treatment period.

Table 4 provides a summary of the monthly and seasonal historical aerial treatment data from 2005 – 2021 including:

– Number of treatment periods per month and average number of treatment periods per season
– Number of sites treated per month for each season and average number of sites treated per season
– Total hectares treated each season and average hectares per treatment period and site per season
– Total flight time per season and average flight time per season

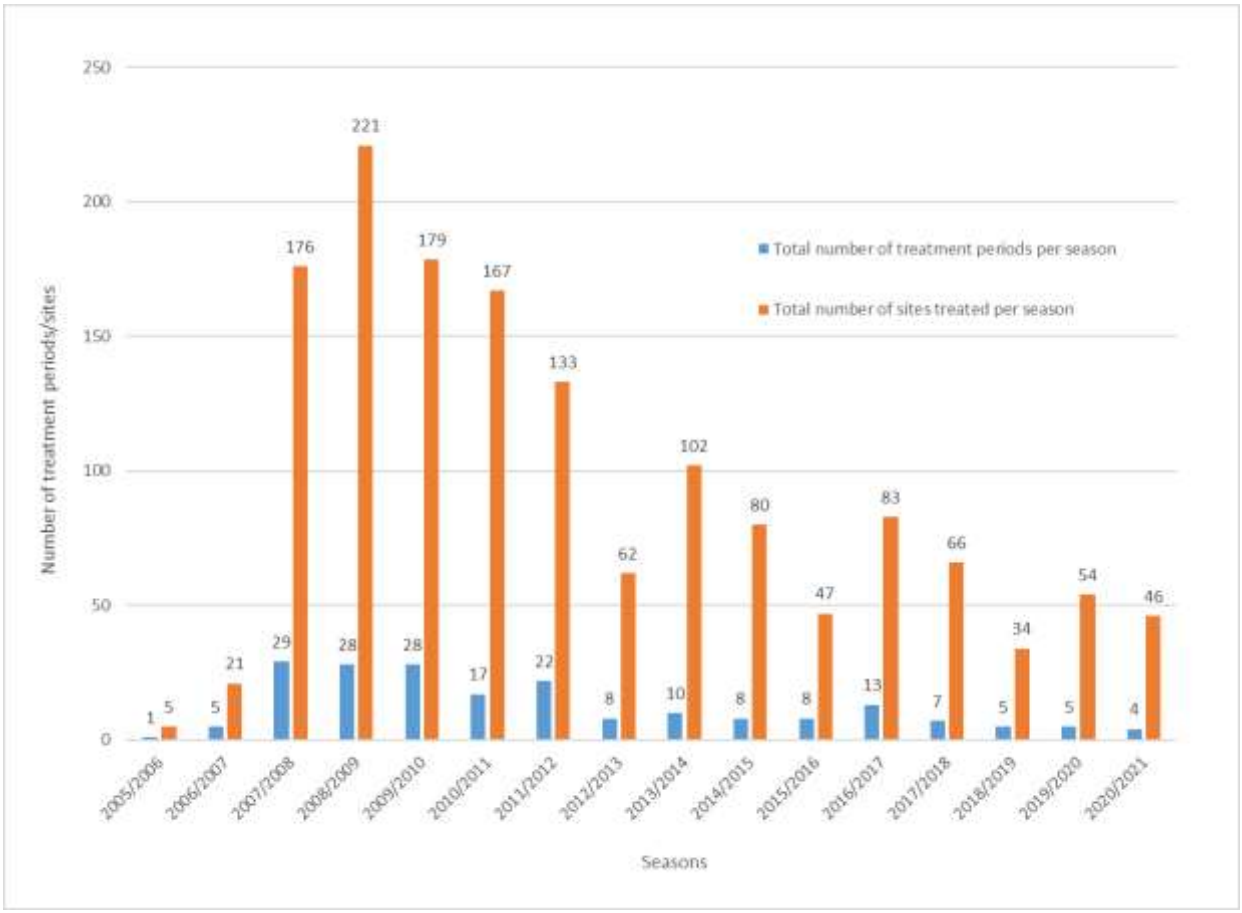
Table 5 provides a summary of the following for each historical aerial treatment site from 2012 – 2021 including:

– Site number and location
– Site area
– Number of treatments for all seasons combined
– Estimated historical treatment area

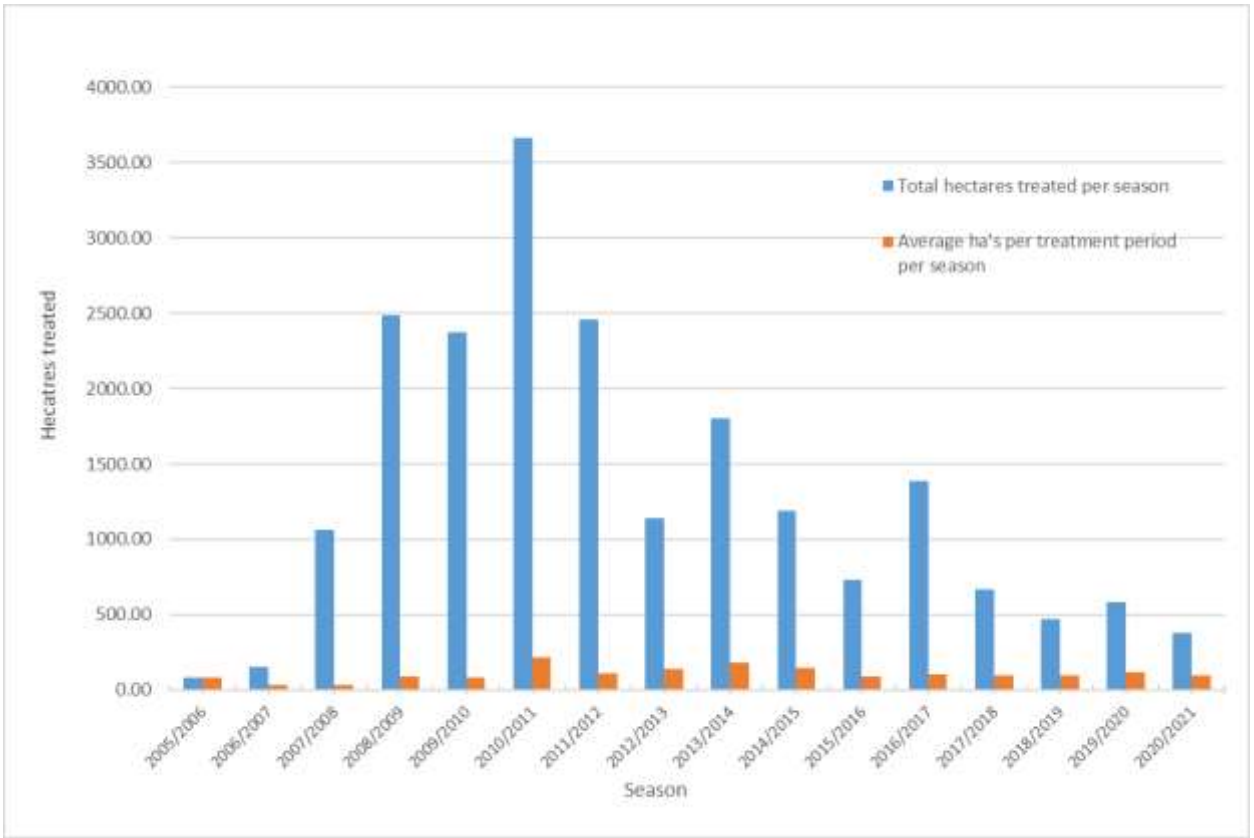
Over the years 2005 to 2021, there were 3,193 days where aerial treatments could have potentially occurred but did not. Applying treatments on 198 treatment periods over the 16 year period has resulted in treatments occurring on six per cent of days that were potentially eligible for treatments to occur. The number of treatment periods per year fluctuated from 1-29 treatment periods (Table 4 and Graph 3). During the year with the highest number of treatment periods, treatments were done on 13% of potentially eligible days.

The number of hectares that are treated with larvicide during an aerial treatment period are recorded by the pilot for each site treatment. Since 2005, the City has treated a total of 20,634.15 hectares (ha) of mosquito breeding sites over 198 treatment periods. The area and number of sites treated each season has varied, ranging from 80-2,485.90 ha and 5-221 treatments (including multiple treatments of the same site) per season (Table 5). Graph 4 displays the total area per season and average area per treatment period for each season. The average area treated each treatment period was 107.45 ha per season, and the average site treatment area was 13.79 ha per season.

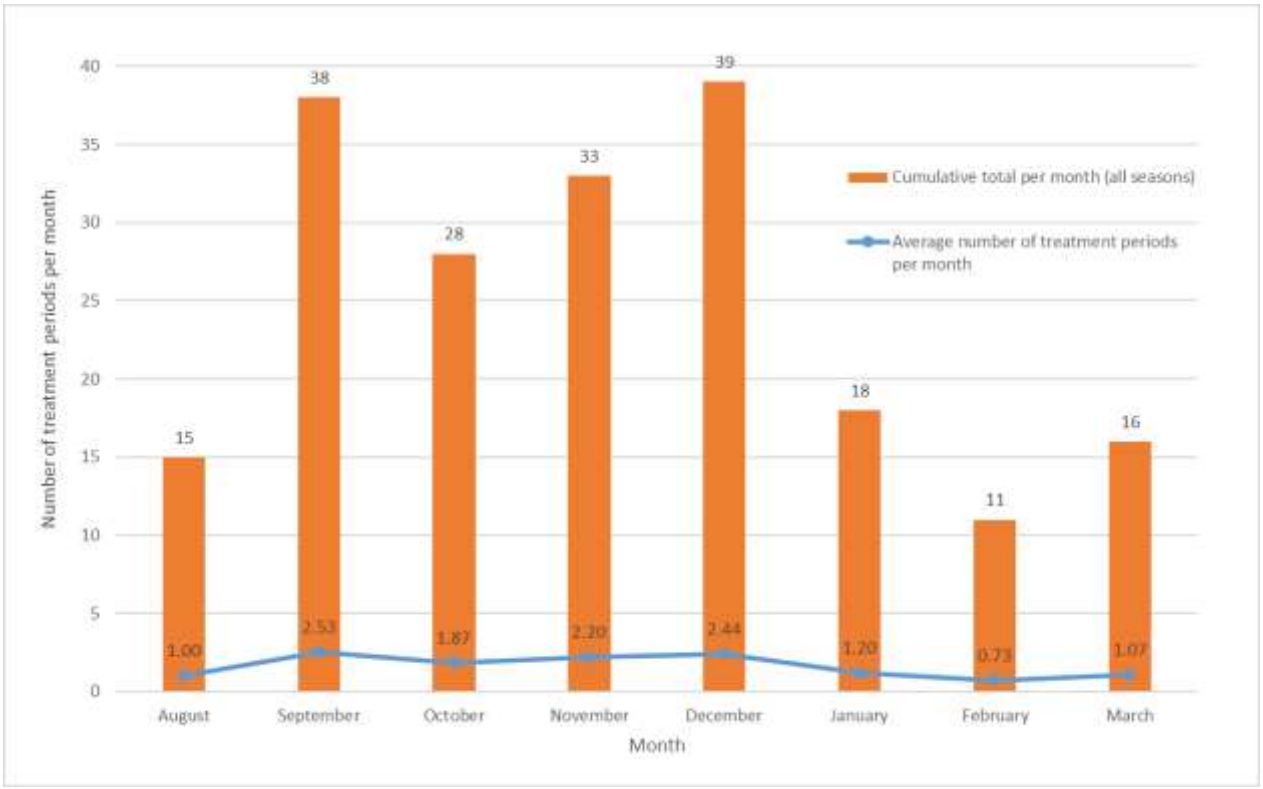
Mosquito breeding is generally higher in September, October and November when water temperatures are increasing and when water levels are high at breeding sites from spring rains. Due to higher larvae abundance, mosquito treatments have tended to occur in this same seasonal pattern. Between 2005-2021, the highest number of mosquito treatments occurred in September through December (Table 5). Graph 5 displays the cumulative total number of treatments occurring in each month where aerial treatments were permitted between 2005-2020.



Graph 3 ***Total number of aerial treatment periods and breeding sites treated per season 2005-2021***



Graph 4 ***Total area treated per season (all sites combined) and average area (ha) treated per treatment period for each season 2005-2021***

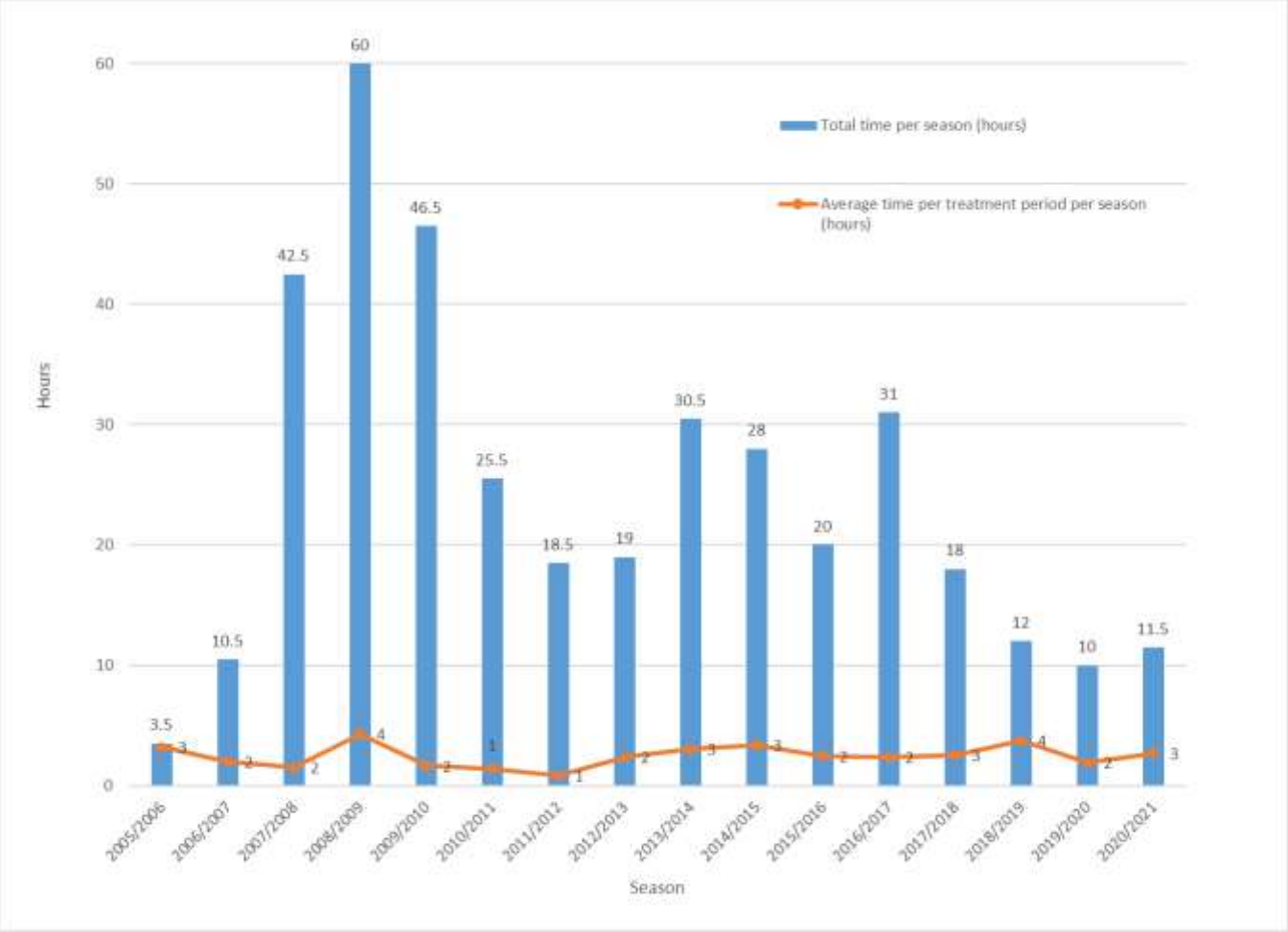


Graph 5 ***Total number of treatment periods per month (all season combined) and average number of treatment periods per month 2005-2021***

Helicopter flying time

The cumulative total number of hours of flying time from 2005-2021 was 384 hours and the average flight time for each treatment period was 2.5 hours. The average flight time for each site was approximately 20 minutes. The season with the highest number of flight hours was the 2008-2009 season, with 60 hours of treatment. The lowest number of flight hours occurred in the 2006-2007 and 2019-2020 seasons, with 10 hours. Although the 2005-2006 season recorded 3.2 flight hours, this season consisted of only one treatment period and is therefore not representative.

Graph 6 displays the total flying time in hours per season from 2005-2021 and the average flying time per day for that season.



Graph 6 ***Helicopter treatment time (hours) per season (all sites combined) and average time per treatment period per season (hours) 2005-2021. Note: rounded to nearest 0.5 hour***

Table 4 Summary of historical aerial treatment site data 2005-2021

	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average number of treatment periods	Cumulative total treatment periods
August treatment periods	0	1	3	3	2	1	1	1	1	1	0	1	0	0	0	0	1.00	15
September treatment periods	0	2	5	7	8	1	2	2	2	2	2	2	1	1	1	0	2.53	38
October treatment periods	0	1	3	4	5	2	3	0	2	0	0	3	3	0	1	1	1.87	28
November treatment periods	0	0	9	3	3	4	5	1	1	1	1	3	0	1	1	0	2.20	33
December treatment periods	1	0	6	5	7	4	5	2	1	2	1	1	1	1	1	1	2.44	39
January treatment periods	0	1	1	4	2	2	2	1	2	1	0	1	0	0	0	1	1.20	18
February treatment periods	0	0	1	0	0	2	1	1	0	0	3	1	1	1	0	0	0.73	11
March treatment periods	0	0	1	2	1	1	3	0	1	1	1	1	1	1	1	1	1.07	16
Total no. of treatment periods per season	1	5	29	28	28	17	22	8	10	8	8	13	7	5	5	4	Total no. treatment periods	198.00

	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average number of treatment periods	Cumulative total treatment periods
Total no. of sites treated per season	5	21	176	221	178	167	133	62	102	80	47	83	66	34	54	46	Total no. sites treated	1475
Total ha's treated per season	80.00	155.50	1060.29	2485.90	2376.07	3664.35	2459.93	1140.64	1801.08	1193.18	730.14	1386.98	669.24	471.06	582.04	377.75	Total ha's treated	20634.15
	3.5	10.5	43	60	46.5	25.5	18.5	19	30.5	28	20	31	18	12	10	11.5	Total flight hrs	387
Average no. of sites per treatment period per season	5.00	4.20	6.07	7.89	6.38	9.82	6.05	7.75	10.20	10.00	5.88	6.38	9.43	6.80	10.80	11.50		
Average total ha's treated per treatment period per season	80.00	31.10	36.56	88.78	84.86	215.55	111.82	142.58	180.11	149.15	91.27	106.69	95.61	94.21	116.41	94.44		
Average area of a treatment site per season (ha)	16.00	7.40	6.02	11.25	13.31	21.94	18.50	18.40	17.66	14.91	15.53	16.71	10.14	13.85	10.78	8.21		

	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average number of treatment periods	Cumulative total treatment periods
Average flight time per treatment period per season (hrs)	3	2	2	4	2	1	1	2	3	3	2	2	3	4	2	3		
Average flight time per treatment site per season (hrs)	0.70	0.50	0.24	0.27	0.26	0.15	0.14	0.31	0.30	0.35	0.43	0.37	0.27	0.35	0.19	0.25		

Table 5 Review of historical data for aerial sites 2012-2021

Location	Site number	Site description	Within or adjacent to Ramsar site	Site area (ha)	Number of treatments (all seasons combined)	Historical treatment area total (ha)
COLLENDINA	2.1	COLLENDINA PUMPING STATION MARSH POND	No	0.43	3	4.3
COLLENDINA	2.17	SOUTHERN LAKE VICTORIA	No	56.08	7	31.82
COLLENDINA	2.2	COLLENDINA AIRFIELD	No	26.39	8	26.39
COLLENDINA	2.3	COLLENDINA/WETLAND BETWEEN AIRSTRIP & CARAVAN PARK	No	16.96	17	16.96
COLLENDINA	2.4	COLLENDINA SOUTH SALT LAKE AT EAST OF CARAVAN PARK	No	13.21	4	14.33
COLLENDINA	2.5	COLLENDINA NORTH SALT LAKE AT EAST OF CARAVAN PARK (2 sites)	No	35.21	19	41.73
COLLENDINA	2.6	COLLENDINA SALT LAKE AT WEST BOUNDARY	No	2.16	9	2.16
OCEAN GROVE	3.10	PACEY'S ISLAND, PRIMETER WETLANDS	Yes	44.96	18	51.02
OCEAN GROVE	3.1	OCEAN GROVE GOLF COURSE RIVER MARSH	Yes	3.28	6	13.12
OCEAN GROVE	3.11	PACEY'S ISLAND, SEVERAL LOW LYING WETLANDS	Yes	180.82	67	418.29
OCEAN GROVE	3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	10.86	61	82.84
OCEAN GROVE	3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	378.90	74	865.19
OCEAN GROVE	3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	25.47	52	140.54
OCEAN GROVE	3.8	THACKER ST TIDAL WETLANDS AND CREEK	Yes	24.53	21	75.23
OCEAN GROVE	3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	14.57	20	84.68
ST LEONARDS	4.3	ST LEONARDS END OF CLIFF ST- BOTH SIDES OF LAKE	Yes	3.72	40	43.58
ST LEONARDS	4.4	SALT LAKE - CLIFF ST	Yes	2.15	2	5.64
ST LEONARDS	4.5	ST LEONARDS BEHIND CHARLIES	Yes	13.68	52	53.05
ST LEONARDS	4.6	PT EDWARDS RESERVE	Yes	113.06	38	402.23

Location	Site number	Site description	Within or adjacent to Ramsar site	Site area (ha)	Number of treatments (all seasons combined)	Historical treatment area total (ha)
ST LEONARDS	4.10	SALT LAGOON PERIMETER AND BACKWATERS STH SIDE	No	7.56	3	1.81
SWAN BAY	7.1	KNIGHTS RD SWAN BAY NORTH	Yes	30.97	34	481.29
SWAN BAY	7.2	NYE RD WETLANDS	Yes	25.95	25	24.21
SWAN BAY	7.3	IBBOTSON ST END OF SWAN BAY	Yes	16.43	22	97.25
SWAN BAY	7.4	SWAN BAY - SOUTH OF SALT LAKE	Yes	2.14	16	3.51
SWAN BAY	7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	161.39	58	1082.65
BARWON HEADS	8.1	BARWON HEADS GOLF COURSE MARSH - PONDS	Yes	45.17	53	401.90
BARWON HEADS	8.13	STACEY'S RD (ROYCOTT PROPERTY) CONNEWARRE	Yes	25.66	56	207.82
BARWON HEADS	8.14	BACKWATERS	Yes	44.68	4	43.08
BARWON HEADS	8.15	HOSPITAL SWAMP WETLANDS	Yes	30.09	6	110.10
BARWON HEADS	8.18	BACK OF LAKE CONNEWARRE (3 sites)	Yes	900.29	33	207.95
BARWON HEADS	8.4	REAR OF SCHOOL - LAKE MURTNAGHURT PERIPHERY	Yes	73.60	57	208.08
BARWON HEADS	8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	20.91	28	17.31
BREAMLEA	9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	90.53	37	538.94
BREAMLEA	9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	No	13.61	46	59.94
BREAMLEA	9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN) (2 sites)	No	22.22	16	30.63
BREAMLEA	9.4	BREAMLEA SALTMARSHES D (BEHIND SURF CLUB)	No	1.52	12	10.66
BREAMLEA	9.5	BLACKGATE RD	No	68.30	40	413.49
LEOPOLD	10.6	MOLLERS LANE PONDAGE EAST SIDE	Yes	1.75	4	1.756
LEOPOLD	10.7	MOLLERS RD LEOPOLD CONNEWARRE MARSH	Yes	17.03	2	12.70

Location	Site number	Site description	Within or adjacent to Ramsar site	Site area (ha)	Number of treatments (all seasons combined)	Historical treatment area total (ha)
LEOPOLD	10.8	REEDY LAKE PERIPHERY (2 sites)	Yes	1352.52	37	809.50
PT HENRY	11.1	PT HENRY RD MARSH DRAIN (2 sites)	No	7.02	9	15.95
PT HENRY	11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	47.21	29	52.90
QUEENSCLIFF	14.3	BURNT PT END OF FELLOWS RD	Yes	72.94	36	210.86
QUEENSCLIFF	14.4	BURNT PT END OF FELLOWS RD	Yes	34.62	29	92.67
QUEENSCLIFF	14.9	SWAN ISLAND GOLF COURSE (2 sites)	Yes	13.65	3	13.65
QUEENSCLIFF	14.1	SWAN ISLAND ARMY (6 sites)	No	10.73	3	10.73
SURF COAST	15.8	TIDAL WETLAND LAKES (4 LARGE)	No	176.13	15	123.41
		TOTAL (53 sites)		**4281.06 ha**	**1231**	**7657.85**

2.4.2.3.2 Ground-based site treatments 2005 – 2021

The City's mosquito management program consists of a combination of activities including ground based/manual treatments. If breeding sites are easily accessible, the areas can be manually treated. Breeding sites around townships like pits, drains and constructed wetlands are always treated by ground-based methods.

The City has completed 816 ground treatments for 43 sites between 15 August 2005 and 15 March 2021 (16 seasons). Table 6 provides a summary of the following for each historical ground-based treatment site from 2005 – 2021 including:

– Site number and location
– Site area
– Number of treatments for all seasons combined
– Estimated historical treatment area

Table 6 Review of historical data for ground-based sites 2005-2021

Location	Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of treatments (all seasons combined)	Percentage of site deemed treatable	Historical treatment area (ha)
PT LONSDALE	1.1	RAILWAY LINE, MARSH & DRAINS	No	0.65	30	100%	0.65
PT LONSDALE	1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	No	2.93	33	60%	1.76
PT LONSDALE	1.7	PITS & PIPES SURVEILLANCE	No	51.19	45	10%	5.12
PT LONSDALE	1.8	PONDAGE OFF FELLOWS RD	No	0.98	n/a	100%	0.98
OCEAN GROVE	3.15	BLUE WATER LAKE WEIR	No	7.39	5	20%	1.48
OCEAN GROVE	3.16	BLUE WATER LAKE CONTAINMENT PIT	No	7.39	10	20%	1.48
OCEAN GROVE	3.2	OCEAN GROVE NATURE RESERVE	No	1.52	1	30%	0.46
OCEAN GROVE	3.3	BLUE WATER LAKE OPEN DRAINS	No	7.39	19	30%	2.22
OCEAN GROVE	3.4	BLUE WATER LAKE RES CATCHMENT AREAS	No	7.39	12	30%	2.22
OCEAN GROVE	3.5	THACKER ST STORMWATER EASEMENT	No	1.24	13	70%	0.87
OCEAN GROVE	3.6	BLUE WATER OPEN DRAIN TO THE RIVER	No	7.39	9	30%	2.22
OCEAN GROVE	3.7	OCEAN GROVE GOLF COURSE CREEK	No	0.67	6	100%	0.67
ST LEONARDS	4.1	MARSH BEHIND HOUSES CLIFF ST - LOWER BLUFF	Yes	35.08	14	20%	7.02
ST LEONARDS	4.12	SALT LAGOON IBBOTSON ST WEST SIDE	No	6.44	1	40%	2.58
ST LEONARDS	4.13	BATMAN RD OPEN DRAINS	No	2.24	46	20%	0.45
ST LEONARDS	4.14	PRIVATE INDENTED HEADS SALT MARSH PAST DOSSETOR RD	No	6.03	7	40%	2.41
ST LEONARDS	4.2	BLUFF RD ST LEONARDS MARSH SWAMP	No	0.71	2	100%	0.71
ST LEONARDS	4.7	RHONDA AVE SALT MARSH ST LEONARDS	No	3.07	18	60%	1.84
ST LEONARDS	4.8	ST LEONARDS LAKE & DRAINS PLUS SPILLWAY	No	0.10	50	100%	0.10
ST LEONARDS	4.8	ST LEONARDS LAKE & DRAINS PLUS SPILLWAY	No	4.25	50	20%	0.85

Location	Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of treatments (all seasons combined)	Percentage of site deemed treatable	Historical treatment area (ha)
PORTARLINGTON	5.1	PT RICHARDS MARSH SWAMP FORESHORE	No	4.65	6	60%	2.79
PORTARLINGTON	5.1	PT RICHARDS MARSH SWAMP FORESHORE	No	15.89	6	40%	6.36
PORTARLINGTON	5.2	RAMBLERS RD PORT MARSH	No	5.84	21	20%	1.17
PORTARLINGTON	5.3	PITS AND PIPES SURVEILLANCE (BOAT RD)	No	0.82	29	100%	0.82
BARWON HEADS	8.11	SHEEPWASH TIDAL WETLANDS	Yes	3.23	1	30%	0.97
BARWON HEADS	8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD	Yes	2.53	3	30%	0.76
BARWON HEADS	8.2	REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	3.68	14	60%	2.21
BARWON HEADS	8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH	Yes	4.55	6	60%	2.73
BARWON HEADS	8.6	OLD TURKEY FARM, MARSH AND PONDS	Yes	5.70	8	60%	3.42
BARWON HEADS	8.9	JIRRAHLINGA - PONDS AND WETLANDS	Yes	1.84	11	30%	0.55
BARWON HEADS	8.9	JIRRAHLINGA - PONDS AND WETLANDS	Yes	16.56	11	20%	3.31
PT HENRY	11.5	2 PONDS AT SALVATION ARMY COMPLEX	No	0.08	5	100%	0.08
PT HENRY	11.5	2 PONDS AT SALVATION ARMY COMPLEX	No	0.09	5	100%	0.09
PT HENRY	11.6	ALCOA WETLANDS - LAGOONS	No	9.71	7	40%	3.88
PT HENRY	11.7	COONEY ST DRAIN	No	1.58	38	70%	1.11
PT HENRY	11.8	DRAIN BEHIND ANIMAL HEALTH LAB	No	4.79	5	40%	1.91
PT HENRY	11.9	DRAIN BEHIND PRESTIGE CARAVANS - BELLARINE HWY	No	1.33	38	70%	0.93
QUEENSCLIFF	14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	2.25	73	80%	1.80
QUEENSCLIFF	14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	4.94	73	80%	3.95
QUEENSCLIFF	14.11	CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	No	1.10	19	80%	0.88
QUEENSCLIFF	14.7	YARRUM CREEK, RAILWAY LINES & RD	No	0.78	30	100%	0.78
QUEENSCLIFF	14.8	RAILWAY LINES, MARSH & DRAIN	No	0.65	36	100%	0.65
QUEENSCLIFF	14.8	RAILWAY LINES MARSH & DRAIN	No	3.64	n/a	70%	2.55
		TOTALS (44 sites)		**250.28 ha**	**816**		**79.79 ha**

2.4.3 Product description

The City currently uses two types of larvicide for the management of mosquito larvae: Bacillus thuringiensis israelensis (Bti) and S-methoprene. Both are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Both products are used widely in Australia and internationally to manage mosquito larvae because of their limited impact on non-target species and the general environment. Table 7 provides a summary of the five products used for both ground and aerial larvicide treatment including product name and type, application rates and container size, ingredients and label details and safety data sheet (SDS) details via hyperlink and in Appendix D. All forms of larvicide used for the proposed mosquito management program are delivered in non-liquid form (e.g. granules, sand, pellets or briquets).

Bti is a naturally occurring soil bacterium which produces a protein crystal containing a number of microscopic toxins that, when ingested, are capable of destroying the gut wall and killing mosquito larvae. The insecticidal crystal proteins target specific parts of specific larval insects with no harmful effect on vertebrates or most other invertebrates (NSW Health 2019). Bti is a variety specific to *Diptera*, especially mosquitoes and blackflies (Glare et al. 1998). This is one of the most commonly used larvicides in Australian estuarine and freshwater habitats. In heavily polluted environments or those containing a high organic content, the efficacy of this product is reduced (NSW Health 2019).

The insect growth regulator, S-methoprene, is a synthetic mimic of the juvenile hormone produced by insect endocrine systems and, when absorbed by the larvae, development is interrupted and immature stages fail to successfully develop to adults, usually dying in the pupal stage (NSW Health 2019). This product is commonly used in Australia, particularly in highly organic rich environments (e.g. waste-water treatment ponds, drains, septic tanks) where Bti may not be as effective. There is a range of commercial formulations (including granule, pellet and briquette) of this product available that provides flexibility in habitat-specific use and, importantly, some formulations provide residual control of mosquitoes for up to three months, making it useful for providing sustained control following flooding, in addition to the potential for “pre-season” treatment of critical mosquito habitats (NSW Health 2019). Further detail regarding the description of both products can be found in the Literature review on the effects of Bti and S-methoprene, previously provided to DCCEEW. Details of the literature review is detailed in section 4.2.2.5 and Appendix F.

It is the intention of the City to continue to use both products for the proposed 2024-2030 program. All sites could potentially be treated with Bti or S-methoprene. However, there are some specific sites that would only be treated with one or the other.

Table 7 ***Product description summary including maximum intended application rate***

Product Name and type	Time between treatments	Maximum product rates	Container size	Ingredient (1)	Ingredient (2)	Label	SDS	Proposed application
Vectobac G -Granule	Minimum 7 days between treatments*	7 kg/ha	18 kg	Bacillus thuringiensis israelensis (Bti) - 2.85%	Other - 97.2%	Here	Here	Ground/aerial - used to break breeding cycle of mosquito. Kills larvae in area.
Prolink Pro Sand - Sand	Minimum of 1 to 2 weeks between treatments**	4 kg/ha	20 kg	S-methoprene – 4 gr/kg	Non-Hazardous other – 996 gr/kg	Here	Here	Primarily aerial/ some ground. Dispersed from drone in hard to access areas

Product Name and type	Time between treatments	Maximum product rates	Container size	Ingredient (1)	Ingredient (2)	Label	SDS	Proposed application
Prolink XR - Briquets	Between treatments = mosquito season or 150 days (whichever is shorter)	1 Briquets/ 10 m2	100 or 200 briquets	S-methoprene – 18 gr/kg	Non-Hazardous other – 982 gr/kg	Here	Here	Ground only - XR Briquets used to prevent emergence of larvae around residential areas. Not to be used in highly environmental sensitive areas or in tidal water or marine habitats where threatened species are known to occur.
Prolink Pellets - Granule	Minimum 30 days between treatments	4 kg/ha	10 kg	S-methoprene – 40 gr/kg	Non-Hazardous other – 960 gr/kg	Here	Here	Primarily ground/ some aerial
VectoPrime FG -Granule	120 days between treatments	4 kg/ha	18 kg	Bti - 5-10%	S-methoprene <1%	Here	Here	Only ground. Product is new to the market and not to be used in highly environmental sensitive areas or in tidal water or marine habitats where threatened species are known to occur.

Table notes:
*Permit issued by APVMA to the City of Gold Coast which describes this. Permit number 85979
** No data is available on this product. Toxicity data is on the active constituent, (S)- Methoprene, has a half-life in soil of approximately 10 days which varies with soil type. The hydrolysis half-life > 4 weeks. Photolysis half-life is < 10 hours. Water solubility is < 2 mg/L.

2.4.4 Proposed monitoring and treatment initiation program

Mosquito breeding sites within the City will be monitored on a rotating basis. These sites are deduced from the historical data from previous seasons, mosquito officer experience and knowledge of the area and community reports of mosquito breeding. If larvae are found, staff will determine the most effective treatment method for the site. Sites are either treated manually or recommended for aerial drone treatment. A 4WD vehicle may be used to access heavily vegetated breeding sites and a drone will be used for aerial treatments.

The City predicts that, over the next six years, monitoring sites may change due to accessibility and environmental conditions, and additional sites, especially constructed wetlands in Development Estates, will need to be monitored.

2.4.4.1 Site selection

Dr Cameron Webb was engaged by the City to produce a report investigating new approaches to managing mosquitoes and mosquito-borne disease in 2019, building on the current strategies (*NSW Government, 2019 New approaches to managing mosquitoes and mosquito-borne disease; building on the current mosquito management strategies of City of Greater Geelong, Borough of Queenscliffe, and Surf Coast Shire, Victoria*). The aim of the assessment was to determine sites that would need higher levels of monitoring by characterising each of the variables. Each variable listed below has threshold values/indicators which influence the inherent risk of each unique site. A part of the report included using the risk assessment framework devised by Byun and Webb 2012 for both aerial and ground sites which took into consideration variables such as:

– Wetland edge
– Wetland shape
– Runoff
– Water
– Hydrology
– Circulation
– Aquatic vegetation
– Water quality
– Adult mosquito density
– Complaints from the public
– Locally acquired RRV/BFV
– Location of water body relative to residential areas
– Terrestrial vegetation

Once aerial and ground sites were assessed, a risk assessment was conducted that posed the mosquito breeding potential at a site against the risk to the community. This risk assessment provided the City with a risk level varying from low to high (see risk assessment matrix – Plate 2).

Assessment of mosquito breeding potential	Assessment of risk to the community		
Risk level/ potential	Unlikely	Possible	Likely
High	Medium	High	High
Medium	Medium	Medium	High
Low	Low	Medium	Medium

Plate 2 Risk assessment matrix – community risk

This assessment formed the basis on which certain sites were chosen to monitor and treat over others as they posed a greater risk. As Greater Geelong increases in population, the number of ground sites requiring monitoring and treatment will grow, with some of the previously assessed sites changing from low to medium or medium to high. The next monitoring program will require further assessments to be completed to ensure the City's mosquito management program is reducing the potential for public health risks for the community.

2.4.5 Monitoring for and initiation of mosquito treatments

The City of Greater Geelong will use the Atlas of Environmental Health Medical Entomology application to assist in monitoring and recording information about the ground-based applications mosquito officers will administer. This application allows the City to record any monitoring or treatments of pre-determined sites and includes a location tag for the officers.

The City proposes to continue monitoring in accordance with the ongoing monitoring program that has been established for 12 years. The proposed monitoring program will include the following elements:

– Collection of climate and rainfall data to understand mosquito breeding patters and inform triggers for treatment timing and options (e.g. temperature, tide, wind speed and rainfall)
– Larval monitoring to understand larval infestation rates and determine classification levels (e.g. moderate to high) to trigger treatment

Monitoring will also include setting light traps around the municipality to survey adult mosquito numbers. The AgriBio Centre at LaTrobe University will be engaged to determine the species and sex of adult mosquitoes and to test the mosquitoes for viruses. This helps to identify any emerging arbovirus issues and potential mosquito breeding sources. Adult monitoring is complimentary to the proposed action and does not determine whether a treatment will be conducted, as the number of larvae at a site is a better trigger in determining what treatment, if any, will be conducted. The locations where adult traps are set will be decided by the Victorian Department of Health and the City to provide useful data for the Victorian Arbovirus Disease Control Program (VADCP).

Other forms of monitoring for surveillance of adult mosquitoes, community awareness and emergency management are also undertaken but are not part of the regular monitoring undertaken.

Figure 1 and Figure 2 display a decision flowchart used to determine the process for treating aerial or ground-based sites.

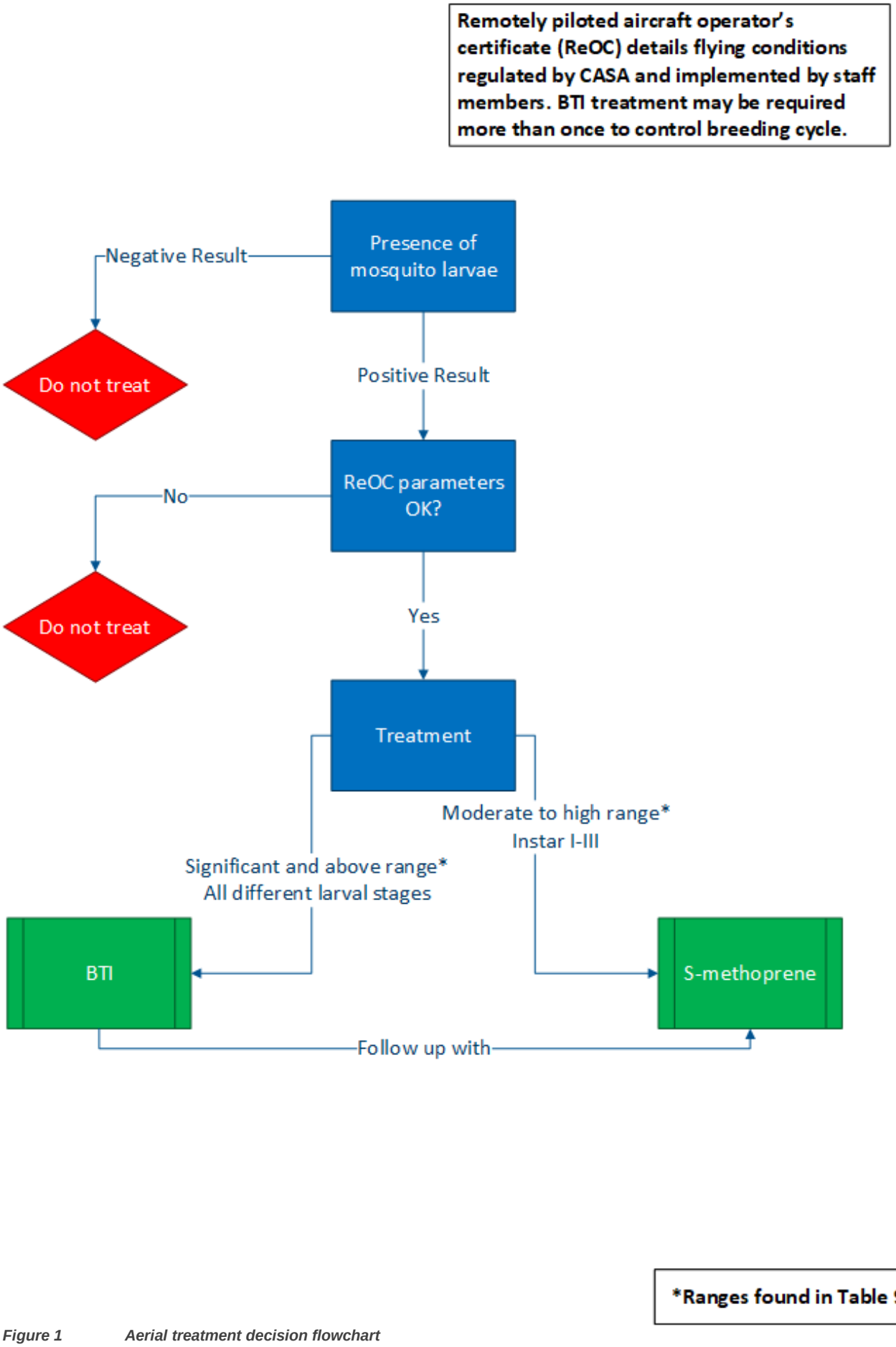


Figure 1 *Aerial treatment decision flowchart*

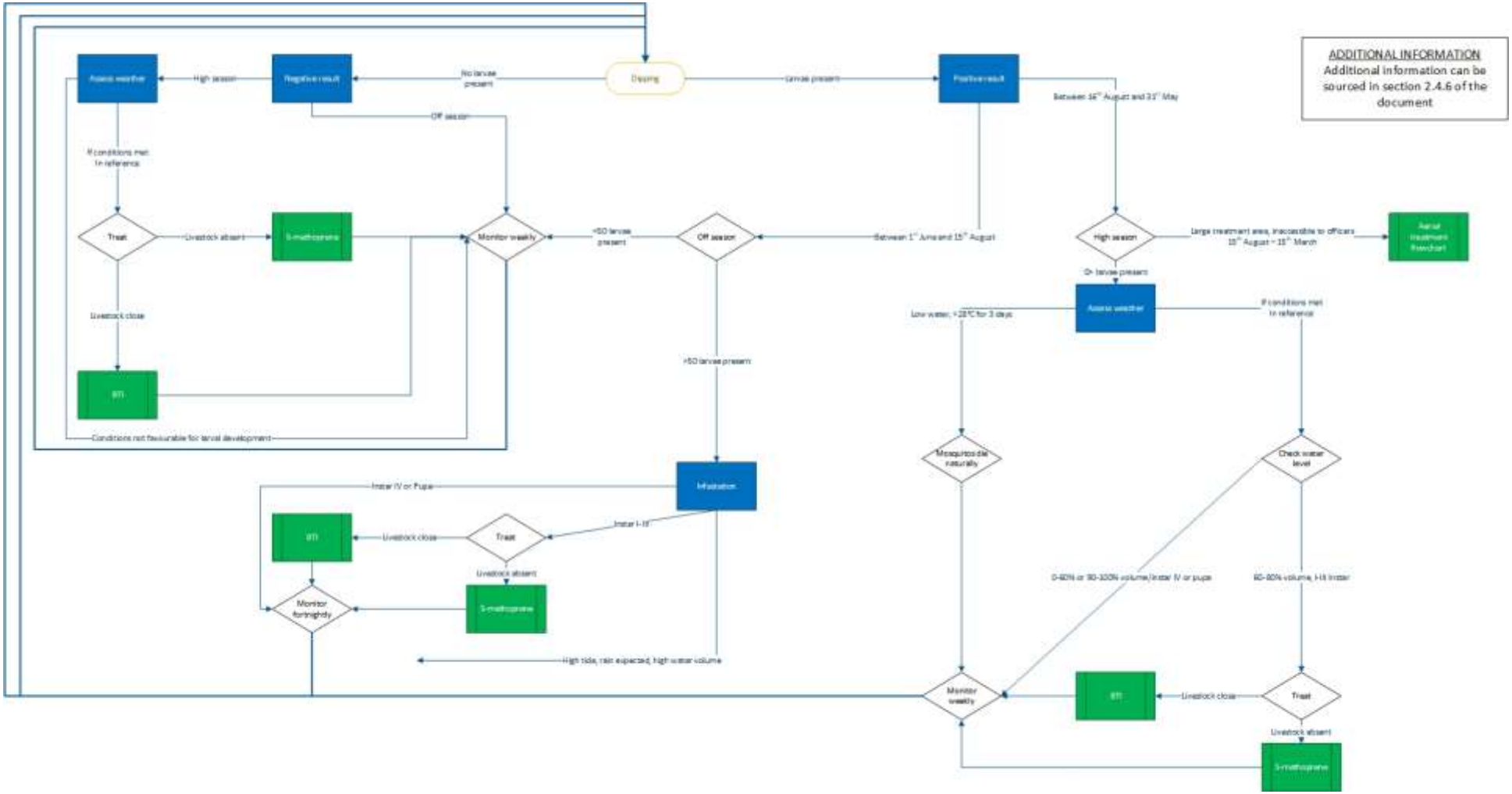


Figure 2 ***Ground treatment decision flowchart***

– ***Climate data***

Mosquito levels vary each year due to a number of climatic factors including rainfall, wind, temperature and tidal events and the way these influence mosquito breeding. These factors also affect the City's ability to carry out monitoring and subsequent treatment. Because of this, weather conditions are monitored regularly to ensure appropriate timing of monitoring and treatment activities. Assessing the predicted weather is important when considering treatment options for sites, as increases/decreases in temperature and water volume can impact larval development and product concentrations. When assessing the weather, officers consider the following variables that may trigger the need for treatment:

– Temperature – will the temperature be high enough to evaporate water from the body, is the temperature going to increase/decrease evaporation
– Tides – is there a tidal prediction above 1.5 metres in the days before and after an application. Tides over 1.5 metres will usually increase volume and result in product moving from its intended site
– Wind speed and direction – is the speed and direction of the wind in the coming days likely to move product outside the treatment area
– Rainfall – how much rain is predicted in the area. High rainfall will result in movement of product outside treatment area

These data have been used to predict episodes of larvae growth in the wetlands and inform ground and aerial based treatments to date. This same approach will apply to the proposed monitoring program.

Larval Monitoring

A variety of mosquito breeding sites will be monitored around the City including wetlands, marshlands, lakes, drains and pits. The sites have been divided into 16 main areas and each area is broken down into a number of smaller locations. In conjunction with the predetermined ground treatment sites, there are also sole monitoring sites which are used to gauge breeding levels across the municipality. This information is used to understand why a specific township area could be noticing an increase in mosquito numbers and if the residents in these areas will contact the City to enquire why. Table 8 lists those monitoring sites that coincide with ground-based treatment sites.

Table 8 Ground-based monitoring site locations

Site Location	# sites	Monitoring sites
Point Lonsdale	2	1.4, 1.7
Collendina	-	Area to be monitored but does not include ground-based treatment sites at this time
Ocean Grove/Wallington	2	3.2, 3.7
Portarlington	1	5.2
Clifton Springs/Drysdale	-	Area to be monitored but does not include ground-based treatment sites at this time
Swan Bay	-	Area to be monitored but does not include ground-based treatment sites at this time. May include aerial treatment sites for future monitoring
Barwon Heads	3	8.3, 8.11, 8.16
Breamlea	-	Area to be monitored but does not include ground-based treatment sites at this time
Leopold	-	Area to be monitored but does not include ground-based treatment sites at this time
Limeburners	-	Area to be monitored but does not include ground-based treatment sites at this time.
Point Henry/Moolap/Botanic Gardens	-	Area to be monitored but does not include ground-based treatment sites at this time.
Lara	-	Area to be monitored but does not include ground-based treatment sites at this time.

Site Location	# sites	Monitoring sites
Armstrong Creek/Warralily	-	Area to be monitored but does not include ground-based treatment sites at this time.
Queenscliff	-	Area to be monitored but does not include ground-based treatment sites at this time.
Surf Coast	-	Area to be monitored but does not include ground-based treatment sites at this time.

Field staff will monitor breeding sites on a weekly basis for larval activity. *A moderate to high level resulting from larval counts (Table 9) will trigger treatment*. Staff determine the most effective treatment product and application method for the site with consideration to climate and rainfall data. Additional monitoring will also take place after high tide events and heavy rainfalls. The tide limits that cause excessive salt marsh flooding are in excess of 1.5 m.

During each site visit, staff will record information into the Environmental Health Atlas Mosquito Monitoring App including:

– Date site was monitored
– Degree of larval infestation
– Recommendation for treatment; including treatment window
– Recommendations for any infrastructure works that can decrease mosquito breeding
– Photos of larvae or site

If network connection is unavailable, staff will record information and email to the office. The web-based program is then updated at a later date. Data is then exported from the web program for analysis by officers.

Larval counts will be estimated by taking a dip of approximately a 100 millilitres (ml) sample of water from a site and counting the number of larvae. The larval numbers are classified as described in Table 9.

Table 9 Larval classification for monitoring

Classification	Range (larvae/dip)
Nil	0
Low	<5
Moderate	6-20
High	21-200
Significant	201-500
Extreme	500+

The mosquito breeding sites around the City are already separated into ground-based sites that are treated manually and aerial sites that can be treated with the drone. Sites have been classified as high, medium and low priority based on larval productivity, ability to affect residential areas, and the assessments undertaken by Dr Cameron Webb. The highest priority sites will be monitored weekly. Medium and low priority sites will be monitored as needed following extreme weather events or complaints about a certain area.

Table 10 Summary of weekly monitoring of mosquito breeding sites 2019-2020

	Aerial sites	Ground sites	Total
Number of sites	63	86	149
Number of monitoring visits	191	125	316
Number of times treated aerially (on 7 occasions)	19	0	19
Number of ground-based applications	3	38	41
Number of site visits	213	263	476

When referring to “sampling” or “dipping” officers will use the following procedure:

1. Using a dip stick (a vessel that holds approximately 100 mL attached to an extender pole) at a breeding site, collect 100 mL of water.
2. Observe the water collected for the presence of mosquito larvae.
3. Estimate abundance – see Plate 3 below.
4. Determine percentages of larvae in certain life stages (instar I-VI, pupae).
5. Return collected water.
6. Proceed to input data into Atlas of Environmental Health app.

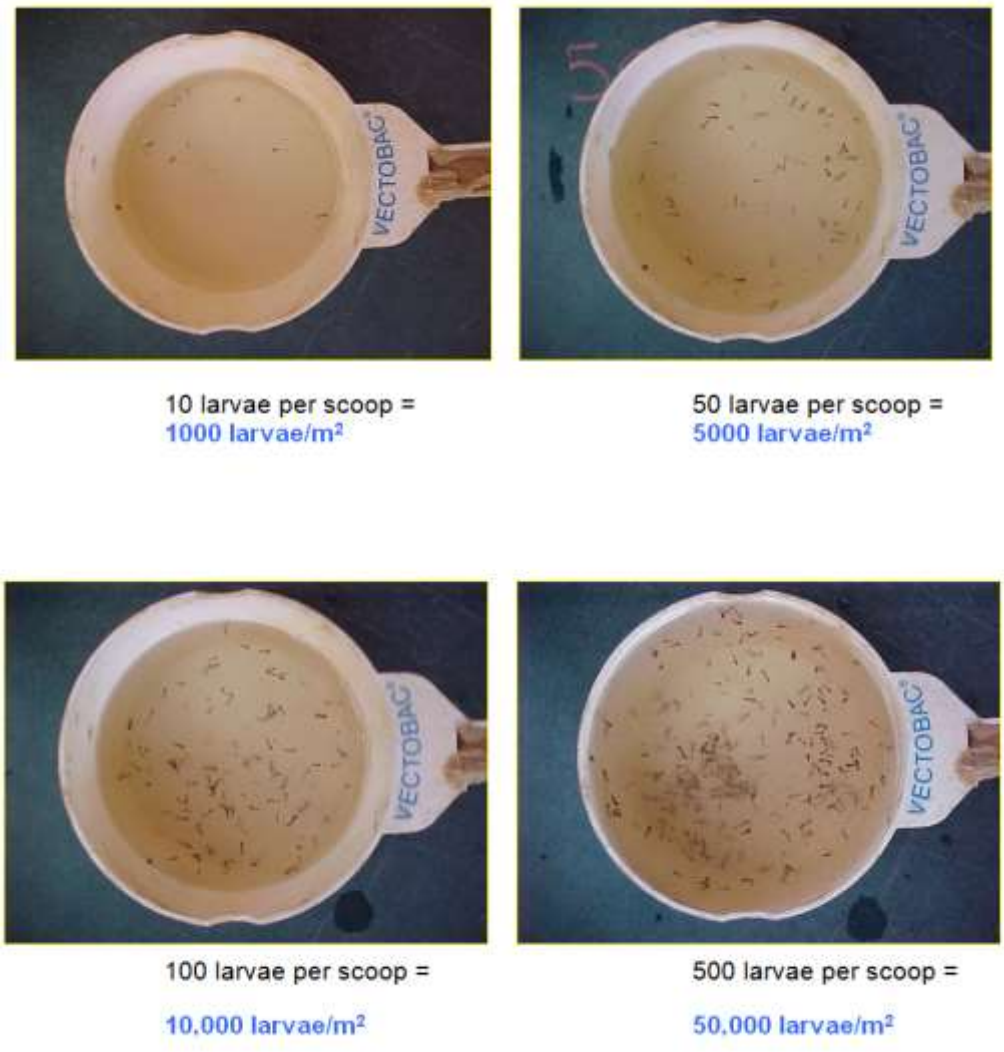


Plate 3 Mosquito larvae abundance guide

Monitor Fortnightly and Monitor Weekly are procedures that are the same and involve the following:

1. Select predetermined site:



Location*
Type* Other
When* 29/01/2024 10:02
Reason* Routine monitoring

2. Conduct dip of approximately 100 ml.
3. Count of mosquito larvae.
4. Input average number of larvae into Atlas of Environmental Health Mosquito Monitoring app:

Water present
Estimated surface area sqm
Estimated surface area sqm
Estimated water surface area in square metres
Quality
Quality of breeding site
Larvae present
Larvae dip average
Larvae dip average
Treatment
Treatment type
Type of treatment used
Treated area sqm
Treated area sqm
Surface treated in square metres
Notes
Notes

5. Input water presence, larvae presence, whether treatment is required and its type.
6. Finish with additional notes and photos of the site.
7. Determine whether treatment necessary based off flowchart and input into app:

2.4.6 Other types of monitoring

During the high season, mosquito light trapping is used as a surveillance tool for adult mosquito levels to assess the need for mosquito management activities within the community and to assess the effectiveness of mosquito management activities.

Adult monitoring and light traps

Mosquito light traps will be set at specific locations across the Bellarine Peninsula on a regular basis. Mosquito light traps are designed to attract and catch mosquitoes. The trap is made of an esky, light, fan, 6 volt battery and catchment net. When the trap is set, dry ice is placed into the esky. As the ice melts, it releases carbon dioxide gas, attracting mosquitoes.

They mistake the gas as a potential food source such as a person or animal. The trap has a battery-operated light and fan, that also attracts mosquitoes. Once the mosquitoes are trapped inside the net, they are unable to be released. The light traps are set overnight at specific sites and specimens are collected the following morning.

Data is recorded for each site including weather conditions and the number of mosquitoes trapped prior to mosquitoes being sent to the laboratory at Agribio within LaTrobe University. The AgriBio laboratory will identify the species and analyse DNA to determine if there are mosquitoes present that are carrying an arbovirus. The information collected onsite and via the laboratory provides general indication of existing adult mosquito infestation rates within townships. The numbers of adult mosquitoes trapped are classified as described in Table 11.

Table 11 Classification of trapped adult mosquitoes

Classification	Range (mosquito/trap)
Nil	0
Low	<10
Moderate	11-100
High	101-200
Significant	201-500
Extreme	500+

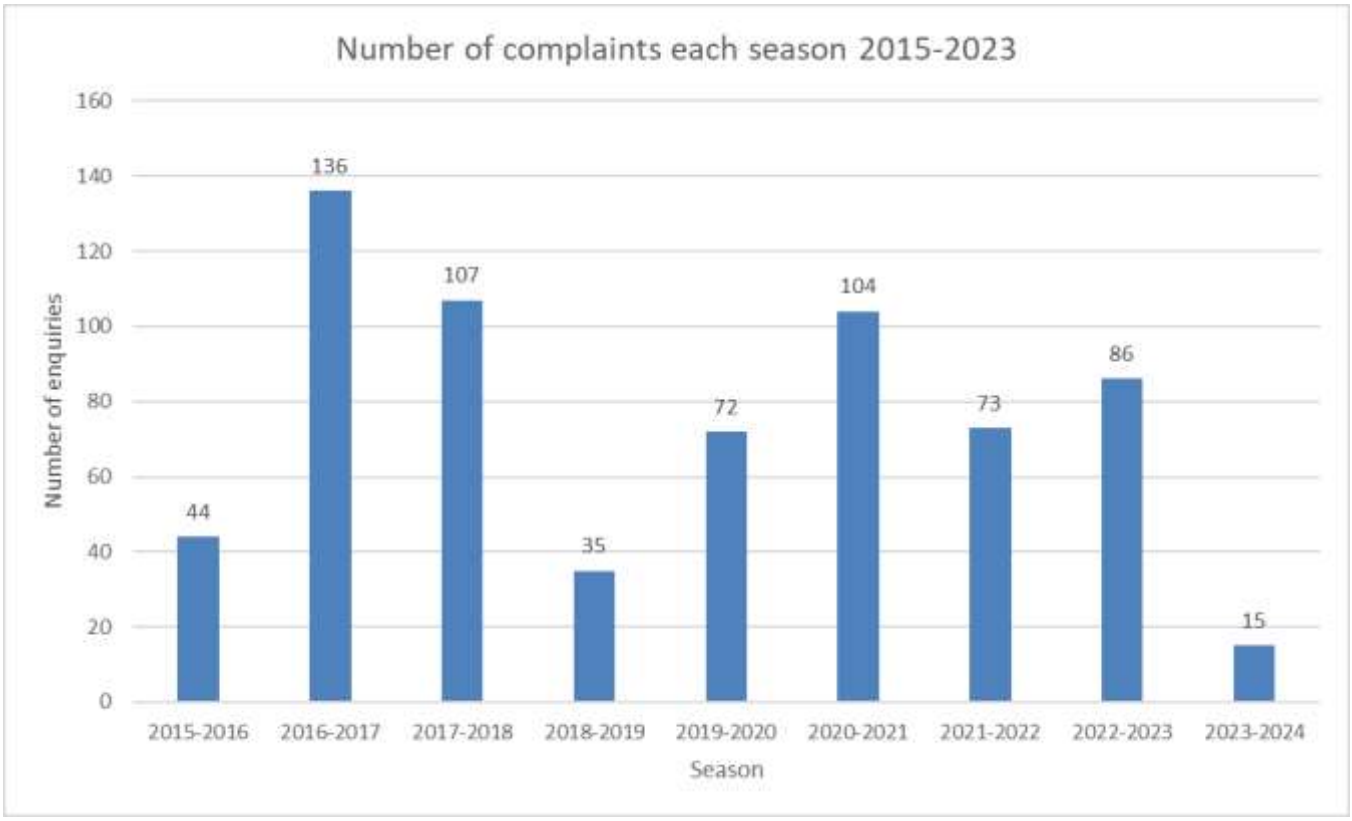
The monthly larval infestation rates and mosquito light trap numbers are then compared to rainfall levels for specific townships. Prior results generally indicate that when rainfall levels are higher, there are high larvae infestations and moderate to high numbers of mosquitoes and conversely when rainfall is low, there are low or negligible larvae numbers as well as low numbers of mosquitoes.

Mosquitoes often stay near their breeding site, but some can travel for several kilometres to find a blood meal. This is evident on the Bellarine Peninsula where most major townships are situated adjacent to multiple wetlands. Traps will be set in populated areas to get an indication of the mosquito levels in townships. The species trapped gives an idea of where the mosquitoes may be breeding, such as a saltwater wetland site or a freshwater site like drainage or easements, as different species breed in different types of water.

Complaint monitoring

The City responds to customer enquiries, ‘Requests for Service’ (RFS) and complaints regarding the mosquito management program.

Graph 7 shows mosquito related enquiries to the City’s Environmental Health Department during the 2022-2023 season were higher than the 2021.



Graph 7 Number of complaints each season 2015-2023

The past few seasons have seen an increase in mosquito enquiries in May following an increase in mosquito numbers potentially due to rain, mild temperatures and larval treatments not being done in wetlands due to the date range conditions of the EPBC Approval conditions.

Emergency management

The Department of Health (DoH) is the responsible organisation for initiating any emergency control procedures to minimise the incidence and transmission of vector-borne diseases.

If required, DoH can instruct the City to alter the program in response to any emerging public health risk stemming from vector-borne diseases.

If the Chief Health Officer authority issues a disease vector control notice, the City will collaborate with DoH to determine the best course of action to prevent actual or potential outbreaks. This may involve additional monitoring of larvae, light trapping or any other physical, chemical and biological controls necessary.

2.4.7 Proposed treatment sites for 2024-2030 program

2.4.7.1 Process for identifying sites, treatment areas, frequency of treatments and maximum intended application rates for the proposed 2024-2030 program

With the move to using drones to treat sites, the City has had to review sites that align with the capacities of an agricultural drone and the legislation governing their use in mosquito management. In addition to the new deployment method and associated constraints (e.g. maximum 400 m line of site from operator) a review of historical aerial and ground-based treatments (section 2.4.2) have been used to determine the following for each of the proposed treatment sites for the 2024-2030 program:

– *Need for future treatments* (inclusion/exclusion of sites) – some sites treated historically have been removed and others combined due to their proximity with neighbouring sites. This has resulted in a reduction of the overall number of sites requiring ground-based treatment (from 36 to 9) and with aerial treatment sites slightly increased (from 36 to 43) for the proposed program (overall reduction in sites from 72 to 52).

– *Type of treatment* – ground-based or aerial. Noting some historically treated ground-based sites are proposed for aerial treatment by drone
– *Site area* – including for some sites a revision of the site boundary and therefore the size of the site. Some aerial and smaller ground-based sites were combined which has changed the overall area of some sites for the proposed program. Site area is defined as the total area in hectares of the site (e.g. 10 ha) that may be treatable over the six-year program.

There has been a significant overall reduction in the total site areas of the program from the previous referral to this proposed program. Approximately 1,000 hectares have been removed from the program. This is due to the change of using drones in the program as opposed to a helicopter. An agricultural drone will have less reach than a helicopter but will allow sites that are closer to residential areas to be treated aerially.

Proposed treatment area (Ha)

– *Aerial sites* – proposed area of the site that would be treated during one treatment. For aerial sites the treatment area was determined by averaging the total historical treatment area between 2012-2021
– *Ground-based sites* – proposed area of the site that would be treated during one treatment. For ground-based sites less than 1 ha, the entire area may be treated. For sites greater than 1 ha, an area estimate calculation will be applied

Forecast frequency of treatments (number per season)

Some sites are likely to require treatment multiple times during one season, and some sites not treated at all for multiple seasons. Forecasting the frequency of treatments based on historical treatment activity allows for prediction of the number of treatments across the six-year program, with consideration for the different seasonal conditions. This accounts for years which may require more treatments and allows for some contingency within the program. The frequency of treatments provided in Table 17 is expected to be the maximum number of treatments any site will receive each season.

– *Frequency of treatments (aerial sites)* – proposed number of treatments needed each season (August through to March for aerial sites) over the course of the six-year (season) program. The frequency of treatments was calculated using the following:
    - Mode = most frequently recurring number of treatments per season (based on historical data range from 2012- 2021)
    - Mean = Total number of historical treatments/9 seasons (based on historical data range from 2012-2021) = XX frequency of treatments. Used when mode = 0
– *Frequency of treatments (ground sites)* – proposed number of treatments needed each season (August through to end of May for ground-based sites) over the course of the six-year (season) program. The frequency of treatments was calculated using the following:
    - Mode = most frequently recurring number of treatments per season (based on historical data range from 2005- 2021)
    - Mean = Total number of historical treatments/16 seasons (based on historical data range from 2005-2021) = XX frequency of treatments. Used when mode = 0

Proposed seasonal treatment area (Ha)

The seasonal treatment area is the cumulative total of treated area across an entire season. The proposed seasonal treatment area is the cumulative total based on the forecast maximum frequency of treatments. i.e. if a site is forecast to require 2 treatments in a season, with a proposed treatment area of 7 ha, the proposed seasonal treatment area would be 14 ha.

– *Seasonal treatment area (ha)* – proposed area of treatment for one season for each aerial and ground-based site. Seasonal treatment area will be calculated by:
    - Frequency of treatments x treatment area = XX ha
    - Where no data exists due to being a new site, sites within, adjacent or closest to the site will be used to determine the proposed seasonal treatment area
    - Where a site has changed from ground-based to aerial, the calculations for the seasonal ground treatments will be carried over to the aerial calculation

As there are new sites that have either never been treated or are being considered for inclusion in the Ramsar site due to the June 2022 review of the Port Phillip Bay (Western Boundary) and Bellarine Peninsula Ramsar Site Boundary, there is no historical data available to predict required treatments for those sites. Sites that are closest in size and vicinity have been used to produce proposed seasonal treatment areas.

Ground-based sites that have changed to aerial and have had an increase or decrease in size will utilise the calculations from their ground-based site treatment data to produce proposed seasonal treatment areas.

Proposed program treatment area (Ha)

The program treatment area is the sum total of treated area across each season over the duration of the six-year program. The proposed program treatment area is calculated from the proposed seasonal treatment area, which is based on historical treatment data.

– *Program treatment area (ha)* – sum of total seasonal treated area proposed to be treated over the course of the six-year program for one aerial or ground-based site. Calculated using the following:
    - Seasonal treatment area of site x six years (assuming a scenario that each site will be treated each year as per the determined frequency each year for six years)

Proposed application rates

The maximum seasonal and program treatment rates were calculated using calculations of mode and mean from Table 11, as per the instructions provided by the manufacturer. The proportion of Bti to S-methoprene treatments at each site was decided by consulting with the City's experienced mosquito management officer and historical data of treatments for each site.

The City refers to the manufacturer's label for both Bti and S-methoprene to determine the seasonal intended application rate and the maximum intended application rate.

The City has provided calculations for both the amount of product (including all constituents) and actual amount of product (only active constituent) applied during treatments in Table 13.

Seasonal intended application rate – is the proposed maximum application rate of larvicide to be applied to a site over the course of a season. To calculate the seasonal intended rate, seasonal treatment area is multiplied by the maximum application rates for both products (7 kg/ha for Bti, 4 kg/ha for S-methoprene).

– *Seasonal intended application rate* – is the proposed maximum application rate of larvicide to be applied to a site over the course of a season. To calculate the seasonal intended rate, seasonal treatment area is multiplied by the maximum application rates for both products (7 kg/ha for Bti, 4 kg/ha for S-methoprene).
– *Program intended application rate* – is the proposed maximum application rate of larvicide to be applied to a site over the course of the proposed six year program. To calculate the maximum intended application rate the seasonal rate is multiplied by six (the proposed number of seasons) to determine the maximum application rate for the duration of the permit.

2.4.7.2 Summary of treatment sites

The City proposes to operate the six year program from late 2024 through to the end of 2030. The program will include treatment of up to 52 sites (9 ground-based and 43 aerial) over the course of the six year program.

Table 12 to Table 19 provide summaries of the following for each of the aerial and ground-based treatment sites proposed for the 2024-2030 program including:

– Site number and site description
– Location with regard to Ramsar site
– Treatment product name, product type
– Proposed treatment area
– Historical mode and range i.e. most likely number of treatments and maximum number of treatments
– Proposed frequency of treatments
– Proposed seasonal treatment area
– Program treatment area

– Seasonal and maximum (program) intended application rates for each product including for all constituents and the active constituent

Table 12 Summary of proposed treatment types

Treatment type	Ground-based	Aerial	Total
	Proposed	Proposed	Proposed
No. of sites	9	43	52
No. of sites within Ramsar site	3	38	41[#]
Site area (all sites combined) – ha*	22.41	3257.31	3279.72
Site area within Ramsar sites (all sites combined) – ha	10.31	3198.6	3208.91
Seasonal treatment area (all sites combined) – ha*	9.72	681.13	690.87
Seasonal treatment area within Ramsar site (all sites combined) – ha	4.46	666.06	670.52
Program treatment area (all sites combined) – ha*	58.26	4086.81	4145.07
Program treatment area within Ramsar sites (all sites combined) – ha	26.74	3996.376	4023.12

Table note:
* inclusive of sites within or adjacent Ramsar sites
# There are potential further inclusions in the Port Phillip Bay and Bellarine Peninsula Ramsar site that are have been put forward by DEECA as detailed on the Engage Victoria website (https://engage.vic.gov.au/port-phillip-bay-and-bellarine-peninsula-ramsar-site-boundary-review). These potential DEECA sites however have not been included, as they are only potential sites.

Table 13 Summary of proposed seasonal and maximum (program) intended application rates per treatment type

Application type	Ground-based	Aerial	Total
	Proposed	Proposed	Proposed
S-methoprene			
Seasonal intended rate S-methoprene (kg)*	15.016	410.157	425.173
Actual amount of S-methoprene for seasonal rate (kg)**	0.060	1.641	1.701
Maximum (program) intended app rate S-methoprene* (kg)*	90.1	2460.942	2551.041
Actual amount of S-methoprene used for Maximum rate (kg)**	0.361	9.844	10.204
Bti			
Seasonal intended rate Bti (kg)*	46.948	4091.311	4138.258
Actual amount of Bti used for seasonal rate (kg)**	1.34	116.417	117.755
Maximum (program) intended app rate of Bti (kg)*	281.69	24547.859	24829.549
Actual amount of Bti used for Maximum rate (kg)**	8.03	699.612	707.644

Tables notes:
* amount includes ingredients 1 and 2 listed in Table 7 **amount includes only ingredient 1, either Bti or S-methoprene

2.4.7.3 Aerial treatment sites

With the move to using drones to treat sites, the City has had to review sites that align with the capacities of an agricultural drone and the legislation governing their use in mosquito management. To reduce the risk of loss of equipment, aerial sites have had a buffer of 400 m from land and safe access points included; this 400 m buffer removes significant portions of sites such as Site 10.8 - Reedy Lake and Site 8.18 - back of Lake Connewarre, while still covering the areas historically treated with a helicopter.

Many ground-based sites that were previously unable to be treated with a helicopter due to safety concerns can now be quickly and efficiently targeted with an agricultural drone, potentially resulting in fewer treatments when compared to manual ground treatments. There are currently five sites that are not within or adjacent to a Ramsar site:

– 3.9 – Wallington Rd, Wetland drains Lings Rd
– 5.1 – Pt Richards Marsh Swamp Foreshore
– 5.3 – Pits and Pipes Surveillance (Boat Rd)
– 11.2 – Pt Henry Foreshore Marsh & Ponds Windmill Rd
– 11.8 – Drain Behind Animal Health Lab

These sites have been included within the proposal as they may provide data pertinent to the physicochemical parameters of water bodies within the region.

Table 14 Aerial-treatment sites including proximity to Ramsar site and site area

Site No.	Site Description	Within of adjacent to Ramsar site	Proposed site area (ha)
2.17	SOUTHERN LAKE VICTORIA	Yes	**77**
2.4	COLLENDINA SOUTH SALT LAKE AT EAST OF CARAVAN PARK	Yes	**13.2**
2.5	COLLENDINA NORTH SALT LAKE AT EAST OF CARAVAN PARK	Yes	**35.2**
2.7	LONSDALE LAKES WILDLIFE RESERVE	Yes	**30.0**
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH	Yes	**3.3**
3.10	PACEY'S ISLAND, PRIMETER WETLANDS	Yes	**32.8**
3.11	PACEY'S ISLAND, SEVERAL LOW LYING WETLANDS	Yes	**145.3**
3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	**10.9**
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	**341.9**
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	**25.5**
3.8	THACKER ST TIDAL WETLANDS AND CREEK	Yes	**23.1**
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	**14.6**
4.12	SLAT LAGOON IBBOTSON ST WEST SIDE	Yes	**84.6**
4.1	MARSH BEHIND HOUSES CLIFF ST – LOWER BLUFF	Yes	**40.9**
4.6	PT EDWARDS RESERVE	Yes	**47.8**
5.1	PT RICHARDS MARSH SWAMP FORESHORE	No	**2.0**
5.3	PITS AND PIPES SURVEILLANCE (BOAT RD)	No	**0.8**
7.1	KNIGHTS RD SWAN BAY NORTH	Yes	**31.0**
7.2	NYE RD WETLANDS	Yes	**25.9**
7.3	IBBOTSON ST END OF SWAN BAY	Yes	**30.1**
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	**161.4**
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS	Yes	**45.2**

Site No.	Site Description	Within of adjacent to Ramsar site	Proposed site area (ha)
8.13	STACEY'S RD (ROYCOTT PROPERTY) CONNEWARRE	Yes	**22.7**
8.14	BACKWATERS	Yes	**44.4**
8.18	BACK OF LAKE CONNEWARRE	Yes	**452.5**
8.2	REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	**40.7**
8.4	REAR OF SCHOOL – LAKE MURTNAGURT PERIPHERY	Yes	**73.6**
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	**20.9**
8.9	JIRRAHLINGA – PONDS AND WETLANDS	Yes	**16.6**
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	Yes	**92.0**
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	Yes	**23.9**
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	Yes	**15.2**
9.5	BLACKGATE RD	Yes	**57.1**
10.7	MOLLERS RD LEOPOLD CONNEWARRE MARSH	Yes	**17.0**
10.8	REDDY LAKE PERIPHERY	Yes	**817.5**
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	**36.5**
11.6	ALCOA WETLANDS – LAGOONS	Yes	**9.7**
11.8	DRAIN BEHIND ANIMAL HEALTH LAB	No	**4.8**
14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	**7.2**
14.3	BURNT PT END OF FELLOWS RD	Yes	**72.9**
14.4	BURNT PT END OF FELLOWS RD	Yes	**30.8**
14.8	CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY	Yes	**2.7**
15.8	TIDAL WETLAND LAKES (4 LARGE)	Yes	**176.1**
Total			**3257.31**

2.4.7.4 Ground-based treatment sites

Some sites previously included as ground-based sites are now drone (aerial) sites, while other sites have been removed due to land ownership or accessibility issues. There are now a total of nine ground sites included within the program that are expected to be treated throughout a season.

Table 15 Ground-treatment sites including current status, proximity to Ramsar site and comparison of site area

Site no.	Site description	Status	Within or adjacent to Ramsar site	Proposed site area (ha)
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	Unchanged	No	**2.93**
1.7	PITS & PIPES SURVEILLANCE	Area changed	No	**0.04**
3.2	OCEAN GROVE NATURE RESERVE	Area changed	No	**1.52**
3.7	OCEAN GROVE GOLF COURSE CREEK	Unchanged	No	**0.67**

Site no.	Site description	Status	Within or adjacent to Ramsar site	Proposed site area (ha)
5.2	RAMBLERS RD PORT MARSH	Unchanged	No	**5.84**
8.11	SHEEPWASH TIDAL WETLANDS	Unchanged	Yes	**3.23**
8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD	Unchanged	Yes	**2.53**
8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH	Unchanged	Yes	**4.55**
14.11	CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	Unchanged	No	**1.10**
Total				**22.41**

2.4.8 Summary of a proposed typical treatment season

The purpose of this section is to clarify the proposed patterns of use and provide a summary of a typical treatment season for the 52 treatment sites within the program area. A typical mosquito season would be where the City does not receive notification from the Department of Health and Human Services for a viral or exotic species detection, there are no large weather events that increase rainfall during elevated temperatures, and larval/adult mosquito abundance does not remain extreme for extended periods of time. Table 17 provides a summary of a typical treatment season.

Assuming a typical treatment season occurs, the City proposes to complete 924 treatments across the six year program, of which up to 612 treatments or 66% will be within sites with MNES values, including:

– Of the 3 ground-based sites that will most likely receive 1 treatment every 2-3 years (less than 1 per season), all are documented with MNES values. This is expected to result in a cumulative total of one to three treatments per site over the six year program (with large time periods (> 2 years) with no treatment.
– Of the 25 (20 aerial and 5 ground-based) sites that will most likely receive 1 treatment per season, all are documented with MNES values. This is expected to result in a cumulative total of about six treatments per site over the six year program (with at least six-month time periods where no treatment occurs.
– Of the 24 sites (23 aerial and 1 ground-based) that may be treated twice or more each season, 23 aerial and one ground-based sites are documented with MNES values (Table 16). However, this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every two to three years. Conservatively, these sites would be expected to result in a cumulative total of approximately 25-30 treatments per site over the six-year program with at least 5 months between treatment season for aerial sites and three months between treatment seasons for ground-based sites.

Should any of the above-mentioned sites require further treatment in a season to reduce public health risks, the City may employ adaptive management strategies to account for the extra treatments such as:

– Conducting water sampling of the site before and after treatments
– Inclusion of the site as a comparison site for bird surveys
– Altering flight path of the drone to limit potential impact to MNES species present
– Halting further aerial/ground treatments at a site as the seasonal maximum nears
– Halting further aerial/ground treatments at a site as the program maximum nears

Furthermore, not all available mosquito habitat is treated each season within the proposed action area and therefore large areas of untreated habitat remain for mosquitos and natural mosquito predators. For example, the total area of sites including Ramsar wetland within the proposed action area is 3,279.72 ha, however the seasonal treatment area of all sites (including Ramsar and non-Ramsar sites) is 690.87 ha or approximately 21% of the reported Ramsar site area within the proposed action area. It is difficult to quantify the area of mosquito breeding habitat within the proposed action area, but it can be assumed with confidence that the area of untreated habitat is much larger than the area being treated as part of the proposed program. For example:

– Site 10.8 - Reedy Lake is 817.5 ha in area and is within the Ramsar site. The seasonal treatment area is 65.64 ha or 8.0% of the site and the cumulative program treatment area is 393.81 ha. A very small portion of this site will be treated each season, with extensive portions of habitat suitable for MNES, including mosquito breeding habitat, not be treated over the course of the program. Treatment area will be restricted to the margins of the site where the mosquito habitat occurs.
– Site 8.18 - Salt Swamp within the Ramsar site occurring at the back of Lake Connewarre Swamp is 452.5 ha. The typical seasonal treatment area is 12.60 ha or 2.8% of the site. The cumulative program treatment area is 50.41 ha or approximately 11% of the site. A very small portion of this site will be treated each season, with extensive portions of habitat suitable for MNES, including mosquito breeding habitat, not treated over the course of the program.

Table 16 Summary of a typical treatment season

Treatment type and number of sites	Number of treatments per typical season	Product type	Time between treatments
Aerial (no sites = 20) In/adjacent to Ramsar and/or documented MNES value = 2.17, 2.4, 2.5, 3.1, 3.10, 8.2, 8.7, 8.9, 8.14, 9.1, 9.2, 9.3, 9.5, 10.7, 11.6 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 3.9, 5.1, 5.3, 11.2, 11.8	1	Primarily Vectobac G -Granule (Bti), occasionally Prolink Pro Sand – Sand (S-methoprene)	At least 6 months , possibly more between treatments
Aerial (no sites = 23) In/adjacent to Ramsar and/or documented MNES value = 2.7, 3.8, 3.11, 3.12, 3.13, 3.14, 4.1, 4.12, 4.6, 7.1, 7.2, 7.3, 7.5, 8.1, 8.4, 8.13, 8.18, 10.8, 14.1, 14.3, 14.4, 14.8, 15.8 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 0	2 or more – some sites may receive more, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every 2-3 years	Primarily Vectobac G -Granule (Bti) then Prolink Pro Sand – Sand (S-methoprene)	At least 7 days between treatments within a season (Bti) At least 14 days between treatments within a season (S-methoprene) At least 5 months between seasons (i.e. no treatments from mid March to Mid August)
Ground (no sites = 3) In/adjacent to Ramsar and/or documented MNES value = 8.11 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 3.2, 3.7	< 1 per year, every 2- 3 years	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-46ethoprene), then Vectobac G – Granule (Bti)	At least 10 months, possibly more between treatments
Ground (no sites = 5) In/adjacent to Ramsar and/or documented MNES value = 8.3, 8.16 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 1.4, 5.2, 14.11	1	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-methoprene), then Vectobac G – Granule (Bti) Site 3.16 S-methorprene (mix of Prolink Pro Sand, Prolink XR Briquets, Prolink Pellets)	At least 6 months , possibly more between treatments

Treatment type and number of sites	Number of treatments per typical season	Product type	Time between treatments
Ground (no sites = 1) In/adjacent to Ramsar and/or documented MNES value = 0 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 1.7	2 or more – some sites may receive more, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every 2-3 years	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-47ethoprene), then Vectobac G – Granule (Bti) Site 1.7 S-methoprene (mix of Prolink Pro Sand, Prolink XR Briquets, Prolink Pellets)	At least 14 days between treatments within a season (Prolink Pro Sand – S-methoprene) At least 30 days between treatments within a season (Prolink Pellets_Granual, S-methoprene) At least 7 days between treatments within a season (Bti) At least 3 months between seasons (i.e. no treatments from May to August)

Table notes: The aerial treatment program will operate from 15 August to 15 March each year and the ground-based treatment program will operate from 15 August through to 31 May each year

Table 17 Typical treatment across a season and cumulative treatment over six years

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of range/ mode/ historical treatments over 9 seasons	Total estimated historical cumulative treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical / maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program cumulative treatment area (ha)
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	Yes	2.93	33/2	1.76	2.93	1/3	1.76	10.55
1.7	PITS & PIPES SURVEILLANCE	No	0.04	45/3	0.04	0.04	8/10	0.32	1.92
2.17	SOUTHERN LAKE VICTORIA	Yes	77	7	31.82	4.55	1/3	4.55	27.27
2.4	COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK	Yes	13.2	4/2/0	14.33	1.43	1/3	1.43	8.60
2.5	COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK	Yes	35.2	7/3/0	41.73	3.79	1/4	3.79	22.76
2.7	LONSDALE LAKES WILDLIFE RESERVE	Yes	30.0	N/A	N/A	2.73	2/5	13.64	81.82
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER	Yes	3.3	6	51.02	8.50	1/2	8.5	51.02
3.2	OCEAN GROVE NATURE RESERVE	No	1.52	1	0.46	0.46		0.46	2.74
3.7	OCEAN GROVE GOLF COURSE CREEK	Yes	0.67	6	0.67	0.67	1/2*	0.67	4.02
3.8	OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK	Yes	23.1	29/5/3	75.23	3.58	3/8	10.75	64.48
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	14.6	20/6/0	84.68	4.23	2/8	8.47	50.81
3.10	PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER	Yes	32.8	12/6/0	13.12	14.58	1/7	14.58	87.47

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of range/ mode/ historical treatments over 9 seasons	Total estimated historical cumulative treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical / maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program cumulative treatment area (ha)
3.11	PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS	Yes	145.3	33/2/5	418.29	6.24	5/7	31.22	187.29
3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	10.9	26/3/4	82.84	1.36	4/7	5.43	32.59
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	341.9	39/9/3	865.19	11.69	3/12	35.08	210.45
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	25.5	26/6/2	140.54	2.70	2/8	5.41	32.43
4.1	MARSH BEHIND HOUSES CLIFF ST – LOWER BLUFF	Yes	40.9	31	87.99	2.84	2/4	11.35	68.12
4.12	SALT LAGOON IBBOTSON ST WEST SIDE	Yes	84.6	49	84.60	1.73	3/6	8.96	53.76
4.6	SWAN BAY NORTH, PT EDWARDS RESERVE	Yes	47.8	19/4/2	402.23	10.59	2/6	21.17	127.02
5.1	PT RICHARDS MARSH SWAMP FORESHORE	No	2.0	6	N/A	N/A	1/3	1.22	7.32
5.2	RAMBLERS ROAD PORT MARSH	No	5.84	21/1	1.17	1.17	1/3	1.17	7.01
5.3	PITS AND PIPES SURVELLANCE (BOAT RD)	No	0.8	29	N/A	N/A	1/3	1.64	9.84
7.1	SWAN BAY NORTH, KNIGHTS RD	Yes	31.0	25/4/3	481.29	14.16	3/7	42.47	254.80
7.2	SWAN BAY – NYE RD WETLANDS	Yes	25.9	28/5/3	24.21	0.97	3/8	2.91	17.43
7.3	SWAN BAY – IBBOTSON ST	Yes	30.1	28/5/4	97.25	4.42	4/9	17.68	106.09
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	161.4	33/6/5	1082.65	18.67	5/11	93.33	559.99
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT	Yes	45.2	33/5/5	401.90	7.58	5/10	37.92	227.49

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of range/ mode/ historical treatments over 9 seasons	Total estimated historical cumulative treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical / maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program cumulative treatment area (ha)
8.2	REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	40.7	14	N/A	N/A	1/2	48.84	293.04
8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH	Yes	4.55	6	2.73	2.73	1/2	2.73	16.38
8.4	REAR OF SCHOOL – LAKE MURTNAGHURT PERIPHERY	Yes	73.6	34/5/6	208.08	3.65	6/11	21.90	131.42
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	20.9	22/5/1	17.31	0.62	1/6	0.62	3.71
8.9	JIRRALINGHA – PONDS AND WETLANDS	Yes	16.6	11	N/A	N/A	1/3	4.98	29.88
8.11	SHEEPWASH TIDAL WETLANDS	Yes	3.23	1	0.97	0.97	1/2*	0.97	5.81
8.13	LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)	Yes	22.7	32/2/5	207.82	3.71	4/7	14.84	89.07
8.14	LAKE CONNEWARRE, BACKWATERS	Yes	44.4	25/6/1	43.08	10.77	1/7	10.77	64.62
8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH ROAD	Yes	2.53	3	0.76	0.76	1/2	0.76	4.55
8.18	SALT SWAMP, BACK OF LAKE CONNEWARRE	Yes	452.5	36/6/2	207.95	6.30	2/8	12.60	75.62
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	Yes	92	33/5/1	538.94	14.57	1/2	29.13	174.79
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	Yes	23.9	18/5/1	59.94	1.30	1/2	2.61	15.64
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	Yes	15.2	7/4/0	30.63	1.91	1/2	3.83	22.97

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of range/ mode/ historical treatments over 9 seasons	Total estimated historical cumulative treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical / maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program cumulative treatment area (ha)
9.5	BREAMLEA SALTMARSHES BLACKGATE RD	Yes	57.1	20/5/1	413.49	10.34	1/2	20.67	124.05
10.7	LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD	Yes	17.0	9/2/1	12.70	6.35	1/3	6.35	38.10
10.8	REEDY LAKE PERIPHERY	Yes	817.5	26/5/3	809.50	21.88	3/8	65.64	393.81
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	36.5	5/1/1	52.90	1.82	1/2	1.82	10.94
11.6	ALCOA WETLANDS – LAGOONS	Yes	9.7	7	N/A	N/A	1/2	3.88	23.28
11.8	DRAIN BEHIND ANIMAL HEALTH LAB	No	4.8	5	N/A	N/A	1/2	1.92	11.52
14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	7.2	73	N/A	N/A	8/10	5.41	32.46
14.3	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	72.9	28/5/3	210.86	5.86	3/8	17.57	105.43
14.4	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	30.8	13/5/3	92.67	3.20	3/8	9.59	57.52
14.8	CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY	Yes	2.7	36	N/A	N/A	3/5	0.23	1.35
14.11	CNR QUEENSCLIFF HWY & FELLOWS ROAD PONDAGE	No	1.10	19/1	0.88	0.88	1/3	0.88	5.28
15.8	BREAMLEA TIDAL WETLAND LAKES (4 LARGE)	Yes	176.1	14/5/2	123.41	8.23	2/7	16.45	98.73
	TOTALS		3279.72 ha		7519.63 ha			690.87 ha	4145.07 ha

Table notes:
* Sites are expected to have one treatment season every 2-3 years, but are shown to have one proposed typical treatment per season in the event that more treatments are required.

Table 18 Aerial treatment site - proposed seasonal and maximum (program) intended application rate for 2024-2030 program

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-methoprene (kg)*	Actual amount of S-methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-methoprene (kg)*	Actual amount of S-methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-methoprene used in the field
2.4	COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK	No	#	#	#	#	10.031	0.286	60.186	1.715	1:0
2.5	COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK	No	#	#	#	#	26.555	0.757	159.333	4.541	1:0
2.7	LONSDALE LAKES WILDLIFE RESERVE	Yes	#	#	#	#	95.455	2.720	572.727	16.323	#
2.17	SOUTHERN LAKE VICTORIA	No	#	#	#	#	31.820	0.907	190.920	5.441	1:0
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER	Yes	#	#	#	#	59.523	1.696	357.140	10.178	1:0
3.8	OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK	Yes	#	#	#	#	75.230	2.144	451.380	12.864	1:0
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	#	#	#	#	59.276	1.689	355.656	10.136	1:0
3.10	PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER	Yes	#	#	#	#	102.044	2.908	612.267	17.450	1:0
3.11	PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS	Yes	#	#	#	#	218.510	6.228	1311.058	37.365	1:0
3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	#	#	#	#	38.025	1.084	228.150	6.502	1:0
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	#	#	#	#	245.527	6.998	1473.161	41.985	1:0

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-methoprene (kg)*	Actual amount of S-methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-methoprene (kg)*	Actual amount of S-methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-methoprene used in the field
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	#	#	#	#	37.838	1.078	227.026	6.470	1:0
4.1	MARSH BEHIND HOUSES CLIFF ST – LOWER BLUFF	Yes	#	#	#	#	79.475	2.265	476.849	13.590	#
4.6	SWAN BAY NORTH, PT EDWARDS RESERVE	Yes	21.170	0.085	127.020	0.508	118.552	3.379	711.312	20.272	4:1
4.12	SALT LAGOON IBBOTSON ST WEST SIDE	Yes	#	#	#	#	62.720	1.788	376.320	10.725	#
5.1	PT RICHARDS MARSH SWAMP FORESHORE	No	#	#	#	#	6.832	0.195	40.992	1.168	#
5.3	PITS AND PIPES SURVEILLANCE (BOAT RD)	No	#	#	#	#	9.184	0.262	55.104	1.570	#
7.1	SWAN BAY NORTH, KNIGHTS RD	Yes	#	#	#	#	297.267	8.472	1783.604	50.833	1:0
7.2	SWAN BAY - NYE RD WETLANDS	Yes	#	#	#	#	20.336	0.580	122.018	3.478	1:0
7.3	SWAN BAY - IBBOTSON ST	Yes	17.682	0.071	106.091	0.424	99.018	2.822	594.109	16.932	4:1
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	93.332	0.373	559.991	2.240	522.659	14.896	3135.952	89.375	4:1
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT	Yes	37.915	0.152	227.491	0.910	212.325	6.051	1273.947	36.307	4:1
8.2	REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	#	#	#	#	273.504	7.795	1641.024	46.769	#

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-methoprene (kg)*	Actual amount of S-methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-methoprene (kg)*	Actual amount of S-methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-methoprene used in the field
8.4	REAR OF SCHOOL - LAKE MURTNAGHURT PERIPHERY	Yes	21.903	0.088	131.419	0.526	122.658	3.496	735.946	20.974	4:1
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	0.618	0.002	3.709	0.015	3.462	0.099	20.772	0.592	4:1
8.9	JIRRAHLINGA – PONDS AND WETLANDS	Yes	#	#	#	#	27.888	0.795	167.328	4.769	#
8.13	LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)	Yes	#	#	#	#	103.910	2.961	623.460	17.769	1:0
8.14	LAKE CONNEWARRE, BACKWATERS	Yes	10.770	0.043	64.620	0.258	60.312	1.719	361.872	10.313	4:1
8.18	SLAT SWAMP, BACK OF LAKE CONNEWARRE	Yes	12.603	0.050	75.618	0.302	70.577	2.011	423.462	12.069	4:1
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	43.698	0.175	262.187	1.049	142.746	4.068	856.478	24.410	7:3
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	No	3.909	0.016	23.455	0.094	12.770	0.364	76.619	2.184	7:3
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	No	5.743	0.023	34.459	0.138	18.761	0.535	112.565	3.208	7:3
9.5	BREAMLEA SALTMARSHES BLACKGATE RD	No	31.012	0.124	186.071	0.744	101.305	2.887	607.830	17.323	7:3
10.7	LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD	Yes	9.525	0.038	57.150	0.229	31.115	0.887	186.690	5.321	7:3

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-methoprene (kg)*	Actual amount of S-methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-methoprene (kg)*	Actual amount of S-methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-methoprene used in the field
10.8	REEDY LAKE PERIPHERY	Yes	98.453	0.394	590.716	2.363	321.612	9.166	1929.673	54.996	7:3
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	1.824	0.007	10.945	0.044	10.215	0.291	61.291	1.747	4:1
11.6	ALCOA WETLANDS – LAGOONS	Yes	#	#	#	#	21.728	0.619	130.368	3.715	#
11.8	DRAIN BEHIND ANIMAL HEALTH LAB	No	#	#	#	#	10.752	0.306	64.512	1.839	#
14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAL		#	#	#	#	30.296	0.863	181.776	5.181	#
14.3	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	#	#	#	#	123.002	3.506	738.010	21.033	1:0
14.4	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	#	#	#	#	59.738	1.516	358.426	10.215	1:0
14.8	CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY		#	#	#	#	1.575	0.045	9.450	0.269	#
15.8	BREAMLEA TIDAL WETLAND LAKES (4 LARGE)	No	#	#	#	#	115.183	3.283	691.096	19.696	1:0
	TOTALS		**410.157**	**1.641**	**2460.941**	**9.844**	**4091.311**	**116.417**	**24547.859**	**699.612**	

Tables notes:
* Amount includes ingredients 1 and 2 listed in (all constituents) Table 7 **amount includes only ingredient 1, either Bti or S-methoprene (active constituent)
# No historical data is available to inform the estimated amount

Example calculation

Site 9.1 – Breamlea Saltmarshes A (East side of Breamlea Road)

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of/range/ mode/ historical treatments over 9 seasons	Total historical treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed frequency of treatments per season	Proposed seasonal treatment area (ha)	Program treatment area (ha)
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	92	33/5/1	538.94	14.57	4.11	29.13	174.79

$$\text{Seasonal intended rate S-methoprene} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate S-methoprene} = \left(29.13\ \text{ha} \times \frac{5\ \text{kg}}{\text{ha}}\right) \times \frac{3\ *}{10} = 43.698\ \text{kg}$$

$$\text{Actual amount of S-methoprene used for seasonal rate} = \text{Seasonal intended rate S-methoprene} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of S-methoprene used for seasonal rate} = 43.698\ \text{kg} \times \frac{4\ **}{1000} = 0.17478\ \text{kg}$$

$$\text{Seasonal intended rate BTI} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate BTI} = \left(29.13\ \text{ha} \times \frac{7\ \text{kg}}{\text{ha}}\right) \times \frac{7\ *}{10} = 142.737\ \text{kg}$$

$$\text{Actual amount of BTI used for seasonal rate} = \text{Seasonal intended rate BTI} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of BTI used for seasonal rate} = 142.737\ \text{kg} \times \frac{2.85\ **}{100} = 4.068\ \text{kg}$$

* Value obtained from Table 18
** Value obtained from Table 7

Table 19 Ground-based treatment site - number, size and proposed treatment area for the proposed 2024-2030 program

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range/mode of historical treatments over 16 seasons	Proposed typical/maximum of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	No	2.93	0.6	1.76	33/5/1	1/6	1.76	10.55
1.7	PT LONSDALE, PITS & PIPES SURVEILLANCE	No	0.04	1	3.58	45/12/8	8/20	0.32	1.92
3.2	OCEAN GROVE NATURE RESERVE	No	1.52	0.3	0.39	1/1/0	1/2*	0.46	2.74
3.7	OCEAN GROVE GOLF COURSE CREEK	Yes	0.67	1	0.67	6/1/0	1/2*	0.67	4.02
5.2	PORT ARLINGTON, RAMBLERS RD PORT MARSH	No	5.84	0.2	1.17	21/7/0	1/8	1.17	7.01
8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH (LAKE MURTNAGHURT)	Yes	4.55	0.6	2.73	6/3/0	1/4	2.73	16.38
8.11	BARWON HEADS, SHEEPWASH TIDAL WETLANDS, BARWON RIVER	Yes	3.23	0.3	0.97	1/1/0	1/2*	0.97	5.81
8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD, BARWON RIVER	Yes	2.53	0.3	0.76	3/2/0	1/3	0.76	4.55
14.11	PT LONSDALE, CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	No	1.10	0.8	0.88	19/3/0	1/4	0.88	5.28
	TOTALS		**22.41 ha**		**12.91**			**9.72 ha**	**58.26 ha**

* Sites are expected to have one treatment season every 2-3 years but are shown to have one proposed typical treatment per season in the event that more treatments are required.

Table 20 Ground-based treatment site - proposed seasonal and maximum (program) intended application rate for 2024-2030 program

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-methoprene (kg)*	Actual amount of S-methoprene used for seasonal rate (kg)**	Maximum (program) intended app rate S-methoprene (kg)*	Actual amount of S-methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	No	7.032	0.028	42.192	0.169	2.461	0.070	14.767	0.421
1.7	PT LONSDALE, PITS & PIPES SURVEILLANCE	No	1.280	0.005	7.680	0.031	0.448	0.013	2.688	0.077
3.2	OCEAN GROVE NATURE RESERVE	No	1.824	0.007	10.944	0.044	0.638	0.018	3.830	0.109
3.7	OCEAN GROVE GOLF COURSE CREEK	No	2.680	0.011	16.080	0.064	0.938	0.027	5.628	0.160
5.2	PORT ARLINGTON, RAMBLERS RD PORT MARSH	No	#	#	#	#	8.176	0.233	49.056	1.398
8.11	BARWON HEADS, REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	#	#	#	#	6.783	0.193	40.698	1.160
8.16	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH (LAKE MURTNAGHURT)	Yes	#	#	#	#	5.313	0.151	31.878	0.909
8.3	BARWON HEADS, JIRRAHLINGA - PONDS AND WETLANDS	Yes	#	#	#	#	19.110	0.545	114.660	3.268
14.11	PT LONSDALE, CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	No	2.200	0.009	13.200	0.053	3.080	0.088	18.480	0.527
	TOTALS		**15.016**	**0.060**	**90.1**	**0.361**	**46.948**	**1.34**	**281.69**	**8.03**

Tables notes: *amount includes ingredients 1 and 2 listed in (all constituents) Table 7 **amount includes only ingredient 1, either Bti or S-methoprene (active constituent)
No historical data is available to predict the proposed typical / maximum number of treatments per season.

Example calculation

Site 14.1– Murray St Drains & March Nth & Sth of Rail

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range/mode of historical treatments over 16 seasons	Proposed frequency of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
14.1	MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	7.2	73	N/A	N/A	8/10	5.41	32.46

$$\text{Seasonal intended rate S-methoprene} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate S-methoprene} = \left(5.41 \text{ ha} \times \frac{5 \text{ kg}}{\text{ha}}\right) \times \frac{3 *}{5} = 16.23 \text{ kg}$$

$$\text{Actual amount of S-methoprene used for seasonal rate} = \text{Seasonal intended rate S-methoprene} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of S-methoprene used for seasonal rate} = 16.23 \text{ kg} \times \frac{4 **}{1000} = 0.06492 \text{ kg}$$

$$\text{Seasonal intended rate BTI} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate BTI} = \left(5.41 \text{ ha} \times \frac{7 \text{ kg}}{\text{ha}}\right) \times \frac{2 *}{5} = 15.148 \text{ kg}$$

$$\text{Actual amount of BTI used for seasonal rate} = \text{Seasonal intended rate BTI} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of BTI used for seasonal rate} = 15.148 \times \frac{2.85 **}{100} = 0.431718 \text{ kg}$$

* Value obtained from Table 20
** Value obtained from Table 7

2.5 Feasible alternatives to the proposed action

2.5.1 Purpose

Provide feasible alternatives to the action to the extent reasonably practicable, including the alternative of taking no action, with a comparative description of the impacts of each alternative on MNES. Consideration of alternative chemicals and/or biological agents should be provided. Sufficient detail must be provided to make clear why any alternative ispreferred to another. Short, medium and long-term advantages and disadvantages of the options should be discussed.

2.5.2 Proposed alternatives

Table 21 provides a summary of the proposed alternatives to the described mosquito management program outlined in section 2. Future applications of Bti and S-methoprene are supported in preference to organophosphate alternatives; this is based on a comparison with previously published literature that has demonstrated organophosphate insecticides to be directly toxic to non-target arthropods. Considering that the appropriate use of Bti and S-methoprene can reduce the incidence of arbovirus transmission among the local human population, the future application of these products is supported.

Table 21 Summary of proposed alternatives to the proposed action

Proposed alternative	Description	MNES consequences	Program consequences	Advantages	Disadvantages
No action/no program	The City does not continue the proposed mosquito management program	None	The City will experience greater nuisance biting, which could lead to increase in health risks. Residents may be unable to enjoy outdoor amenities due to number of mosquitoes. Educational material to community continues.	No impact to MNES Potential for some MNES species to benefit from increases in mosquito larvae and adults as a result of increased food source.	Increased health risks associated with mosquito borne diseases and higher numbers of biting insects. Potential for public health outbreak. Decrease in health and wellbeing of the community. Decreases ability of the community to enjoy the environment. *Mycobacterium ulcerans* infections becoming more prevalent.
Modified action – reduced control	The City undertakes mosquito management at sites without MNES (sites with MNES include Ramsar wetland areas, other wetlands that provide habitat for MNES species, other known sites outside of wetlands that provide habitat for MNES species)	Minimal	Ground applications continue outside MNES habitats. Not enough officers to apply ground treatments to all of Geelong. Ground treatments insufficient to reduce mosquito number effectively.	The program avoids direct impacts (e.g. drone disturbance) over MNES wetlands.	Increased health risks associated with mosquito borne diseases and higher numbers of biting insects. Potential for public health outbreak. Decrease in health and wellbeing of the community. Decreases ability of the community to enjoy the environment. *Mycobacterium ulcerans* infections becoming more prevalent.

Proposed alternative	Description	MNES consequences	Program consequences	Advantages	Disadvantages
ULV fogging with pyrethroid based chemical	The City could utilise an ultra-low volume fogging machine to disperse products such as Aqua-K-Othrine in heavily affected areas. This treatment will be done closer to businesses and local residential areas. This will be done at sites without MNES.	Minimal if not used near water bodies. Pyrethroids are very toxic to fish and aquatic invertebrates.	Senate inquiry into "cancer clusters" caused aversion of community to fogging. Cannot treat near water, where mosquitoes breed. Can only be conducted after mosquitoes emerge. Cleaning of equipment after every application time consuming.	Reactive to community concerns. MNES unaffected if treatment not over bodies of water. Low concentrations required for desired effect.	Pyrethroids are very toxic to fish and aquatic invertebrates. Will impact other important species (such as bees). Community concerns about fogging have previously led to senate inquiry.
Use of pyridine-based chemical control agents	The City could begin using chemical control agents such as pyriproxyfen to control mosquito populations. Granular and liquid forms available, pyriproxyfen mimics insect hormones and disrupts growth cycles, like Methoprene.	High Pyridine-based chemicals are highly toxic to aquatic life. Long lasting effects to ecosystem.	High risk of chronic exposure for mosquito officers. Heavy restrictions over use of pyridine.	Can be used up till pupation of mosquito larvae, allowing for effective control of mosquitoes.	Severe impacts on aquatic life in wetlands. Toxic to humans and pets. Exposure risk for officers applying treatment.
Introduction of *Pseudomugil signifer* (blue-eye fish)	The City could introduce a predatory fish species into the MNES wetland as a biological control agent. This fish preys upon the larvae of mosquitoes and reduce the number of adults that emerge in a season.	Medium, possibly significant *L. raniformis* (Growling Grass Frog) populations impacted, as *P. signifer* fish will consume eggs of frog species. May also predate juvenile Australian Grayling, Yarra Pygmy Perch and eat food sources	Constant monitoring of release areas required. More in-depth studies into impacts on MNES species. Passive method of mosquito management, harder to anticipate when more fish are needed based on tides, temperatures etc.	Decreased usage of chemical controls for mosquito populations. No disturbance via aerial treatments.	Impact on vulnerable species in MNES wetland. Less reactive to community concerns. Reduced control of mosquito populations (i.e. cannot easily reduce numbers of predator to increase numbers of mosquitoes).
Introduction of *Toxorhynchites speciosus* (elephant mosquito/mosquito eater)	The City could introduce a predatory mosquito species into the MNES wetland as a biological control agent. This species of mosquito preys upon other mosquito species (most notably *A. notoscriptus*) and does not require blood meals to reproduce).	Unknown - not enough data available.	Species is difficult to cultivate. Species does not target pest species in Geelong, will need additional control measures. High cost, low reward.	No disturbances from aerial treatments. Reactive to community concerns. Potential for some MNES species to benefit from higher numbers of mosquito populations.	Unknown impacts on MNES and other species. Difficult to cultivate *T. speciosus* in-house. Cannibalistic species – reduced effectiveness as biological control agent. Not direct predator of *A. camptorhynchus*.

Proposed alternative	Description	MNES consequences	Program consequences	Advantages	Disadvantages
Use of organophosphorus chemical control agents.	The City could begin using chemical control agents such as diazinon to control mosquito populations. Granular and liquid forms available, diazinon disrupts the neurological system of organisms.	Extreme Very highly toxic to birds. Moderately toxic to aquatic life.	Extreme risk of chronic exposure for mosquito officers. Risk of acute exposure for residents. Contamination risk for environment. High PPE requirements for product.	Highly effective chemical control agent. Can be used in a ULV fogging machine or applied diluted.	Disastrous impacts on all MNES species. Potential for diazinon to leech into groundwater and contaminate drinking water. High exposure risk for officers applying treatment.
Liquid mosquito film	The City could use a film producing product such as Aquatain AMF to suffocate mosquito larvae.	Unknown – not enough data. Silicon not known to be hazardous, but interactions within specific MNES habitats not researched.	Can only be applied effectively to larger bodies of water. Not a feasible option for drains. Will suffocate other invertebrates also.	Easy to use application of product. Degrades into silicates. Good for small bodies of water (i.e. ponds, drains, gutters, water tanks etc.) Effective up till pupation of larvae.	Treatment of such a large body of water impractical. No control over how far film is produced. Will suffocate other invertebrates also.

3. Description of the environment and Matters of National Environmental Significance

3.1 Purpose

The preliminary documentation must provide a general description of the environment of the proposed action area, as well as surrounding areas, that may be impacted by the proposed action both in the short and long term. Specific matters this section must address include, but are not limited to:

- *A description of the current land use, topography, surface and groundwater bodies, waterways and vegetation communities within the proposed action area and surrounds*
- *A description of any protected matters (including, but not limited to those listed above) that are, or have the potential to be, in the proposed action area and surrounds*
- *A description of invasive or threatening species that are likely to be present in the vicinity of the site, including but not limited to:*
  - *Mosquitofish (Gambusia holbrooki)*
- *Information about the methods, data and scientific literature used to identify and assess the environmental values within the proposed action area and surrounds, including survey data and historical records*
- *Survey data relating to the proposed action area must be provided for the relevant listed species and/or communities and migratory species, be as recent as possible and must not have been collected more than 5 years before the date the draft preliminary documentation is submitted to the Department*
- *Details of any consultation or advice sought from relevant experts*

<u>Listed threatened species and communities and listed migratory species</u>

For listed threatened species and communities and listed migratory species that are known, or have the potential, to be present within the proposed action area and surrounds and are likely to, or may be significantly impacted by the proposed action, the preliminary documentation must include a minimum of:

- *Information on the abundance, distribution, ecology and habitat preferences for each listed species or community or listed migratory species*
- *Quantification of the extent of habitat and the number of individuals present, or historical patterns of use, within the proposed action area and surrounds (including mapping identifying known and/or potential habitat)*
- *Assessment of the quality and importance of known or potential habitat for the relevant listed species or community within the proposed action area and surrounds*
- *Information detailing known populations or records of individuals within at least 5 km of the proposed action area and the size of these populations, if available*
- *An assessment of the adequacy of any surveys undertaken (including survey effort and timing). In particular, the extent to which these surveys were appropriate for the listed species or community or listed migratory species and undertaken in accordance with relevant Departmental survey guidelines*
- *Details of any current or proposed research, monitoring and trial release programs in the vicinity and for the duration of the proposed action (for Orange-bellied Parrot)*

<u>Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site</u>

For the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, the preliminary documentation must include, as a minimum:

- *A description, including mapping, that shows the location of Ramsar site in relation to the proposed action and a quantification (in hectares) of the area of the Ramsar site within the proposed action area*
- *The listing criteria and ecological character of the Ramsar site including the site's importance in the East Asian-Australasian Flyway*

– *A summary of the critical components, processes and services that the Ramsar site provides as described in the draft Ecological Character Description for the Ramsar site*
– *A discussion of the existing threats to the matters that may be impacted by the proposed action*

3.2 Description of the environment of the proposed action area

3.2.1 Current land use

The majority of the proposed action area is on the Bellarine Peninsula within and beyond the municipality limits of the City of Greater Geelong. The Bellarine Peninsula is located approximately 90 kilometres from Melbourne and approximately 12 kilometres to the east of the urban area of Geelong, with a total area of more than 550 square kilometres (55,000 hectares). It features significant wetland areas and open farmed landscapes with the distinct townships of Barwon Heads, Drysdale/Clifton Springs, Indented Head, Leopold, Ocean Grove, Point Lonsdale, Portarlington, Queenscliff, Breamlea, St Leonards and the rural living area around Wallington. These townships are located along the coast, are popular with holiday makers, and in recent years have attracted increased numbers of permanent residents.

The Bellarine Peninsula is surrounded by Port Phillip Bay to the east, Corio Bay to the north and Bass Strait to the south. The western boundary of the Bellarine Peninsula follows an irregular alignment running generally north-south along the suburban boundary of Leopold, west of Reedy Lake and to the coast at Breamlea. The Bellarine Peninsula has a rich history of Aboriginal and European activity and settlement which contributes to the cultural and historical significance of the broader region.

The proposed action will take place on state and private land tenures including the following nature/conservation reserves:

– Lake Connewarre Wildlife Reserve including Reedy Lake (within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site)
– Swan Bay including Swan Bay - Edwards Point Wildlife Reserve (within Ramsar site)
– Lake Murtnaghurt (eastern portion within Ramsar site)
– Point Lonsdale and Queenscliff Foreshore Reserves (partially within Ramsar site)
– Lake Victoria – part of the Lonsdale Lakes Nature/Wildlife Reserve
– Ocean Grove Nature Reserve
– Salt Lagoon. St Leonards Wildlife Reserve
– Breamlea Flora and Fauna Reserve, Breamlea Coastal Reserve and Breamlea Recreation Reserve.
– Lake Campagna
– Portarlington (Point Richard) Flora and Fauna Reserve

The private and state tenured lands on which the proposed aerial and ground treatment will take place traverse a number of planning zones under the City of Greater Geelong Planning Scheme, including:

– Public Conservation and Resource Zone (PCRZ)
– Farming Zone (FZ)
– Industrial 1 Zone (IN1Z)
– Rural Conservation Zone (RCZ) including schedules RCZ5, RCZ6, RCZ7, RCZ10, and RCZ11
– Public Use Zone 11 (PUZ11)
– Rural Living Zone
– Port Zone
– Neighbourhood Residential Zone (NRZ) including schedules NRZ1 and NRZ6
– Transport Zone (TRZ) including schedules TRZ1, TRZ2, and TRZ 3
– Township Zone

– Comprehensive Development Zone 2 (CDZ2)
– Public Park and Recreation Zone (PPRZ)
– Special Use Zone (SUZ) including schedules SUZ1 and SUZ3
– General Residential Zone 2 (GRZ2)
– Comprehensive Development Zone 1 (CDZ1)
– Urban Growth Zone 2 (UGZ2)

3.2.2 Topography, surface and groundwater bodies, and waterways

3.2.2.1 Topography

The Bellarine Peninsula is a gently to moderately undulating landform that protrudes in an east and north-easterly direction into Port Phillip Bay. The peninsula's eastern regions host several bays and islands such as The Rip, Lonsdale Bay, Swan Bay, Swan Island, Rabbit Island and various other small islands. The slopes and flats of the eastern shoreline of the Bellarine Peninsula are low-sloping and occasionally gently undulating. At the coastal edge, the landform is very flat with low-energy beaches, salt lakes and some minor cliffs no more than five metres high at Indented Head.

A small, flat and seasonally inundated landscape is found between Point Lonsdale and Ocean Grove in the Swan Bay catchment. This area is dominated by waterbodies and wetlands, including Lake Victoria, and is mostly pastoral in the remainder. High, vegetated sand dunes at the coastal edge and prominent slopes inland are important topographic features.

The central and north-eastern regions host a gently undulating topography with no major rivers, mountains or significant landforms. The most distinct feature in the western region of the peninsula is the Barwon River which flows through a series of large lakes and extensive wetlands before emptying into Bass Strait at Barwon Heads.

Reedy Lake and Lake Connewarre are a low-lying area and the natural discharge point for the rivers and creeks draining the surrounding area.

3.2.2.2 Surface water and waterways

The hydrological system of the Bellarine Peninsula consists of a mixture of entirely fresh water lakes (e.g. Reedy Lake), fresh water river and creeks, to saline ocean bays and estuaries. Wetlands in the area comprise six discrete wetland types including shallow swamps, marine water estuaries, freshwater lakes and seagrass beds (Ramsar 1998). Low-lying parts of the area are natural discharge points for small streams and the Barwon River, which drains from southern central Victoria. The Lake Connewarre Complex is the largest wetland system within the area, with an upper freshwater section (Reedy Lake) and a lower section comprising a broad, shallow estuary linked to the sea by the Barwon River. The Barwon River mouth opens to Bass Strait at the central southern point of the Bellarine Peninsula. Fresh water carried in rivers, lakes, swamps and floodplains associated with the Barwon River also flow towards this mouth .

The Barwon River has its headwaters in the Otway Ranges, along the south coast of Victoria. It is joined by two main rivers from the north: the Leigh River and the Moorabool River which drain the southern slopes of the Victorian Central Highlands (Great Dividing Range). The river is about 160 kilometres long and has a catchment of around 8,590 km^2. It passes through the City of Geelong and then across the Bellarine Peninsula to enter the sea at Barwon Heads (Dahlhaus and Reeves 2013). The Barwon, Leigh and Moorabool rivers are highly regulated and have a number of onstream urban water supply dams, as well as diversions to and from other catchments (Dahlhaus and Reeves 2013).

The wetlands and estuary associated with the lower reach of the river (i.e., one section of the Ramsar Site) occupies low-lying land known as the Moolap Sunkland, a graben-like structure between the uplifted Bellarine High and the Barrabool Hills (Dahlhaus and Reeves 2013).

A number of waterways and waterbodies are within or the vicinity of the treatment area of the proposed action. A description of these areas is provided in Table 22.

Table 22 Waterbodies and waterways within the treatment area and surrounds

Waterbody	Description
Barwon River	The Barwon River is a perennial river of the Corangamite catchment, located in the Otways and the Bellarine Peninsula. The Barwon River rises in the Otway Ranges and flows generally north by east and then east, joined by thirteen tributaries including the Leigh and Moorabool rivers and flowing through Lake Connewarre, before reaching its mouth and emptying into Bass Strait at Barwon Heads. The estuarine section of the river forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site as a wetland of international importance, as well as of the Bellarine Wetlands Important Bird Area. The Barwon River Estuary is the largest in the region at approximately 19 km in length and with a catchment area of 17,310 ha and extends from the internationally significant wetland at Lake Connewarre to the sea at Barwon Heads. From its highest point including its source confluence, the river descends 295 m over its 160 km course.
Swan Bay	Swan Bay is a shallow 3000 ha marine embayment at the eastern end of the Bellarine Peninsula. It comprises two enclosed depressions, elongated west-east and separated by a low ridge. Swan Bay contains a variety of ecosystems that make it environmentally important for waterbirds and migratory waders. These include salt marsh, intertidal mudflats and vast seagrass beds on which almost everything living in the bay relies on for food. Although much of the surrounding land is farmland, some remnant woodland survives in the adjoining Edwards Point Nature Reserve and in Swan Bay itself. The bay has been recognised as having international importance and the Port Phillip Heads Marine National Park almost entirely occupies the bay (Rosengren 2009).
Lake Connewarre	Lake Connewarre is a large (880 ha), shallow, estuarine lagoon linked to the sea by the mangrove-fringed channel of the Lower Barwon River. It contains a diverse range of wetlands and vegetation including mangrove and saltmarsh communities. It features a variety of swamps, marshes, lakes and river areas and provides habitat to a wide range fauna. It is also the largest area of native vegetation on the Bellarine Peninsula. Lake Connewarre forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site as a wetland of international importance. The water quality and plant communities of Lake Connewarre are influenced by daily tidal changes with lake water coming from the sea via the Barwon River (Parks Victoria, 2010).
Reedy Lake	Reedy Lake is a shallow 550 ha intermittent freshwater lake or swamp on the lower reaches of the Barwon River. Reedy Lake is connected to Lake Connewarre by the Barwon River. Reedy Lake is a brackish fresh water lake and is almost completely covered by water plants including tall stands of Phragmites and Cumbungi. Water levels within the lake are artificially altered to replicate a more natural cycle (Parks Victoria, 2010). Reedy Lake is listed under the Ramsar Convention as a wetland of international significance, as part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.
Lake Murtnaghurt (also referred to as Murtnaghurt Lagoon)	Lake Murtnaghurt, is a shallow, ephemeral wetland west of the town of Barwon Heads on the southern coast of the Bellarine Peninsula in Victoria, Australia. It comprises two enclosed depressions, elongated west-east and separated by a low ridge. The wetland is about 2 km in length, and up to 600 m wide, with 4.5 km of shoreline enclosing an area of 81 ha. It is connected by a narrow 2.7 km paleochannel extending from the lagoon northwards to the main tidal channel of the lower Barwon River (Rosengren 2009). The western section Murtnaghurt forms part of Lake Connewarre State Game Reserve, which is included in the internationally important Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Wetland Site. Although the eastern section is owned by the Barwon Heads Golf Course, the biodiversity values are spread across the entire lake. It is also part of the larger Lake Connewarre and Barwon River Estuary Important Bird Area (IBA) identified by Birds Australia.
Armstrong Creek	Armstrong Creek is an ephemeral stream with intermittent hydrologic connection to the estuary of the Barwon River (Reedy Lake and Lake Connewarre) during periods of peak flow.
Lake Victoria	Lake Victoria is a shallow sub-coastal lagoon forming part of the Swan Bay systems of wetlands on the Eastern Bellarine Peninsula, south-east of Geelong. Lake Victoria, although it varies in water level provides a relatively stable environment for waterbirds, maintaining its high salinity even when full and never drying out in summer. The site is part of the Swan Bay and Port Phillip Bay Islands Important Bird Area, identified as such by BirdLife International. Birds of conservation significance for which the lake and its surrounds are important include the Hooded Plover, Little Egret and Orange-bellied Parrot. It sometimes holds internationally significant numbers of red-necked stints and banded stilts (Hewish 2010).

Waterbody	Description
Thompson Creek	Thompsons Creek is located approximately 10 km south of Geelong, originating in the Gherang region and entering the sea at Breamlea. For most of the year there is very little flow from the headwaters to its discharge into the sea, although in some years substantial flows and even floods have resulted after periods of sustained and heavy rains. The catchment is located within the geomorphic division known as the South Victorian Coastal Plain. The land is gently undulating and elevation generally does not exceed 70 m. At the mouth of Thompsons Creek, the land is flat and subject to tidal influences resulting in the formation of a large semi-saline saltmarsh. This complex covers an area of about 200 ha behind the sand dunes that run parallel to the coastline (Thompsons Creek Catchment Committee 1998).
Salt Lagoon	Salt Lagoon is a shallow and highly-saline lagoon located near the sea in the north-eastern part of the Bellarine Peninsula (near St Leonards). It is surrounded by saltmarsh vegetation and has an associated salt meadow. The lagoon is home to 41 different species of waterbirds, 16 of which have special conservation status or are listed as protected. The lagoon also provides potential habitat for Orange-bellied Parrots. Additionally, it is important for Common Greenshanks to spend the winter there after migrating from Europe and Asia (Conservation Volunteers n.d.). There are two basins, with relict beaches, spits and islands occurring in both basins. There is no obvious former tideway to connect the lagoon to Port Phillip Bay, but there are two sites where such a connection seems likely. One is at the southeastern edge of the lagoon where there is a low sandy ridge only 40 m wide separating the lagoon from the bay, and the other is a marshy area north of Dossetor Road (Agriculture Victoria 2018).

3.2.3 Vegetation types and communities

The Bellarine Peninsula is based primarily on sedimentary rock, deposited in river channels, floodplains and lakes. The region also has large expanses of volcanic rock, some of which are buried by younger sediments. A history of complete or partial marine submergence over time has slowly formed the peninsula's current geology and soil types (Our Coast 2020). The range of bedrock and soil types on the peninsula have allowed a diversity of vegetation types and habitats to evolve, some of which now comprise wetland sites. Vegetation types vary from non-native and native grasslands and sedgelands, to coastal dune scrub, coastal saltmarsh, mangroves, tall marsh, freshwater and estuarine swamps.

The proposed aerial and ground-based mosquito treatment sites include freshwater wetlands, estuaries, intertidal shorelines, sub-tidal beds, and inland saline wetlands. There are four broad vegetation types that occur within these, all of which are critical to the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. These include seagrass, saltmarsh, mangroves and freshwater wetland vegetation. These vegetation types are discussion in more detail in section 3.2.3.1.

3.2.3.1 Ecological Vegetation Classes (EVCs)

Ecological Vegetation Classes (EVCs) are the standard unit for classifying vegetation types in Victoria. EVCs are described through a combination of floristics, lifeforms and ecological characteristics, and through an inferred fidelity to specific environmental attributes. Ecological Vegetation Class (EVC) benchmarks relate to a single EVC within one bioregion. The project area occurs within two bioregions – the Otway Plain and the Victorian Volcanic Plain. A review of NatureKit (DEECA 2024) was undertaken to determine which, if any, EVCs are modelled to be present within the vicinity of the proposed action. The review indicates that a number of Endangered EVCs may be present within the vicinity of the proposed action. Descriptions of the EVCs modelled to occur within the treatment areas (DEECA 2024) are provided in Table 23.

Table 23 Ecological Vegetation Classes expected to be present within the proposed action area

EVC	Description	Status	Location
132 Plains Grassland	Treeless vegetation mostly less than 1 m tall dominated by largely graminoid and herb life forms. Occupies fertile cracking basalt soils prone to seasonal waterlogging in areas receiving at least 500 mm annual rainfall.	Endangered	Lake Connewarre Complex Breamlea Flora and Fauna Reserve

EVC	Description	Status	Location
891 Plains Brackish Sedge Wetland	Treeless EVC dominated by sedges and herbs that are generally indicative of saline conditions. True halophytic species such as samphires, if present, only occur with very low cover. Occurs in estuaries and along poorly defined drainage lines or associated with shorelines of brackish lakes.	Endangered	Lake Connewarre Complex
898 Cane Grass-Lignum Halophytic Herbland	Occurs within shallow depressions on otherwise flat terrain, where annual rainfall is approximately 600 mm. Geology is Quaternary sedimentary estuarine sands, and soils are silty clays, subject to periodic freshwater flooding. Varies from an open shrubland to grassland/sedgeland or herbland depending on site characteristics.	Vulnerable	Lake Connewarre Complex
302 Coastal Saltmarsh/Mangrove Shrubland Mosaic	Coastal Saltmarsh (EVC 9) occurs on and immediately above marine and estuarine tidal flats and contains distinct floristic communities as bands or zones in the same location, depending on the positioning of the various floristic communities in relation to the saline environment. Consists of a range of life forms including succulent herbs, low succulent shrubs, rushes and sedges. Mangrove Shrubland (EVC 14) to 2 m tall. Confined to protected low energy coastal environments where there is sufficient shelter from strong wave action and currents to allow the accumulation of fine sediments, generally on mud flats within the tidal zone.	Endangered	Lake Connewarre Complex Swan Bay Breamlea Flora and Fauna Reserve Lonsdale Lakes Nature/Wildlife Reserve St Leonards Salt Lagoon
858 Coastal Alkaline Scrub	Near-coastal, deep calcareous (alkaline) and largely stable sand dunes and swales commonly dominated by *Moonah Melaleuca lanceolata ssp. lanceolata*. It occurs at low elevations of 20-60 m above sea level, average annual rainfall is approximately 550- 950 mm, and it occurs on a variety of geologies and soil types. Low woodland or tall shrubland to 8 m tall, typically with a medium shrub layer, small shrub layer and sedges, grasses and herbs in the ground layer.	Endangered	Lake Connewarre Complex St Leonards Salt Lagoon Point Henry Foreshore Reserve Lonsdale Lakes Wildlife Reserve Breamlea Flora and Fauna Reserve Swan Bay
3 Damp Sands Herb-rich Woodland	A low, grassy or bracken-dominated eucalypt open forest or woodland to 15 m tall with a large shrub layer and ground layer rich in herbs, grasses, and orchids. Occurs mainly on flat or undulating areas on moderately fertile, relatively well-drained, deep sandy or loamy topsoils over heavier subsoils (duplex soils).	Vulnerable	Lake Connewarre Complex Portarlington (Point Richard) Flora and Fauna Reserve
175 Grassy Woodland	A variable open eucalypt woodland to 15 m tall or occasionally Sheoak woodland to 10 m tall over a diverse ground layer of grasses and herbs. The shrub component is usually sparse. It occurs on sites with moderate fertility on gentle slopes or undulating hills on a range of geologies.	Endangered	Lake Connewarre Complex Breamlea Flora and Fauna Reserve

EVC	Description	Status	Location
1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Coastal Dune Scrub (EVC 160) occupies the secondary dunes along ocean and bay beaches and lake shores. Closed scrub to 3 m tall with occasional emergent trees on siliceous and calcareous sands that area subject to high levels of saltspray and continuous disturbance from onshore winds. Coastal Dune Grassland (879) consists of grasses and halophytes (succulents) that colonise the foredunes of ocean beaches. Soils are siliceous sands that have a very low humus content.	Depleted	Lonsdale Lakes Wildlife Reserve Breamlea Flora and Fauna Reserve
55 Plains Grassy Woodland	An open, eucalypt woodland to 15 m tall occurring on a number of geologies and soil types. Occupies poorly drained, fertile soils on flat or gently undulating plains at low elevations. The understorey consists of a few sparse shrubs over a species-rich grassy and herbaceous ground layer.	Endangered	Swan Bay
899 Plains Freshwater Sedge Wetland	Occurs in seasonally wet depressions on volcanic and sedimentary plains, typically associated with fertile, silty, peaty or heavy clay paludal soils. Primarily sedgy-herbaceous vegetation, sometimes with scattered or fringing eucalypts or tea-tree/paperbark shrubs in higher rainfall areas. A range of aquatic herbs can be present, and species-richness is mostly relatively low to moderate, but higher towards drier margins.	Vulnerable	Lake Connewarre Complex
74 Wetland Formation	Wetland Formation is a default EVC label used to cover a wide range of freshwater wetlands found scattered throughout the bioregion whereby the EVCs could not be identified by field assessment or mapped appropriately. Wetlands generally occur in topographic depressions associated with standing water ranging from permanent to ephemeral water bodies. Structurally, they can consist of herbland, sedgeland and rushland elements and sometimes can have a shrubby component especially on drier verges.	Endangered	Lonsdale Lakes Wildlife Reserve

3.3 Description of Matters of National Environmental Significance

3.3.1 Summary of MNES within proposed action area

A search was completed using the Protected Matters Search tool (PMST 2024, Appendix C) to determine MNES relevant to the proposed action (Appendix A). Of the nine MNES, three are known from or have potential to occur within the proposed action area (see Table 24).

Table 24 Matters of National Environmental Significance (MNES) relevant to the proposed action

Matter of National Environmental Significance (MNES)	Relevant to the Proposed Action?	Comments
1. World heritage properties	No	There are no world heritage places that would be impacted by the Project.
2. National heritage places	No	There are no national heritage places that would be impacted by the Project.

Matter of National Environmental Significance (MNES)	Relevant to the Proposed Action?	Comments
3. Wetlands of international importance (listed under the Ramsar Convention)	Yes	Part of the *Port Phillip Bay (western shoreline) and Bellarine Peninsula* Ramsar site occurs within the proposed action area
4. Listed threatened species and ecological communities	Yes	90 threatened species and seven (7) ecological communities are known or predicted to occur within the proposed action area
5. Migratory species protected under international agreements	Yes	64 migratory species are known or predicted to occur within the proposed action area
6. Commonwealth marine areas	No	There are no Commonwealth marine areas that would be impacted by the proposed action.
7. The Great Barrier Reef Marine Park	No	The Great Barrier Reef Marine Park would not be impacted by the proposed action.
8. Nuclear actions (including uranium mines)	No	The proposed action is not a nuclear action.
9. A water resource, in relation to coal seam gas development and large coal mining development	No	The proposed action is not a coal seam gas or coal mining development

A review of the three relevant MNES (Wetlands of international importance, Listed threatened species and ecological communities, and Migratory species protected under international agreements) and other matters protected by the EPBC Act identified by the PMST search was undertaken to determine if further assessment was required (see Table 25).

Table 25 Preliminary determination of MNES that will be addressed within this preliminary documentation

Preliminary assessment of MNES or other matters identified by PMST	Values	Potential impact and next steps
Is the proposed action likely to have ANY direct or indirect impact on the ecological character of a Ramsar wetland?	The Port Phillip Bay (western shoreline) and Bellarine Peninsula Ramsar site occurs within the proposed action area.	There is potential to impact the ecological character of the Ramsar site. The Ramsar site is further discussed in sections 3.3.4 and 3.4.
Is the proposed action likely to have ANY direct or indirect impact on the members of any listed species or any threatened ecological community, or their habitat?	90 threatened species are or may be relevant to the proposed action including 18 flora and 72 fauna species. Seven ecological communities may be relevant to the proposed action.	There is potential to impact listed threatened fauna species. See additional information in section 3.3.3 and Table 42 Of the 18 listed flora predicted to occur by the PMST search, one is known from and 11 may occur within the proposed action area. However, as no vegetation or habitat will be removed or modified by the proposed action, it is highly unlikely that any of the listed flora species will be impacted by the proposed action. Therefore, listed threatened flora are not considered further as part of this assessment. Of the seven communities predicted by the PMST to occur in the project area, six are likely and one may occur within the proposed action area: – Natural Damp Grassland of the Victorian Coastal Plains – Grassy Eucalypt Woodland of the Victorian Volcanic Plain – White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland – Natural Temperate Grassland of the Victorian Volcanic Plain – Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria ecological community – Giant Kelp Marine Forests of South East Australia – Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains

Preliminary assessment of MNES or other matters identified by PMST	Values	Potential impact and next steps
		However, as no vegetation or habitat will be removed or modified by the proposed action, it is highly unlikely that any of the seven ecological communities will be impacted by the proposed activity. Therefore, ecological communities are not considered further as part of this assessment.
Is the proposed action likely to have ANY direct or indirect impact on the members of any listed migratory species, or their habitat?	64 listed migratory species are or may be relevant to this project.	There is potential to impact migratory species. See additional information in section 3.3.3 and Table 42.
Is the proposed action to be undertaken in a marine environment (outside Commonwealth marine areas)?	The proposed action will be undertaken in intertidal areas adjacent to the Swan Bay marine area and other non-Commonwealth marine areas.	There is potential to impact on intertidal and fringing marine areas. These areas are assessed as habitat for Migratory birds and as a Ramsar site (See additional information in section 3.3.3 and Table 42).
Is the proposed action to be taken on or near Commonwealth land?	Crows Nest Camps (Queenscliff), Staff College (Fort Queenscliff), Swan Island Training Area, Avalon Airfield, Myers Street (opp. Geelong Hospital) are areas of Commonwealth land located near the proposed action area. However, no Commonwealth land is located within the proposed action area (refer Table 26 for more information).	No further assessment required as the proposed action is highly unlikely to impact these Commonwealth land areas; therefore further consideration of the *EPBC Act Significant Impact Guidelines 1.2 – Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies* (Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) 2013) has not been considered. See section 3.3.2.1.
Is the proposed action to be taken by the Commonwealth agency?	No	No further assessment required.
Is the proposed action to be undertaken in a Commonwealth Heritage Place Overseas?	No	No further assessment required.

3.3.2 Other matters protected by the EPBC Act

The EPBC Act also covers actions on, or impacting on, Commonwealth land or actions by Commonwealth agencies. It also covers Commonwealth heritage places outside of Australia. These are discussed in sections 3.3.2.1 and 3.3.2.2.

3.3.2.1 Commonwealth Land

Under the EPBC Act Significant Impact Guidelines, Commonwealth Land includes land owned or leased by the Commonwealth or a Commonwealth agency.

No Commonwealth Land identified through the PMST search is within the vicinity of proposed aerial or ground-based treatment sites. Further, no additional Commonwealth Lands were identified by searching the Commonwealth Land-Public Land Management database interactive map on National Map (Australian Government, 2021). A description of the Commonwealth Land provided within the Protected Matters Search Tool (PMST) is provided in Table 26.

Because no Commonwealth Land is within the vicinity of proposed aerial or ground-based treatment sites, the *EPBC Act Significant Impact Guidelines 1.2 – Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies* (Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) 2013) have not been considered further.

Table 26 Commonwealth Land within the Vicinity of the proposed action

Commonwealth Land	Description	Treatment Site No.
Crows Nest Camp - Queenscliff	Other than the name of the site provided by the PMST search, no additional information could be found for this Commonwealth Land. It could not be located on the Commonwealth Land - Public Land Management database (State Government of Victoria, 2021).	Not within vicinity of treatment site
Myers Street (opp. Geelong Hospital)	This location is identified as 'Newland Barracks' on the Commonwealth Land - Public Land Management database (DATA VIC 2021). Newland Barracks is a military facility in Victoria. Newland Barracks is situated in Geelong city centre, close to Old Geelong Gaol.	Not within vicinity of treatment site
Staff College-fort Queenscliff	Fort Queenscliff is located in the Borough of Queenscliffe, some 106 km from Melbourne, on the western side of the entrance to Port Phillip. It occupies an area of 6.7 hectares on high ground known as Shortland's Bluff and overlooks the shipping lanes leading to Melbourne and Geelong.	Not within vicinity of treatment site
Swan Island Training Area	Swan Island was a Commonwealth facility with portions controlled by both the Department of Navy and Department of Army.	Not within vicinity of treatment site

3.3.2.2 Commonwealth Heritage Places

The Protected Matters Search Tool (PMST) indicates that there are three Commonwealth Heritage Places within the vicinity of the proposed action (Table 27). None of the Places identified by the PMST are located within a proposed ground or aerial treatment site. The description of each of the Commonwealth Heritage Places on DCCEEW's Australian Heritage Database are provided below.

Table 27 Commonwealth Natural and Historic Heritage Places within the Vicinity of the proposed action

Heritage item	Place ID	Type	Treatment Site No.
Swan Island and Naval Waters	105401	Natural	Not within treatment site
Swan Island Defence Precinct	105270	Historic	Not within treatment site
Fort Queenscliff	105417	Historic	Not within treatment site

Swan Island and Naval waters (105401)

Swan Island is the largest emergent sand accumulation feature in Port Phillip Bay. The island, which has been built principally by wave actions rather than by aeolian forces, has played a major role in determining the pattern of sedimentation in Swan Bay and preserves geomorphological evidence of changing Quaternary sea levels. The eastern and northern shores of the eastern arm of Swan Island are of regional significance as an example of active coastal depositional and erosional processes. The patterns of erosion and accretion on these shores provide a good indicator of sand movements into Port Phillip Bay.

Swan Island and Naval Waters is an integral part of Swan Bay, an internationally significant wetland which is important as wader and waterfowl habitat, and provides important habitat for 46 water bird species: of which 26 species are listed under the Japan-Australia and China-Australia migratory bird agreements; and 8 species are listed under the Bonn Convention on Migratory Species.

It is possible that Indigenous cultural values of national estate significance exist in this place. As yet the Australian Heritage Commission has not identified, documented or assessed these values.

Swan Bay Defence Precinct (105270)

Swan Island is significant as a cultural landscape containing a rich collection of historic elements including fortification earthworks, battery emplacements, underground command centre and tunnel network, jetties and buildings relating to the early and important theme of coastal defence in south-eastern Australia. The island fort was developed from 1877 in response to fears of Russian invasion of Britain's colonies in the late nineteenth century.

Fort Queenscliff (105417)

Fort Queenscliff, developed from 1860 onwards, is historically significant for its association with Victoria's, and Australia's, military history. The Fort was begun as a result of fears of foreign aggression and was further developed in the latter part of the nineteenth century amid renewed concerns about attack. The Fort was the first and the primary defence site for Port Phillip Bay and played a command role in relation to the other fortifications around the heads of the bay. Fort Queenscliff was a key element in making the bay the most heavily defended British port in the southern hemisphere at the time. During the twentieth century, as the strategic importance of coastal defences was revised, the Fort became a central instructional college for army officers. The Fort continues to play a defence role, after more than 140 years of operation. The Fort also has strong associations with the early maritime history of Melbourne and Port Phillip Bay. Its role as a navigational aid and signalling post are significant, especially as the earliest such structures around the bay were constructed on this site. The Telegraph Station is the second oldest such building in Victoria.

3.3.3 EPBC Act listed threatened and migratory species

From the information provided in the preliminary documentation request, the Department considers that the protected matters that may be significantly impacted by the proposed action include, but are not limited to:

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Migratory, Marine

Since the preliminary documentation request was made by the Department in 2021, there have been significant changes to the EPBC listings. New species have been listed as threatened, and other species have had their classifications changed. These changes are addressed in sections 3.3.3.1.2 and 3.3.3.1.3.

3.3.3.1 Methods used to identify and evaluate threatened and migratory species

A database search and literature review were completed to:

– Provide information on the abundance, distribution, ecology and habitat preferences for each of the six species, and
– Determine the likelihood of additional threatened and migratory species listed in the PMST search occurring within the proposed action area

3.3.3.1.1 Review of information

The database and literature review included the following information sources:

– The Victorian Biodiversity Atlas (VBA, 2021), maintained by the Department of Environment, Land, Water and Planning (DEECA) - to identify and document the historical records (including restricted records), abundance and distribution of relevant species within the treatment sites and search area (10 km buffer of the treatment sites)
– Commonwealth Atlas of Living Australia (ALA, 2021) – to identify additional records not included in the Victorian Biodiversity Atlas database. The ALA is a collaborative, digital and open infrastructure that aggregates biodiversity data from multiple sources throughout Australia, and includes records not contained within the VBA. The ALA receives support through the Australian Government's National Collaborative Infrastructure Strategy and is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO).
– NatureKit (NK, 2021), maintained by DEECA – to obtain Habitat Importance Models (HIM) and Habitat Distribution Models (HDM) which map the modelled importance and extent of habitats for the above-mentioned species within the search area as of 2017

– The HIM reflects the relative importance of modelled habitat in different places as determined by the amount of habitat available, its condition, and how much the habitat is connected across the landscape. HIMs indicate which patches of habitat may be relatively more important to a species' persistence than others. Most HIMs contain values ranked between 1 and 100, with higher values indicating a higher likelihood of important habitat. For the HIM used for this report the orange, then red areas indicate the habitat most likely to be of moderate to high importance for the species (DELWP 2018, NK 2021). For this assessment we reviewed the HIM against historical species records, aerial photography, on ground observations from Senior GHD Ecologists and City of Greater Geelong staff and EVC mapping to provide comment regarding the accuracy of the modelling. For most species, the HIM appears to overestimate the area of habitat available for each species within the search area (e.g., includes areas of open water where the species is highly unlikely to occur).
– Not all species have an HIM. Where a HIM layer was not available for a species, the HDM (Habitat Distribution Model) layer was used in its place. HDMs show "the predicted habitat suitability of a location for a listed species on a scale of 1 to 100. Higher values indicate a greater likelihood of suitability; lower values were considered unlikely to be suitable habitat for the species and were removed from the model" (NK, 2021). The HDM is lower resolution than the HIM.
– Species Profile and Threats Database (SPRAT, 2021), maintained by the Department of Agriculture, Water and the Environment (the Department) **http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl** - to understand the ecology, habitat preferences and population information for each relevant species
– GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020
– GHD 2021 - Desktop assessment of Orange-bellied Parrot, history of habitat use in proposed action area. Unpublished report to the City of Greater Geelong, December 2021
– GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019
– GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018

In addition to the literature and database review as described above, a request for information was submitted to Rachel Pritchard (Natural Environment Program Officer, DELWP) in 2021 for further information regarding the Orange-bellied Parrot within the proposed program area. Information received included an outline of areas in the Bellarine Peninsula that are important to Orange-bellied Parrots currently; the location and timing of Orange-bellied Parrot releases and migration on the Bellarine; and suggestions on how the impacts of mosquito treatment on the Orange-bellied Parrot may be minimised. The information provided included two maps:

– Map 1 – a heat map based on the number of Orange-bellied Parrot sightings (noting this is influenced by the location of released birds in 2021)
– Map 2 – with the location of sightings with different colours to indicate 'migrants' i.e. birds that flew here from Tasmania, 'released birds' i.e. birds that DELWP released at Lake Connewarre in April 2021, and 'unknown' for birds seen but not identified so that there was uncertainty about which category they were in

DELWP noted that importantly, the population of Orange-bellied Parrots in the wild is now growing, and expanding into sites not used for many years, or never previously recorded. DELWP therefore strongly recommended a flexible approach to flag emerging important locations as they appear over time (by using sightings in year X to inform the location-specific timing of spraying in year X+1).

– As requested by DELWP in 2021, maps and supporting notes have been withheld. The information on Orange-bellied Parrot in this document incorporates a summary of the information provided by DELWP.

3.3.3.1.2 Review of information for newly listed species

Since the preliminary documentation request, there have been additions to the threatened species lists under the EPBC Act, such that additional protected matters now need to be considered as to whether they are likely to be significantly impacted by the proposed action. These include:

– Southern Whiteface (*Aphelocephala leucopsis*) – Vulnerable (listed 31-Mar-23)

– Sooty Shearwater (*Ardenna grisea*) – Vulnerable (listed 21-Dec-23)
– Ruddy Turnstone (*Arenaria interpres*) – Vulnerable (listed 5-Jan-24)
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Vulnerable (listed 5-Jan-24)
– Gang-gang Cockatoo (*Callocephalon fimbriatum*) – Endangered (listed 2-Mar-22)
– Brown Treecreeper (south-eastern) (*Climacteris picumnus victoriae*) – Vulnerable (listed 31-Mar-23)
– Grey Falcon (*Falco hypoleucos*) – Vulnerable (listed 9-Jul-20)
– Latham's Snipe (*Gallinago hardwickii*) – Vulnerable (listed 5-Jan-24)
– Black-tailed Godwit (*Limosa limosa*) – Endangered (listed 5-Jan-24)
– Hooded Robin (south-eastern) (*Melanodryas cucullata cucullata*) – Endangered (listed 31-Mar-23)
– Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable (listed 31-Mar-23)
– Grey Plover (*Pluvialis squatarola*) – Vulnerable (listed 5-Jan-24)
– Diamond Firetail (*Stagonopleura guttata*) – Vulnerable (listed 31-Mar-23)
– Common Greenshank (*Tringa nebularia*) – Endangered (listed 5-Jan-24)
– Terek Sandpiper (*Xenus cinereus*) – Vulnerable (listed 5-Jan-24)
– Yellow-bellied Glider (south-eastern) (*Petaurus australis australis*) – Vulnerable (listed 2-Mar-22).

To obtain relevant historical information on these species, a new VBA search was performed in February 2024. Note that this new search does not contain restricted records, which apply to some species. The new VBA search was also used to update threatened species' classifications and to check for significant additions to the historical record for the species that had already been considered for the preliminary documentation (see section 3.3.3.1).

3.3.3.1.3 Changed-classification species

In addition to new listings presented in section 3.3.3.1.2, other threatened species have had their classifications changed since the preliminary documentation request. Species relevant to this project include:

– Alaskan Bar-tailed Godwit (*Limosa lapponica baueri*) – Transfer from Vulnerable to Endangered (05-Jan-2024)
– Red Knot (*Calidris canutus*) – Transfer from Endangered to Vulnerable (05-Jan-2024)
– Great Knot (*Calidris tenuirostris*) – Transfer from Critically Endangered to Vulnerable (05-Jan-2024)
– Eastern Dwarf Galaxias (*Galaxiella pusilla*) – Transfer from Vulnerable to Endangered (15-Nov-2023)
– Yarra Pygmy Perch (*Nannoperca obscura*) – Transfer from Vulnerable to Endangered (15-Nov-2023)
– Victorian Grassland Earless Dragon (*Tympanocryptis pinguicolla*) – Transfer from Endangered to Critically Endangered (01-Jun-2023)
– Golden Sun Moth (*Synemon plana*) – Transfer from Critically Endangered to Vulnerable (07-Dec-2021)

Where a significant impact assessment was deemed necessary for any of these species with regard to this project, the assessment has been re-evaluated using the new classification.

3.3.3.1.4 Likelihood of occurrence assessment

The review process identified a large number of species, but not all of the fauna species identified are equally likely to occur in the proposed action area. The following categories were excluded:

– Species listed only as marine species in the PMST search are excluded from this assessment as the proposed activity does not occur over Commonwealth marine areas. Species listed as marine and threatened or migratory under the EPBC Act are considered for further assessment.
– Listed threatened marine mammals, marine reptiles and marine fish (not including the Australian Grayling, which uses marine and freshwater habitats) are excluded as the proposed activity does not occur over marine habitats and is therefore unlikely to impact the habitat types used most frequently by these species (e.g. marine environments, beaches and off shore islands)

For all other species, the likelihood of occurrence within the proposed action area was evaluated using the information from the literature review and online databases to inform the following rationale:

– **PRESENT** – Species known to occur within or in close proximity to the treatment sites based on findings from the literature review and database search
– **POSSIBLE** – Potentially suitable habitat occurs within a treatment site(s) and species' known range encompasses the proposed action area. Species recorded historically within 1 km of the proposed action area, and generally within the last 10 years
– **UNLIKELY** – Species' known range encompasses the proposed action area, but suitable habitat does not occur within treatment sites, or occurs within proposed action area but may be marginal (e.g. very small extent) and of low quality. Species may or may not be recorded historically within 1 km of the proposed action area, but generally not within the last 10 years.
– **HIGHLY UNLIKELY** – No historical records of the species within 1 km of the proposed action area and/or no suitable habitat within proposed action area

The detailed likelihood of occurrence evaluation is provided in Appendix G. A summary of the threatened species and migratory species that are known or potentially relevant to this project is provided in Table 28.

Table 28 Summary of threatened fauna species and migratory species considered for this referral as an outcome of the likelihood of occurrence process (Appendix G)

MNES Fauna group	EPBC Act listing	Present	Possible	Unlikely/Highly unlikely	Number of species considered for this assessment
Threatened birds*	Vulnerable	10	2	21	11
	Endangered	5	1	7	5
	Critically Endangered	4	0	3	3
Threatened frogs	Vulnerable	1	0	0	1
Threatened terrestrial reptiles	Vulnerable	0	0	3	0
Threatened terrestrial mammals	Vulnerable	1	0	3	0
	Endangered	0	1	1	0
Threatened fish (excluding marine fish)	Vulnerable	0	1	0	1
	Endangered	1	0	1	1
Migratory bird species*	Terrestrial birds	4	1	2	0
	Wetland birds	28	1	2	20
	Marine birds	14	4	10	8

*Table note: 16 of the threatened bird species are also listed as migratory species under the EPBC Act.

3.3.3.2 Description of threatened species and their habitats known or likely to occur within proposed action area

Five of the species that are listed by the Department in the preliminary documentation request (section 3.3.3.1) and that may be impacted by the proposed action are listed as threatened:

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered, migratory marine bird species
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, migratory shorebird
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, migratory shorebird

According to the likelihood of occurrence assessment (Appendix G), a further three species that are newly listed as threatened under the EPBC Act could also be impacted by the proposed action:

– Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable, terrestrial bird species
– Common Greenshank (*Tringa nebularia*) - Endangered, migratory shorebird
– Sharp-tailed Sandpiper (*Calidris acuminata*) - Vulnerable, migratory shorebird

A detailed description of the abundance, distribution, ecology and habitat preferences is provided for each of the above-listed eight species in subsequent sections. Table 29 summarises the following information for each species:

– Occurrence type within the proposed action area (e.g. resident, breeding or non-breeding)
– Known habitats within the proposed action area
– Number of historical records within the search area and number of records within treatment sites
– Area of modelled habitat within search area and area of modelled habitat within treatment sites

Two figures have been developed for each of the five species. The first figure displays the historical distribution of records and the DEECA Habitat Importance Modelling (HIM) or Habitat Distribution Modelling (HDM) within the search area (10 km buffer of the treatment sites). Habitat Distribution Modelling (HDM) is shown for species where HIM is not available. No modelling is shown for species that have neither HIM nor HDM. The second figure displays the same data but focused on the proposed action area. For most species, the HIM/HDM overestimates the area of habitat available for each species within the search area (e.g. includes areas of open water where a species might be highly unlikely to occur).

Fifteen other threatened species that are less likely to be of concern in relation to the proposed action based on the likelihood of occurrence assessment are also discussed in section 3.3.3.2.10.

3.3.3.2.1 Orange-bellied Parrot (*Neophema chrysogaster*)

The Orange-bellied Parrot is a small grass parrot that migrates each year between summer breeding areas in Tasmania and winter foraging areas in coastal Victoria and South Australia. In Victoria and South Australia, the parrots are seen almost exclusively in coastal and sub-coastal areas, west as far as the Yorke Peninsula in South Australia, and east to Westernport Bay in Victoria (occasionally further). Historically, parts of the Bellarine Peninsula have been favoured locations for non-breeding Orange-bellied Parrots. Individual Orange-bellied Parrots are considered to show high site fidelity, returning to the same winter location, at around the same time of year, each winter (Rachel Pritchard, DELWP, pers. comm., November 2021).

Habitat areas at Lake Connewarre and Swan Bay are considered to be extremely important to the Orange-bellied Parrot at present. Monitoring of the parrots in the Bellarine area has shown that the Orange-bellied Parrots tend to visit Lake Connewarre between May and June/July each year, then visit Swan Bay between August and September each year (Rachel Pritchard, DELWP, pers. comm., November 2021).

Figure 3 and Figure 4 display the species' historical records and the DEECA Habitat Importance Modelling (HIM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HIM overestimates the area of habitat available for this species within the search area. It includes extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging, perching or roosting.

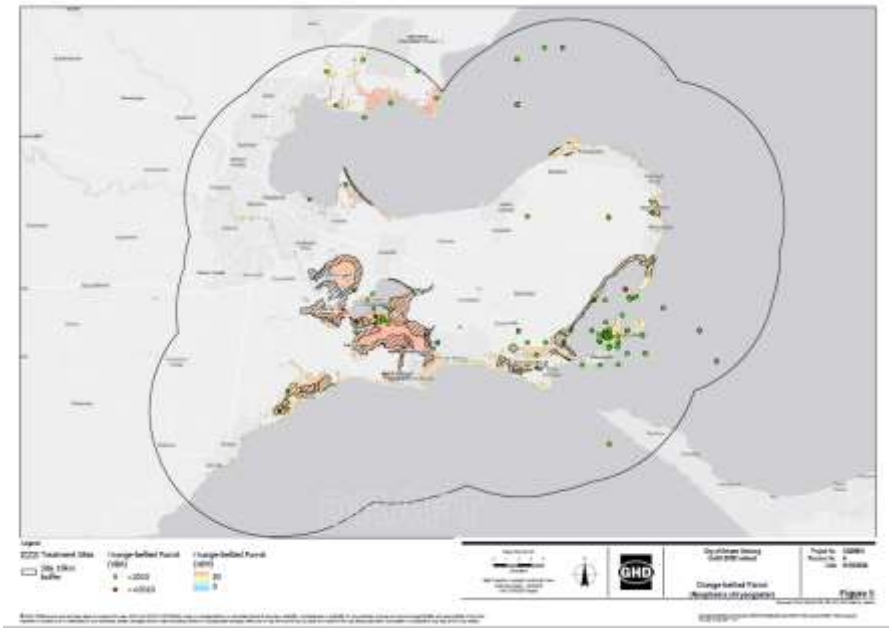
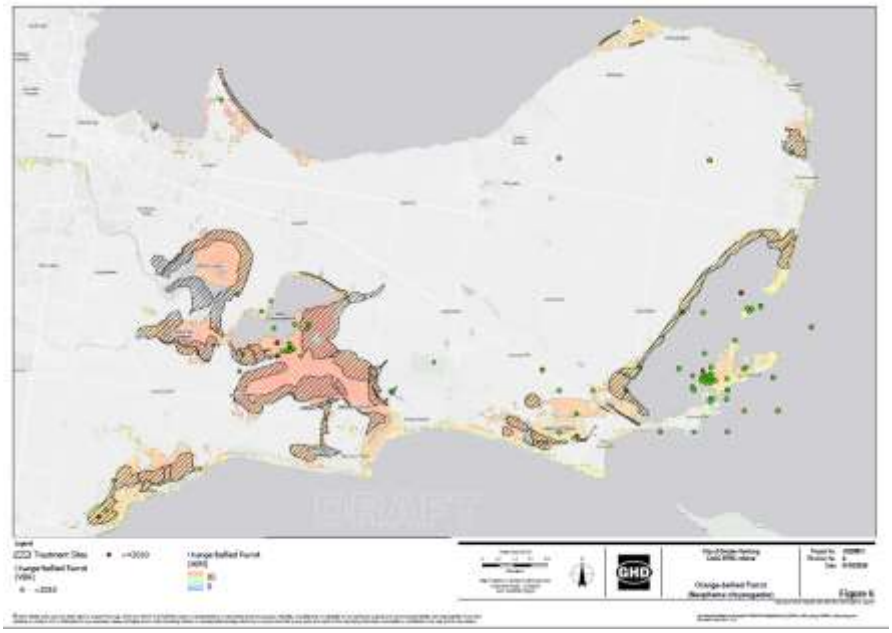


Figure 3 Orange-bellied Parrot – historical records and Habitat Importance Modelling; 10 km search area

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Figure 4 Orange-bellied Parrot – historical records and Habitat Importance Modelling; proposed action area



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On the mainland, Orange-bellied Parrots primarily seek coastal saltmarsh habitats, as well as littoral heathlands and low scrublands. Possibly in response to seasonally changing food availability, Orange-bellied Parrots appear to be semi-nomadic in winter, moving between food sources and locations (Ehmke & Tzaros 2009, DELWP 2016).

Alarming declines in the species' population size were reported before 1980, leading to the formation of the Orange-bellied Parrot Recovery Team in 1983, and implementation of the first Orange-bellied Parrot Recovery Plan in 1984 (Brown and Wilson 1984, Vine 2010). Since that time, this species has been well surveyed. Fledging success each year is uncertain, making it difficult to determine current population size. According to Steven Davidson (Birdlife Australia, Project Officer for Birdlife Australia's Orange-bellied Parrot Project), the general consensus in mid-2020 was that fewer than 30 wild birds existed at that time, and that estimate had remained relatively unchanged over the previous five or six years.

Given the plight of the Orange-bellied Parrot, and in association with findings presented by Stojanovic *et al.* (2020), captive breeding programs have been undertaken successfully, and some of the fledglings have been released recently to the wild in a five-year (2019 - 2023) Mainland Release Trial (undertaken as a partnership between DELWP and Zoos Victoria, and involving Birdlife Australia, Corangamite CMA and Melbourne Water). At least some of the observations of this species in recent years, and within the proposed action area, are of captive bred birds.

The history of observations of the Orange-bellied Parrot on the Bellarine Peninsula is presented in Graph 8 to Graph 11. These graphs are based on VBA data rather than ALA data, because the VBA data include more observations and observations from more recent years (ALA observations stop in 2008, VBA includes observations up to 2013).

Observations of Orange-bellied Parrots on the Bellarine Peninsula increased dramatically in the 1970s (Graph 8), roughly coinciding with the dawning awareness of the species' declining conservation status. Observations and counts then remained relatively high through the 1980s and 1990s, as the actions and monitoring associated with the species' recovery plan were implemented. Counts of the species peaked in 1988, with a summed count of nearly 1000 birds sighted (this value is likely to include repeated sightings of a smaller number of individuals) from approximately 40 observations. Observations peaked in the early 1990s, coinciding with a dramatic reduction in birds counted. Since 1994, counts of Orange-bellied Parrots have been consistently low, increased in a couple of years by increased observations, likely in response to increased effort following a known sighting ('twitching').

Observations and counts of Orange-bellied Parrots on the Bellarine Peninsula show a strongly seasonal pattern (Graph 9). Birds are all but absent between November and March, and present during the winter months, peaking in July.

Since 2000, mean annual counts of Orange-bellied Parrots on the Bellarine Peninsula have been generally small (Graph 10), mostly with less than 10 birds observed on average. The standard errors are also relatively small, suggesting that bird counts are consistently low. A higher average is evident in 2006, and the large standard error associated with that mean suggests that the mean is raised by a small number of larger counts.

Mean counts of Orange-bellied Parrots on the Bellarine Peninsula in the last ten or so years (post-2010) have been significantly less than average counts historically (pre-2010) (Graph 11). Fewer birds visit today than have visited historically.

In addition to the database records of Orange-bellied Parrot, there are recent observations of this species on the Bellarine Peninsula and at other sites connected with the Mainland Release Trial. These observations are not yet in either the VBA or ALA databases. In April 2021, 12 captive-reared Orange-bellied Parrots were released at Lake Connewarre, another 12 were released at The Spit Nature Conservation Reserve near Werribee, and another 12 were released at a site on the northern shore of Westernport Bay. Since then, there have been a number of reported sightings of Orange-bellied Parrots at or near those sites, with each report bringing a slightly different focus.

For Lake Connewarre, birds were released in mid-April 2021 (prior to the arrival of natural migrants – wild birds), and more birds are expected to be released there in April 2022 and April 2023 (Rachel Pritchard, DELWP, pers. comm., November 2021). Since April 2021, released birds have been observed in the vicinity of the release site, along with small numbers of naturally migrating birds and other birds whose status was not determined (natural migrants or captive bred birds). Individual naturally migrating birds were also seen on the southwest shoreline of Lake Connewarre, and at Swan Bay and near Portarlington (Rachel Pritchard, DELWP, pers. comm., November 2021).

DELWP (2021) reported in May 2021 that five wild birds were seen to have joined the flocks of released birds. Two wild birds observed at Lake Connewarre were juveniles who migrated from Tasmania in autumn 2021, for their first mainland winter. One other wild juvenile bird and two adults were observed with released birds at the Spit Nature Conservation Reserve.

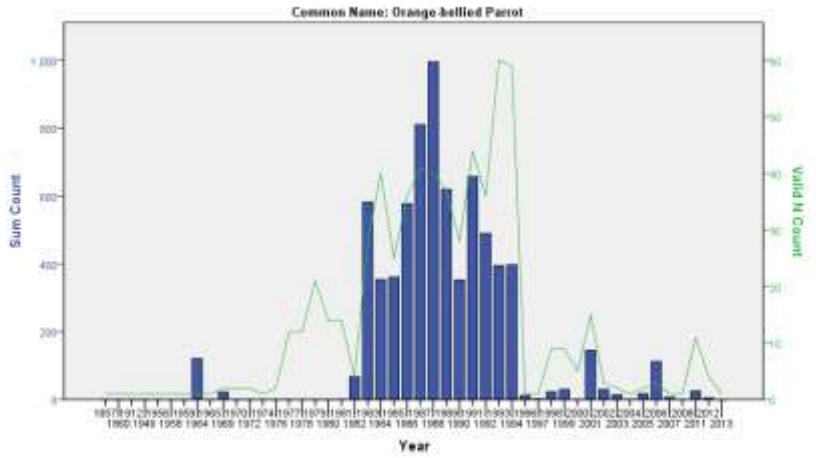
According to CCMA (2021), 11 of the released parrots at Lake Connewarre were known to be surviving one month after release. By the end of June 2021, five migrating Orange-bellied Parrots had been seen with released birds in Lake Connewarre (four wild-born birds and one captive-bred bird released in Tasmania in late summer) (CCMA 2021).

Moonlit Sanctuary (2021) reported a May 2021 sighting of a natural wild migrant bird (a juvenile from the 2020/21 breeding season) feeding in saltmarsh at the Westernport site alongside two captive-released birds from this year's release and another bird from last year's release. This is reportedly the first time a naturally migrating Orange-bellied Parrot has been confirmed at Westernport Bay for more than a decade.

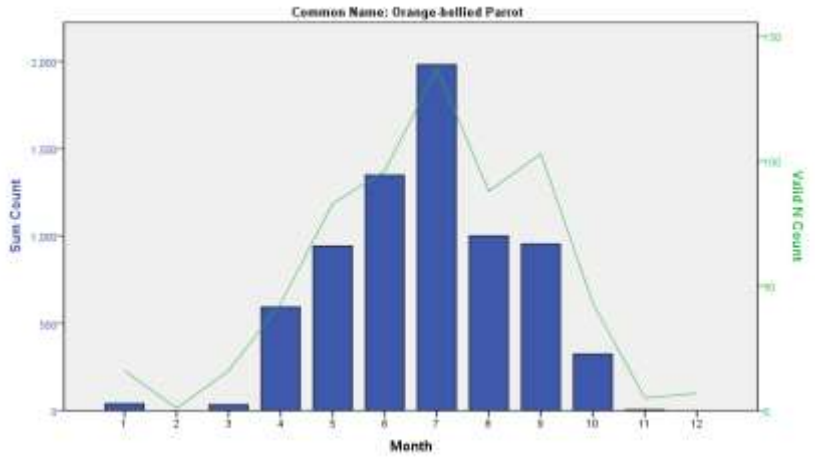
In a recent report, Birdlife Australia (2021) reported that flocks of Orange-bellied Parrots had been observed at all three sites, "consisting of individuals released this year, released last year and, most excitingly, individuals that have migrated from Melaleuca this year." Ten parrots were seen at The Spit and nine were seen at Lake Connewarre. Overall, ten naturally migrating birds have been observed with captive-bred released birds across the three sites (Birdlife Australia 2021).

According to the December 2021 Birdlife Australia e-news, "the fortunes of the Critically Endangered Orange-bellied Parrot have improved greatly in recent years. A series of releases of captive-bred birds combined with careful stewardship of birds breeding in the wild in Tasmania has seen their population increase dramatically from a handful of birds just a few years ago" (https://birdlife.org.au/media/good-numbers-of-obps-return-to-tas/). In all, 52 Orange-bellied Parrots are reported to have migrated back to their breeding grounds in south-western Tasmania this season, which is one more than in 2020. The 52 birds comprised 34 wild-bred birds and 18 captive releases (released at Melaleuca, Tasmania, in previous breeding seasons – there is no mention in the article of birds released on the mainland). In 2022, 77 birds returned to the Tasmanian breeding grounds at Melaleuca, which was the largest number of returns recorded in more than 15 years (Department of Natural Resources and Environment Tasmania 2024). This provides some hope for the species' recovery.

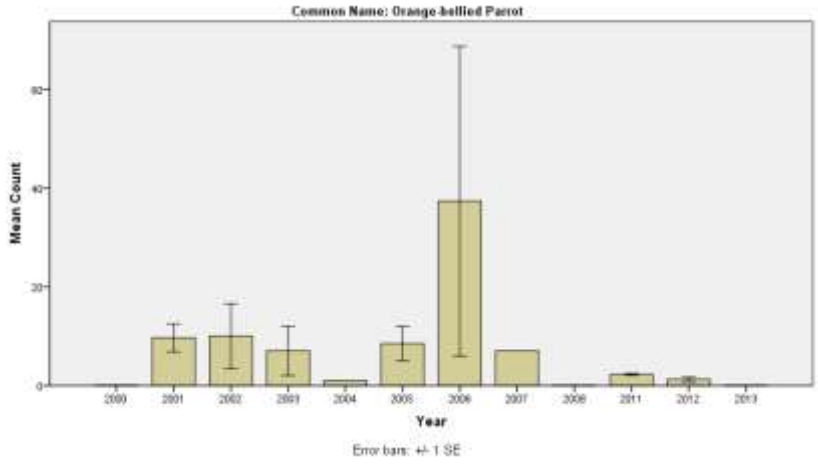
For the Bellarine Peninsula, if the overall Orange-bellied Parrot population continues to increase, then birds are increasingly likely to turn up at locations where they may not have been seen for some time, and that have possibly been considered to this point to be not important to the species. According to DELWP (2016), all non-breeding locations occupied since 2000 are considered to be essential for the survival of the species. A flexible approach to treatment of sites is likely to be required to balance the public health needs of managing mosquitoes with the conservation needs of the Orange-bellied Parrot (Rachel Pritchard, DELWP, pers. comm., November 2021).



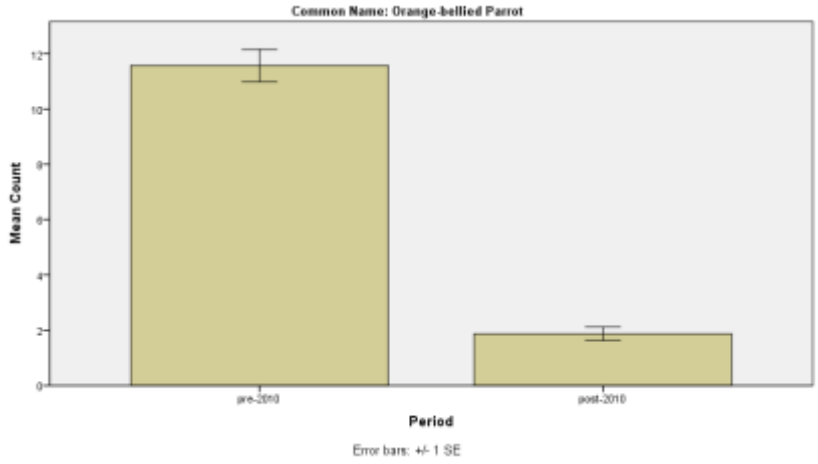
Graph 8 ***Summed counts and numbers of observations per year (all years) – Orange-bellied Parrot, Bellarine Peninsula***



Graph 9 ***Summed counts and numbers of observations per month (all years) – Orange-bellied Parrot, Bellarine Peninsula***



Graph 10 ***Mean counts (and Standard Error) per year since 2000 – Orange-bellied Parrot, Bellarine Peninsula***



Graph 11 ***Mean counts (and Standard Error) before and after 2010 – Orange-bellied Parrot, Bellarine Peninsula***

3.3.3.2.2 Blue-winged Parrot (*Neophema chrysostoma*)

The Blue-winged Parrot is a small parrot, closely related and similar in appearance to the Orange-bellied Parrot. It favours grasslands and grassy woodlands, and inhabits a range of habitats from coastal, sub-coastal and inland areas, right through to semi-arid zones. The Blue-winged Parrot is often found near wetlands, and in altered environments such as airfields, golf courses and paddocks, where it forages mainly on the ground for grass seeds and seeds of herbaceous plants (Birdlife Australia 2024; DCCEEW 2023).

The Blue-winged Parrot occurs and breeds in Tasmania, Victoria, and south-eastern South Australia. Nesting occurs in a tree hollow or stump, and the breeding season is from October to February (Birdlife Australia 2024). The VBA contains no nesting records on the Bellarine Peninsula. The species is partly migratory between Tasmania and the mainland – some birds migrate to and from Tasmania after breeding each year, leaving Tasmania in March to April and returning in August to October. Some birds over-winter in Tasmania or on the Bass Strait islands (Birdlife Australia 2024).

Populations of the Blue-winged Parrot are thought to be in decline. The clearing of forests is likely to have reduced potential nest sites for this species, while potentially benefiting the species in regard to feeding (Birdlife Australia 2024).

In southern Victoria, the Blue-winged Parrot occurs right along the coast and hinterland, including throughout the Bellarine Peninsula. Figure 5 and Figure 6 display the species' historical records and the DEECA Habitat Distribution Modelling (HDM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HDM overestimates the area of habitat available for this species within the search area. The higher-value areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging, perching or roosting.

The history of observations of the Blue-winged Parrot on the Bellarine Peninsula is presented in Graph 12 to Graph 15 below. These graphs are based on VBA data.

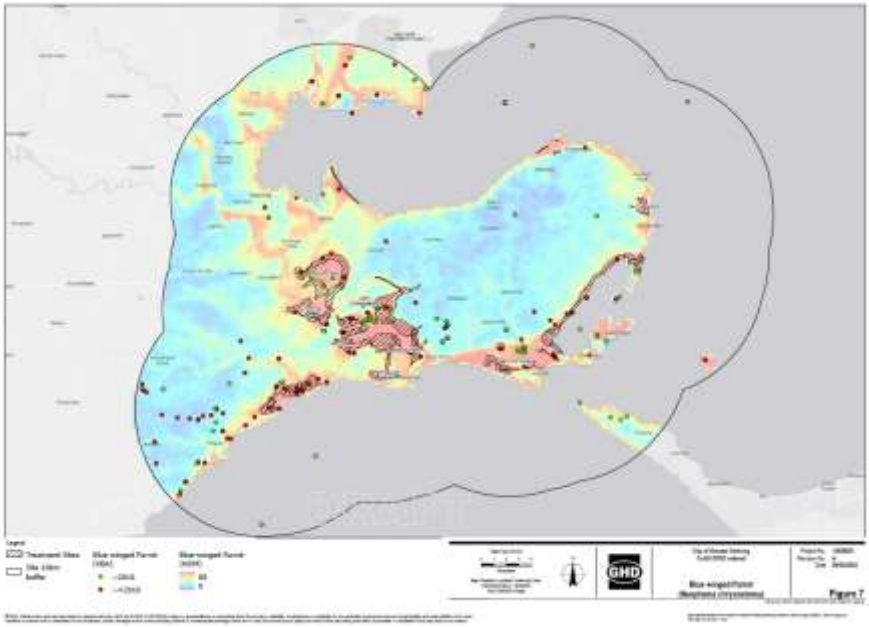
The historical records of the Blue-winged Parrot have remained reasonably consistent up until the 2010s, at which time the reported counts increased greatly (Graph 12). Observations peaked in 2014, with more than 3000 birds observed. The increase in records in recent years is likely to coincide with the dawning awareness of the declining conservation status of the closely related Orange-bellied Parrot (see section 3.3.3.2.1). Increased search effort for the Orange-bellied Parrot is highly likely to result in increased records of the more common Blue-winged Parrot.

Observations and counts of Blue-winged Parrots on the Bellarine Peninsula show a strongly seasonal pattern (Graph 13). Birds are uncommon between September and March, and present in far greater numbers during the winter months, peaking in July. This pattern is similar to the seasonal pattern shown by the Orange-bellied Parrot (see section 3.3.3.2.1).

Since 2000, mean annual counts of Blue-winged Parrots on the Bellarine Peninsula have been moderately small (Graph 14), mostly with fewer than 50 birds observed on average. The standard errors are also relatively small, suggesting that bird counts are consistent.

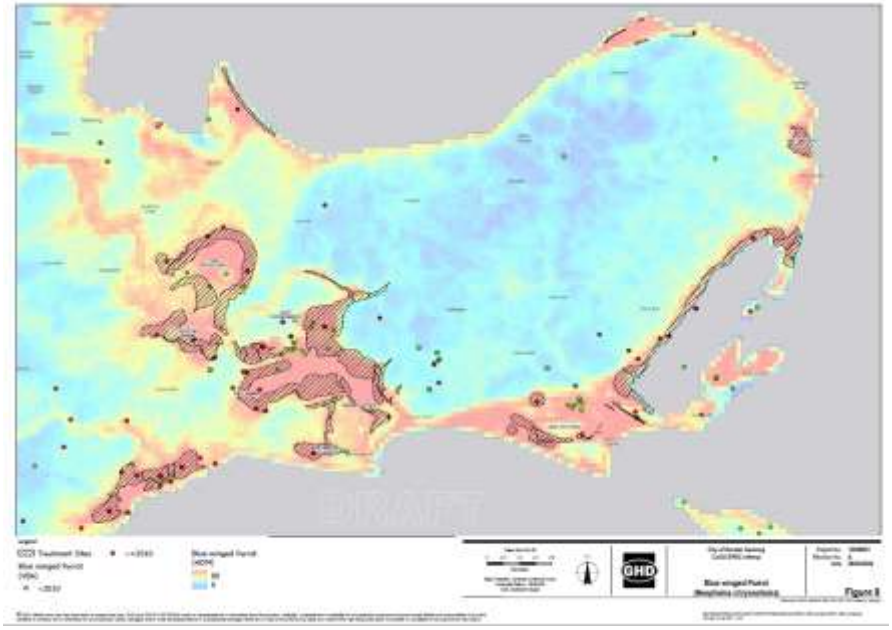
Mean counts of Blue-winged Parrots on the Bellarine Peninsula in the last ten or so years (post-2010) have been significantly higher than (approximately double) the average counts historically (pre-2010) (Graph 15). More birds are being counted in recent years than in earlier years.

Figure 5 *Blue-winged Parrot – historical records and Habitat Distribution Modelling; 10 km search area*

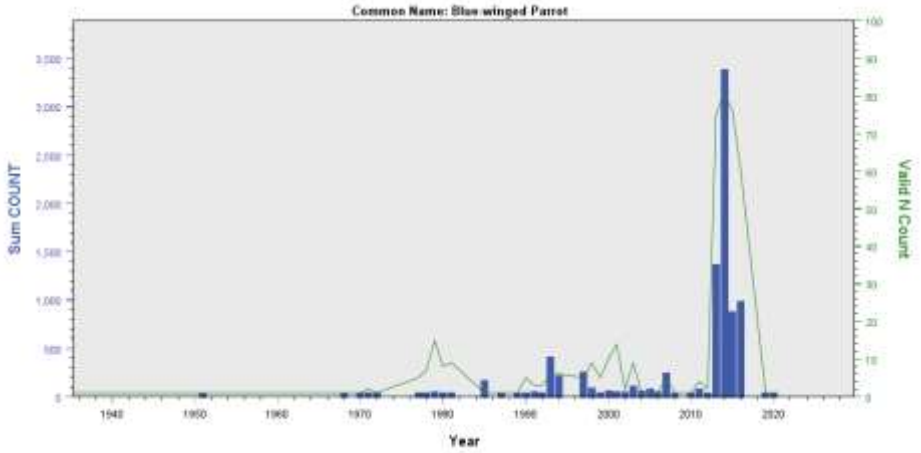


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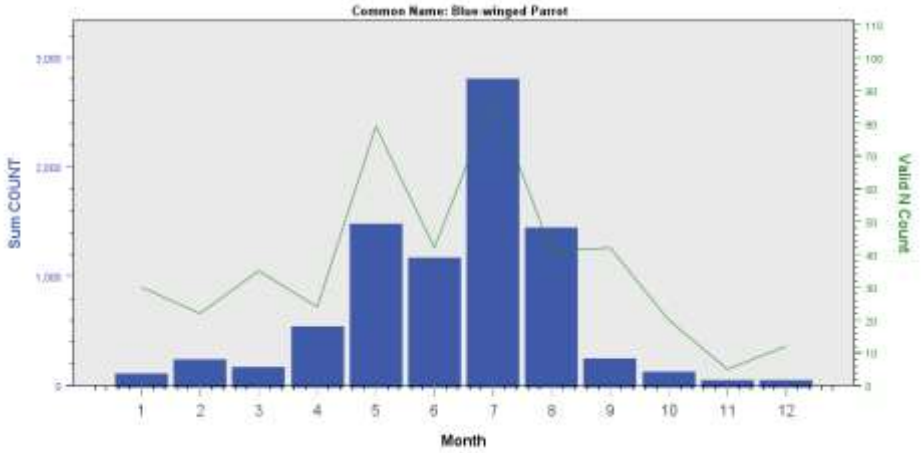
Figure 6 Blue-winged Parrot – historical records and Habitat Distribution Modelling; proposed action area



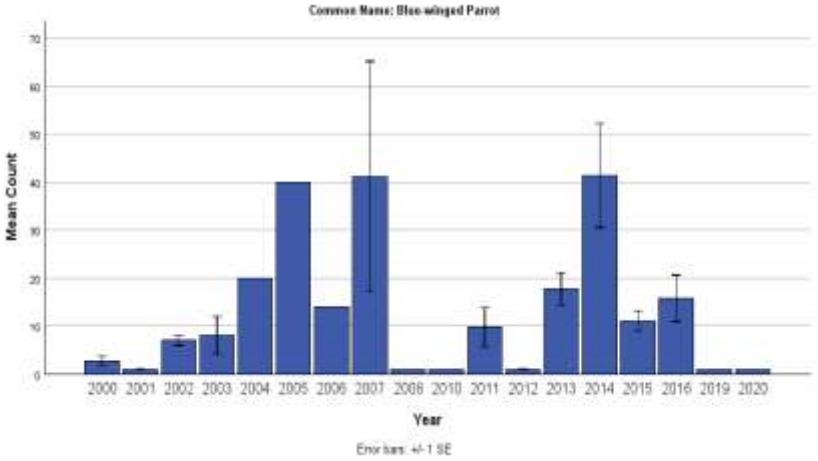
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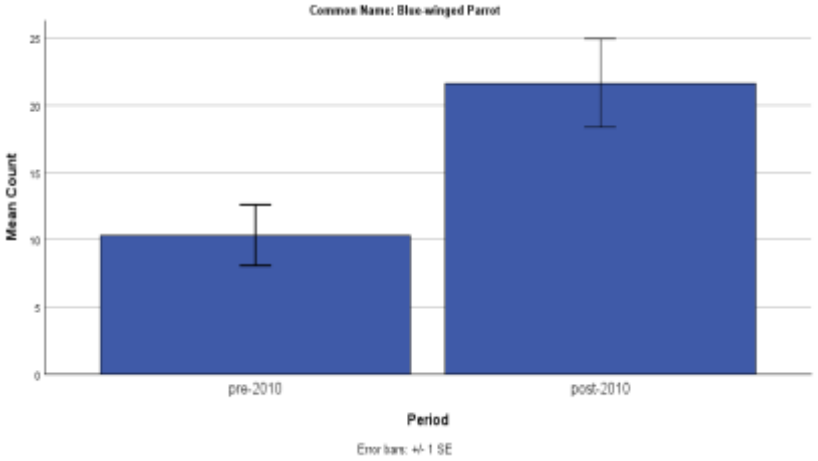
Graph 12 ***Summed counts and numbers of observations per year (all years) – Blue-winged Parrot, Bellarine Peninsula. VBA data for this species stop in 2020.***



Graph 13 ***Summed counts and numbers of observations per month (all years) – Blue-winged Parrot, Bellarine Peninsula***



Graph 14 ***Mean counts (and Standard Error) per year since 2000 – Blue-winged Parrot, Bellarine Peninsula***



Graph 15 ***Mean counts (and Standard Error) before and after 2010 – Blue-winged Parrot, Bellarine Peninsula***

3.3.3.2.3 Growling Grass Frog (*Litoria raniformis*)

Previously widespread across Victoria, and absent only from the western desert regions and the eastern alpine regions (Littlejohn 1963, 1982; Hero et al. 1991 in Mahony 1999), the Growling Grass Frog (also known as Southern Bell Frog) has disappeared in recent decades from most of its former range across Victoria (NSW DEC 2005a). It persists in isolated populations in the greater Melbourne area, in the south-west of Victoria and a few sites in central Victoria and Gippsland (Atlas of Victorian Wildlife database cited in Clemann and Gillespie 2004).

Figure 7 and Figure 8 display the species' historical records and the DEECA Habitat Importance Modelling (HIM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HIM overestimates the area of habitat available for this species within the search area. It includes extensive areas of open water and tidal habitat, such as lower Lake Connewarre and the Barwon River estuary, and along the Swan Bay foreshore, where the species is unlikely to occur due to brackish or salt water.

This species is found mostly amongst emergent vegetation (Robinson 1993), including Typha sp. (bullrush), Phragmites sp. (reeds) and Eleocharis sp.(sedges), in or at the edges of still or slow-flowing water bodies such as lagoons, swamps, lakes, ponds and farm dams (NSW DEC 2005a). The species can be found floating in warmer waters in temperatures between 18–25°C. Additionally, this species occurs in a range of habitats, including clays or well-watered sandy soils, open grassland, open forest, and ephemeral and permanent non-saline marshes and swamps, montane eucalypt forest, dry sclerophyll forest in coastal Victoria, steep-banked water edges (like ditches and drains) and gently graded edges containing fringing plants, and formerly, some areas of higher altitudes (Ehmann & White 1997; NSW DEC 2005a).

Submerged vegetation is important habitat for breeding success as it provides egg-laying sites, calling stages for males, and food and shelter for tadpoles. Grassland provides adults with habitat for foraging, dispersal and shelter, and may also provide overwintering sites (Clemann & Gillespie 2004; Hamer & Organ 2006). Hamer and Organ (2006) found that large and relatively permanent waterbodies, with a high proportion of emergent vegetation cover, were more likely to be occupied by this species. The species is dependent upon permanent freshwater lagoons for breeding. The ideal breeding habitat is the shallow part of lagoons (up to approximately 1.5 m) where there is generally a complex vegetation structure (Threatened Species Unit 2001).

Growling Grass Frogs feed mainly on terrestrial invertebrates such as beetles, termites, cockroaches, moths, butterflies and various insect larvae (M. Christy undated, pers. comm. cited in NSW DEC 2005a). They sometimes prey on other frogs, including younger frogs of their own species (Barker and Grigg 1977; Hero et al. 1991). They also feed on vertebrates such as lizards, snakes and small fish (Littlejohn 1982). This species is described as being a 'sit-and-wait' predator, that is, they do not actively hunt for food but rather sit and wait for prey to move into feeding range (M. Christy undated, pers. comm. cited in NSW DEC 2005a). The species is also believed to be a nocturnal feeder (G. Pyke undated, pers. comm. cited in NSW DEC 2005a).

Surveys conducted by GHD at Reedy Lake on behalf of the Corangamite Catchment Management Authority (GHD 2017) in December 2016 recorded this species across eight sites in or near Reedy Lake (VBA 2021). During those surveys, the Growling Grass Frog was the most ubiquitous species, being heard at 8 of the 11 sites over two nights. It was difficult to determine how many individuals were calling during the survey – at least 11 frogs were heard on night 1 and eight were heard on night 2. Historical VBA records suggested that the species only occupied habitats towards the eastern edge of the Lake (near the farm dam near the end of Fitzgerald Road). This assessment demonstrated that the species is more widespread than that in the Reedy Lake system, and that its habitat also includes the western edge (near Coppards Road) and parts of the lake itself (as heard from Woods Road), at least with the water conditions encountered at the time of survey. Other surveys completed at the same sites in September 2017 did not record this species, however it was noted that overall frog diversity was lower, temperatures were cooler when compared to the December 2016 surveys (GHD 2017) and September is not within the species' peak calling season.

In 2010, Beacon Ecological conducted a targeted survey at Cowies Creek in North Geelong, approximately 12 km north of the proposed action area. This species was detected at eight survey sites and a nearby wetland appears to be an important breeding site for the species in the local area (Aboltins 2010).

The history of database observations of the Growling Grass Frog on the Bellarine Peninsula is presented in Graph 16 to Graph 19. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2015, ALA includes observations up to 2020). Overall, surveys for this species appear to be localised and sporadic - there does not appear to have been a consistent survey effort for this species over the years. However, it is a species that is readily detectable in the right season and reasonably well known, and with the well-documented history of observations across the region by experienced naturalists (mainly bird-watchers), there is a good chance that most of the populations of Growling Grass Frog that occur on the Bellarine Peninsula are known about.

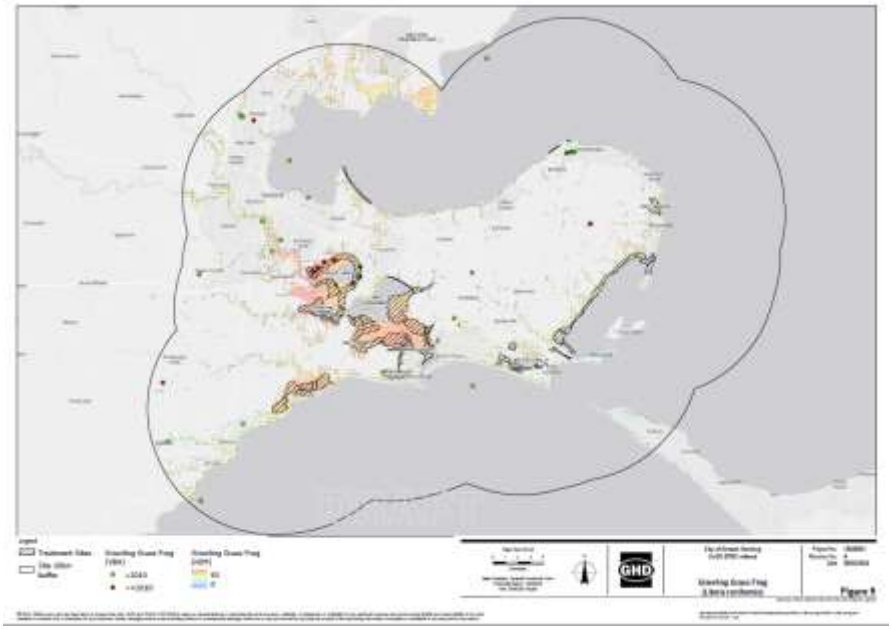
Observations of Growling Grass Frogs on the Bellarine Peninsula have been consistently small, except for one year in 2016, when an exceptionally large number of observations lead to an exceptionally high summed count (Graph 16). Other than 2016, summed counts of this species in the area tend to be 250 frogs or fewer.

Observations and counts of Growling Grass Frogs on the Bellarine Peninsula show a strongly seasonal pattern (Graph 17). Frogs are reported mainly between September and March, with highest numbers in January and February. For frogs (unlike most of the bird species), absence of records in some months does not automatically equate to absence of animals, because frogs are detected mostly by their calls. When not calling, the frogs are likely to still be present at the same waterbodies, or in suitable refuge habitat nearby.

Since 2000, mean annual counts of Growling Grass Frogs on the Bellarine Peninsula have varied (Graph 18). In most years, the average count is approximately 10 frogs or fewer, but in 2005, 2009, 2013 and 2015, high average counts are evident, with the highest average being approximately 35 frogs in 2013. For the years of high counts, relatively large standard errors suggest that the numbers of frogs counted in those years varied broadly. The high summed count that was evident in 2016 in Graph 16 is not evident as a high average count for 2016 in Graph 18, which suggests that the 2016 summed count contained a few observations of larger counts, but that most counts were of smaller groups (i.e. less than 10 frogs).

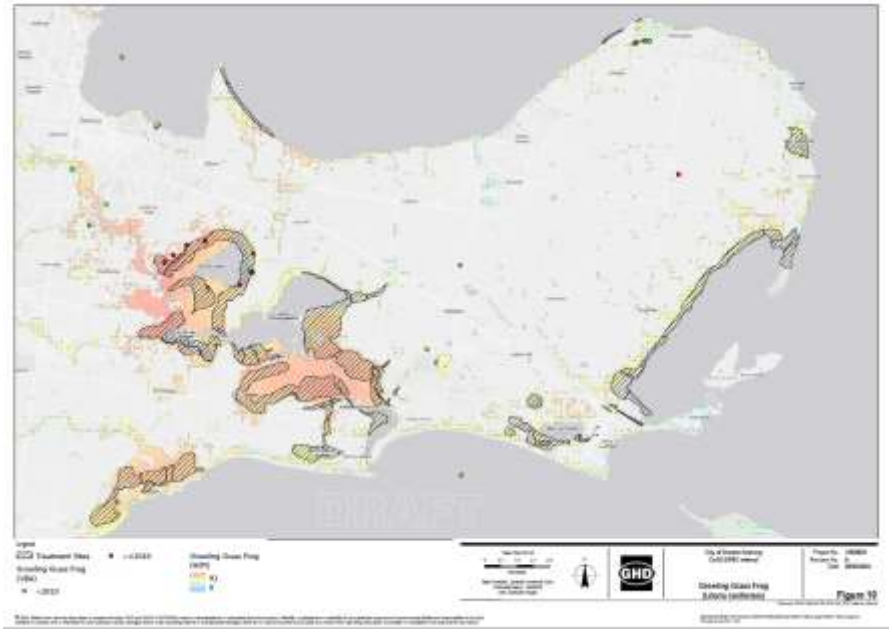
Mean counts of Growling Grass Frogs on the Bellarine Peninsula in the last ten or so years (post-2010) have been significantly less than average counts historically (pre-2010) (Graph 19).

Figure 7 *Growling Grass Frog – historical records and Habitat Importance Modelling; 10 km search area*

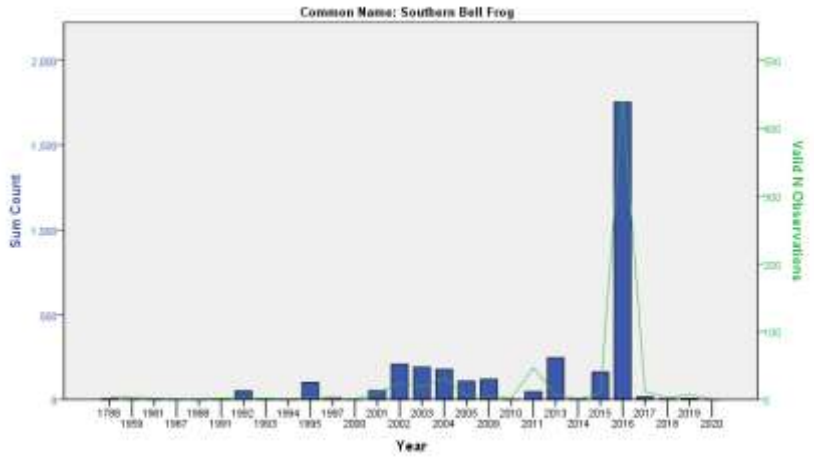


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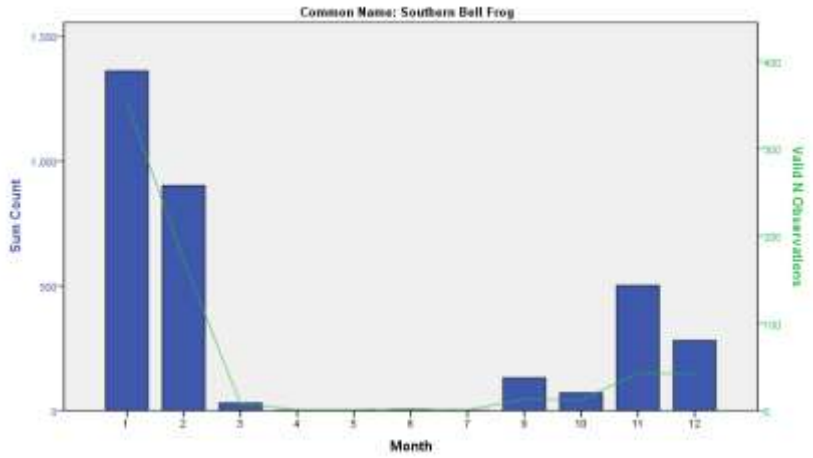
Figure 8 Growling Grass Frog – historical records and Habitat Importance Modelling; proposed action area



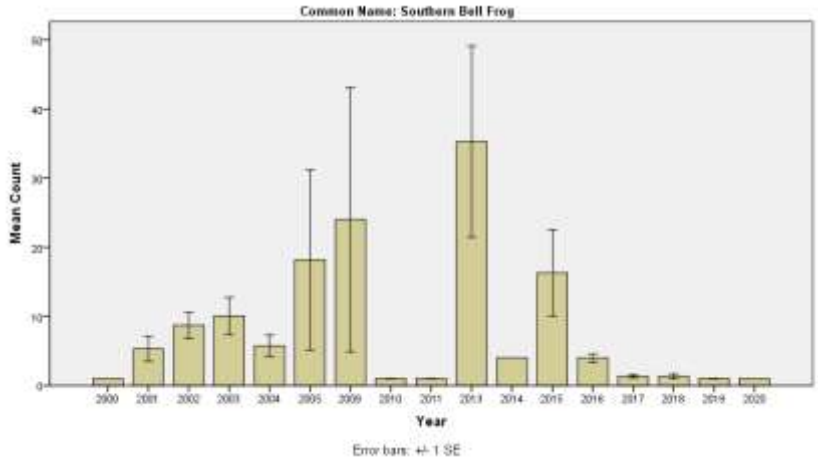
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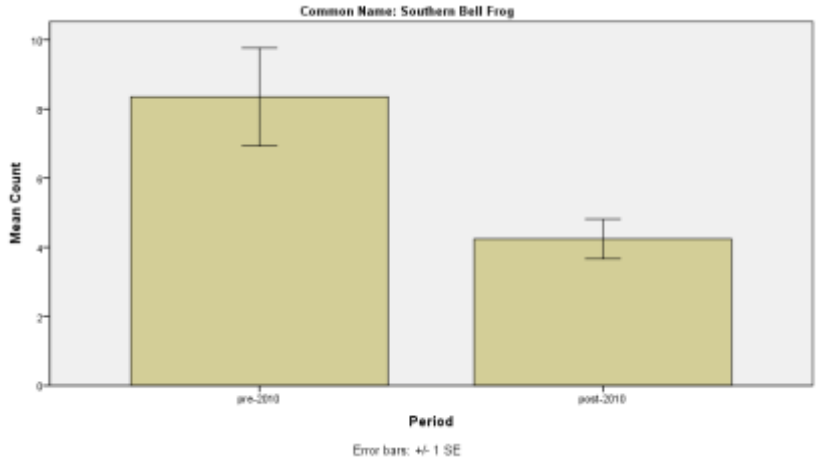
Graph 16 ***Summed counts and numbers of observations per year (all years) – Growling Grass Frog***



Graph 17 ***Summed counts and numbers of observations per month (all years) – Growling Grass Frog***



Graph 18 ***Mean counts (and Standard Error) per year since 2000 – Growling Grass Frog***



Graph 19 ***Mean counts (and Standard Error) before and after 2010 – Growling Grass Frog***

3.3.3.2.4 Australian Grayling (*Prototroctes maraena*)

This species is known to occur in streams and rivers on the eastern and southern watershed of the Great Dividing Range, from Sydney south to the Otway Ranges of Victoria, and in Tasmania. The species is found in fresh and brackish waters of coastal lagoons (Koster et al 2019). In recent decades, this species had been most frequently collected in Victoria from the Tambo, Barwon, Mitchell and Tarwin River systems (VBA).

Figure 9 and Figure 10 display the species' historical records (VBA 2024 data) and Habitat Importance Modelling (HIM) (NatureKit, DEECA) for the species within the search area (10 km buffer of the treatment sites) and proposed action area.

The Australian Grayling is diadromous, spending part of its lifecycle in freshwater and at least part of the larval and/or juvenile stages in coastal seas (Miles et al. 2013). Adults (including pre-spawning and spawning adults) inhabit cool, clear, freshwater streams with gravel substrate and areas alternating between pools and riffle zones (DEWHA 2008) such as the Tambo River, which is also known to have granite outcrops (Berra 1982). The species has also been associated with clear, gravel-bottomed habitats in the Mitchell and Wonnangatta Rivers (Victoria) and in a muddy-bottomed, heavily silted habitat in the Tarwin River (Victoria) (Jackson 1980). The species has been found more than 100 km upstream from the sea (Jackson & Koehn 1988).

Australian Grayling are omnivorous, feeding on a variety of small aquatic organisms, including crustaceans (such as cladocerans), insects and their larvae and algae. Non-aquatic insects have also been taken from the water surface by this species (Backhouse et al. 2008a). The stomach contents of specimens from the Mitchell River in eastern Victoria were examined, with aquatic insect larvae dominating the stomach contents, but small components of plant material, including macrophytes and filamentous algae, were also present (Jackson 1976). The diet of the Tambo River population consists of immature aquatic insects, gastropods and, most commonly, plant material (diatom/organic matrix) (Berra et al. 1987). There was little dietary overlap between summer and the other seasons in all size classes examined, but there was significant dietary overlap between the size groups for all seasons except summer (Berra et al. 1987). Green algae (*Stigeoclonium* sp.) occurred only in the stomachs of the largest size group in summer where it made up 25% of the volume (Berra et al. 1987). The teeth of Australian Grayling are well adapted for combing filamentous algae with specimens observed to nibble on filamentous algae growing on the downstream side of rocks (Berra 1982).

Little is known of this species' preferred water chemistry. During January–November 1979 in the Tambo River, water temperatures ranged from 5–26 °C and the pH was approximately 8 (Berra 1982). Hall and Harrington (1989) located a population of adult Australian Grayling in consecutive years in an urban area of the lower reaches of the highly turbid Barwon River, where the salinity was approximately 1.5 parts per thousand (ppt).

There appear to be no reliable population estimates for the Australian Grayling. The species is reported to be relatively uncommon and is often only caught in small numbers (less than 10). Larger populations appear to be restricted to a few rivers (for example the Tambo River in Victoria), however very few rivers within the distribution range have been studied. The species is known to have declined in numbers and distribution within NSW (DPI 2006; Jackson & Koehn 1988; Jenkins et al. 2009). Research into the species has indicated that the species undergoes large, annual fluctuations in population numbers, depending on prevailing conditions. The species' high fecundity means it is capable of explosive population increases when conditions are favourable (Jenkins et al. 2009). All rivers and streams where this species is found are considered important to the species' survival as it is unknown which populations are the most effective in terms of reproductive success (DAWE 2021a).

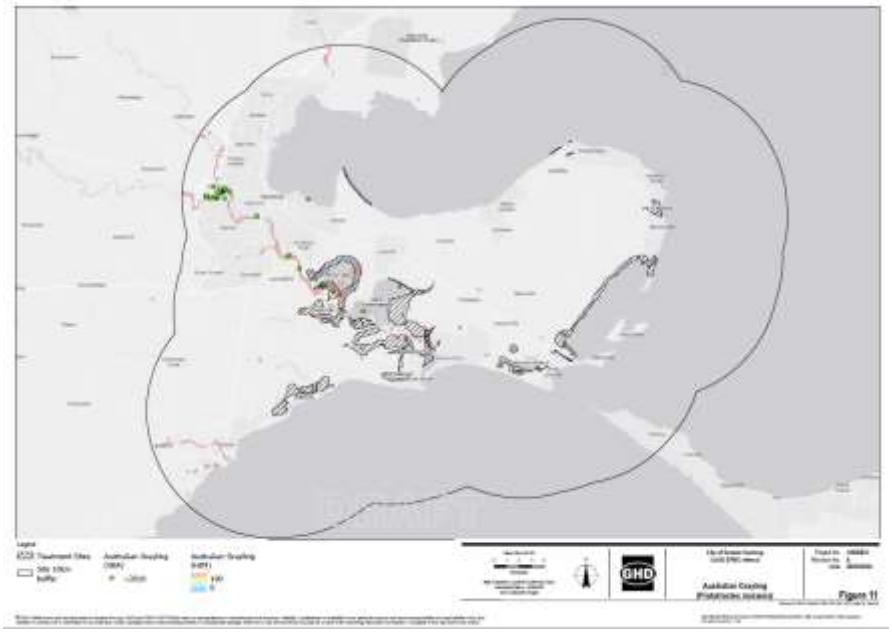
The history of database observations of the Australian Grayling on the Bellarine Peninsula is presented in Graph 20 to Graph 22. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 1998, ALA includes observations up to 2013).

There are notably few historical observations of the Australian Grayling on the Bellarine Peninsula (Graph 20). Other than in 1986, when an atypically large number of counts lead to a summed total of more than 250 fish, observations of this species in the area have numbered 10 or fewer. There are long periods of time over which no observations are available: e.g., 1873 to 1916 (43 years), 1916 to 1981 (65 years), 1987 to 1997 (10 years), 1998 to 2013 (15 years).

Observations and counts of the Australian Grayling on the Bellarine Peninsula show a strongly seasonal pattern (Graph 21). Fish have been reported mostly in May and June, but smaller numbers of records occur for most other months. There are no historical Bellarine records of this species from August, September, November or December, and small summed counts in January and February, with reasonably high relative survey effort (>10 observations in January, compared with a peak effort around 15 in May and June).

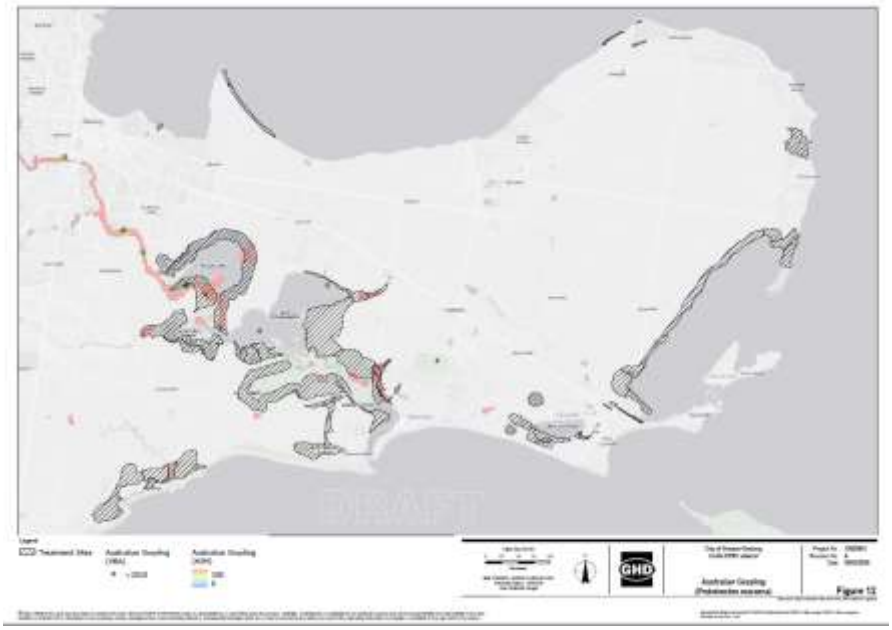
The single count of one Australian Grayling on the Bellarine Peninsula in the last ten or so years (post-2010) is notably less than average counts historically (pre-2010) (Graph 23). Small sample sizes of Australian Grayling observations make for difficult interpretation of historical versus current populations.

Figure 9 Australian Grayling – historical records and Habitat Importance Modelling; 10 km search area

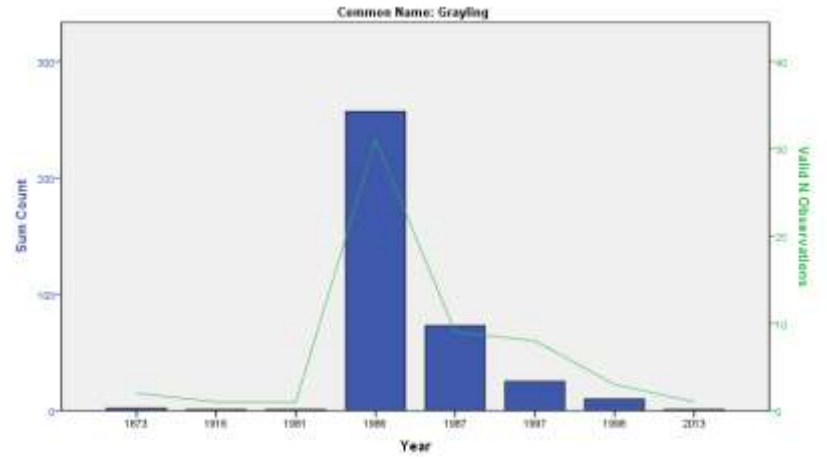


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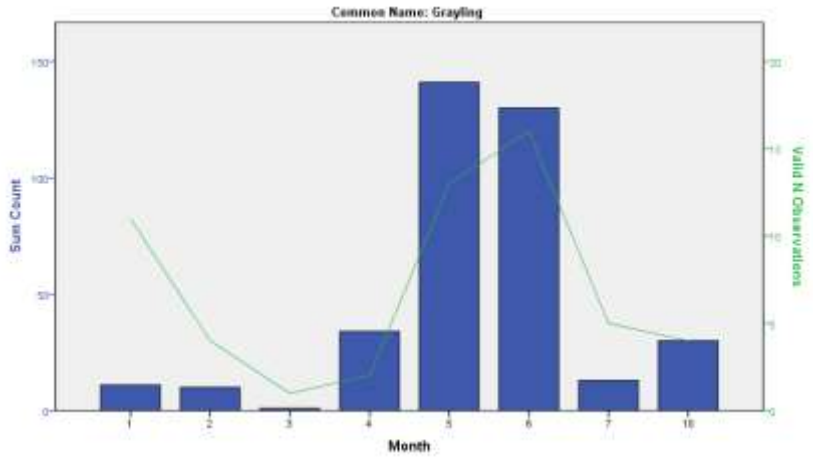
Figure 10 Australian Grayling – historical records and Habitat Importance Modelling; proposed action area



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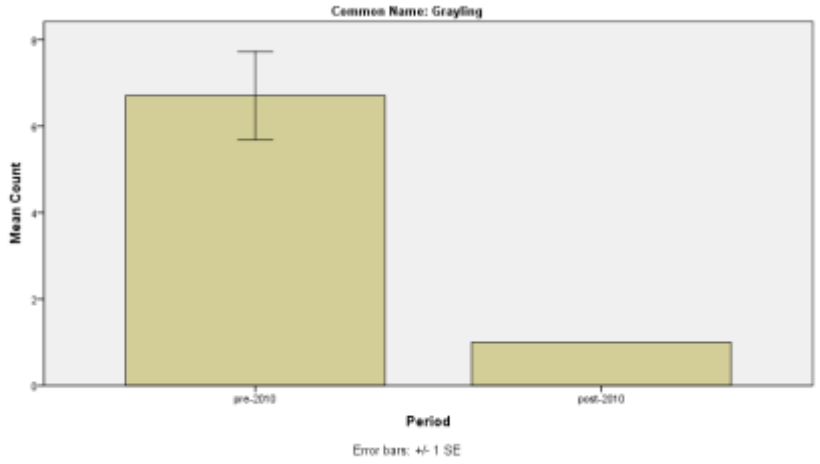
Graph 20 ***Summed counts and numbers of observations per year (all years) – Australian Grayling***



Graph 21 ***Summed counts and numbers of observations per month (all years) – Australian Grayling***

No graph – one post-2000 observation only.

Graph 22 ***Mean counts (and Standard Error) per year since 2000 – Australian Grayling***



Graph 23 ***Mean counts (and Standard Error) before and after 2010 – Australian Grayling***

3.3.3.2.5 Eastern Curlew (*Numenius madagascariensis*)

The Eastern Curlew is Australia's largest shorebird and a long-haul flyer – it takes an annual migratory flight to Russia and north-eastern China to breed, arriving back in Australia in August to feed on intertidal mudflats. It is a shy species, and tends to take flight at the first sign of danger, long before other nearby shorebirds become nervous (DAWE 2021b).

Figure 11 and Figure 12 display the species' historical records and the DEECA Habitat Importance Modelling (HIM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.

Breeding occurs in the Northern Hemisphere summer, from early May to late June, often in small colonies of two to three pairs. The birds nest on small mounds in swampy ground, often near where wild berries are growing. The nest is lined with dry grass and twigs. Some birds may delay breeding until three to four years of age (del Hoyo et al., 1996).

The Eastern Curlew is endemic to the East Asian–Australasian Flyway. Eastern Curlews breed in Russia, Mongolia and north-eastern China The species is a common passage migrant in Japan, Republic of Korea, China and Indonesia, and is occasionally recorded moving through Thailand and the Malay Peninsula. During the non-breeding season, a few birds visit southern Republic of Korea, Japan and China. About 25% of the population is thought to winter in the Philippines, Indonesia and Papua New Guinea but most (estimated at 73% or 28 000 individuals) spend the non-breeding season in Australia (Marchant & Higgins, 1993).

Within Australia, this species has a primarily coastal distribution. The species is found in all states, particularly the north, east, and south-east regions including Tasmania. In Victoria, the main strongholds are in Corner Inlet and Western Port Bay, with smaller numbers of birds visiting Port Phillip Bay and scattered locations elsewhere along the coast. Two thirds of the birds that visit Victoria are female (Nebel et al. 2013); given that the species is monogamous, it is likely that male-skewed non-breeding populations occur elsewhere, but sex ratios have not been studied in populations outside Victoria. Eastern Curlews may be found on islands in Bass Strait and along the north-west, north-east, east and south-east coasts of Tasmania. In South Australia, the species is scarce between the Victorian border and Cape Jaffa, and patchily distributed from the Coorong north-west to the Streaky Bay area, and has previously been recorded in Lake Alexandrina and Lake Albert, South Australia (Marchant & Higgins, 1993).

Along the coast of Australia, this species is most commonly associated with sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass (Zosteraceae), often near mangroves, on salt flats and in saltmarsh, rockpools and among rubble on coral reefs, and on ocean beaches near the tideline. Occasionally, the species occurs on ocean beaches (often near estuaries), and coral reefs, rock platforms, or rocky islets. The birds are often recorded among saltmarsh and on mudflats fringed by mangroves, and sometimes within the mangroves. The birds are also found in coastal saltworks and sewage farms, but are rarely seen on near-coastal lakes or in grassy areas (Marchant & Higgins, 1993).

During high-tide periods, the species roosts on sandy spits, sandbars and islets, especially on beach sand near the high-water mark, and among coastal vegetation including low saltmarsh or mangroves. They occasionally roost on reef-flats, in the shallow water of lagoons and other near-coastal wetlands (Marchant & Higgins, 1993). Eastern Curlews typically roost in large flocks, separate from other shorebirds (Marchant & Higgins, 1993).

While in Australia, the species is carnivorous, mainly eating crustaceans (including crabs, shrimps and prawns), small molluscs, as well as some insects. In Victoria, ghost-shrimps are an important part of the diet (Dann 1986, 1987). In Roebuck Bay, Western Australia, the birds feed mainly on large crabs, but will also catch mantis shrimps and chase mudskippers (Rogers, 1999).

The birds are both diurnal and nocturnal, with feeding and roosting cycles determined by the tides. Eastern Curlews find the burrows of prey by sight during the day or in bright moonlight, but also locate prey by touch. The sexual differences in bill length lead to corresponding differences in diet and behaviour (Marchant & Higgins, 1993). Eastern Curlews usually feed singly or in loose flocks. Occasionally, this species is seen in large feeding flocks of hundreds (Marchant & Higgins, 1993).

The history of database observations of the Eastern Curlew on the Bellarine Peninsula is presented in Graph 24 to Graph 27. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2009, ALA includes observations up to 2020).

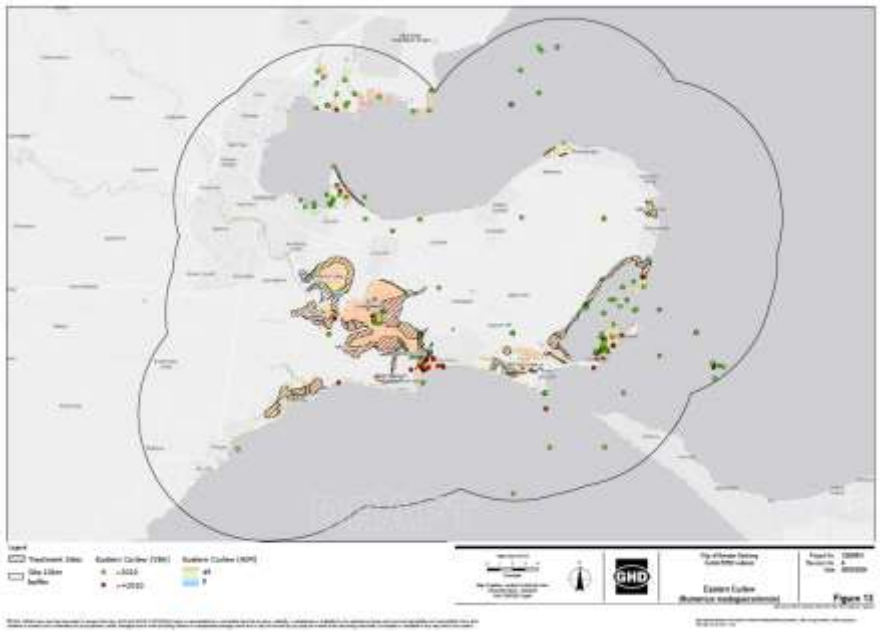
Observations of Eastern Curlew on the Bellarine Peninsula have varied greatly in effort and summed counts (refer to Graph 24. Very small numbers of records exist prior to the mid-1960s, and then there is the highest summed count of any year – more than 500 birds (this value likely represents multiple counts of smaller numbers of individuals). Records since the mid-1970s present a good understanding of Eastern Curlew observations in this area: in some years, there are very few birds reported and few people searching, while in other years, there is relatively high effort and counts. The most consistent years for counts are since 2008, after which the inter-annual variation is less evident.

Observations and counts of Eastern Curlews on the Bellarine Peninsula show a strongly seasonal and potentially bi-modal pattern (refer to Graph 25). There are reports of curlews in every month, but most records by far are from January and February. There is a pronounced increase in observations December and March, and another smaller one between August and November. The Eastern Curlew appears to be in smallest numbers on the Bellarine Peninsula from April to July inclusive.

Since 2000, mean annual counts of Eastern Curlews on the Bellarine Peninsula have remained consistently small (Graph 26). In most years, the average count is of approximately 10 birds or fewer. Higher average counts are evident in 2002, 2003 and 2006, and the relatively large standard errors for those years suggest that the numbers of birds counted in those years varied broadly.

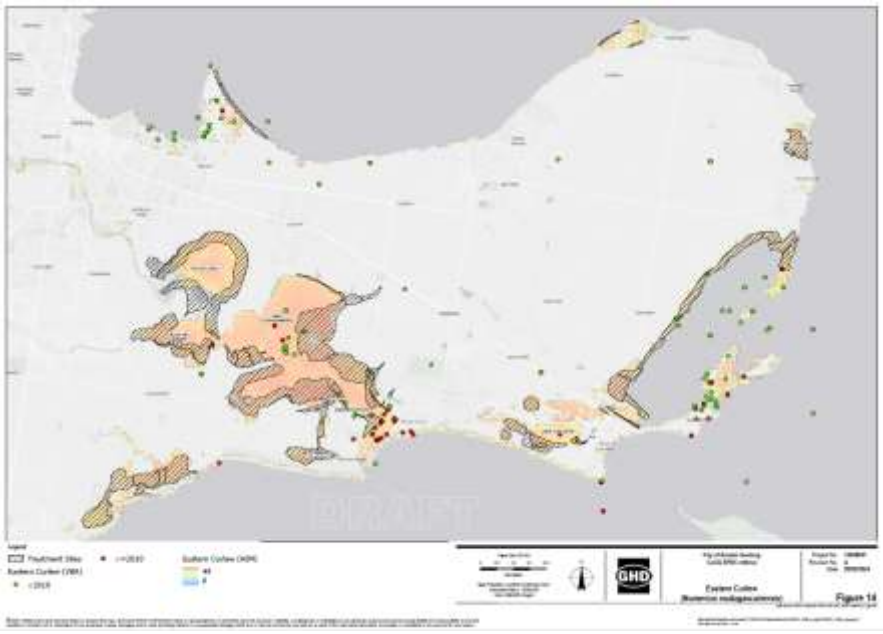
Mean counts of Eastern Curlews on the Bellarine Peninsula in the last ten or so years (post-2010) are slightly smaller than average counts historically (pre-2010), but the difference is unlikely to be significant (refer to Graph 27). This suggests that the numbers of curlews that visit the Bellarine Peninsula today are similar to the numbers of birds that have visited historically.

Figure 11 Eastern Curlew – historical records and Habitat Importance Modelling; 10 km search area

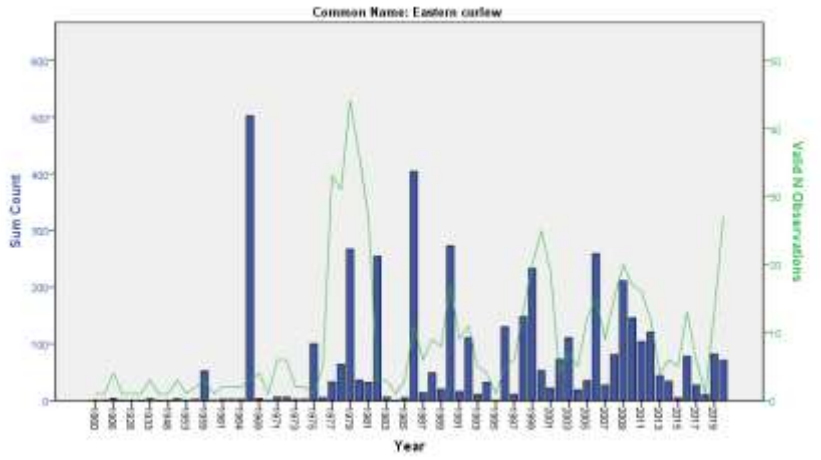


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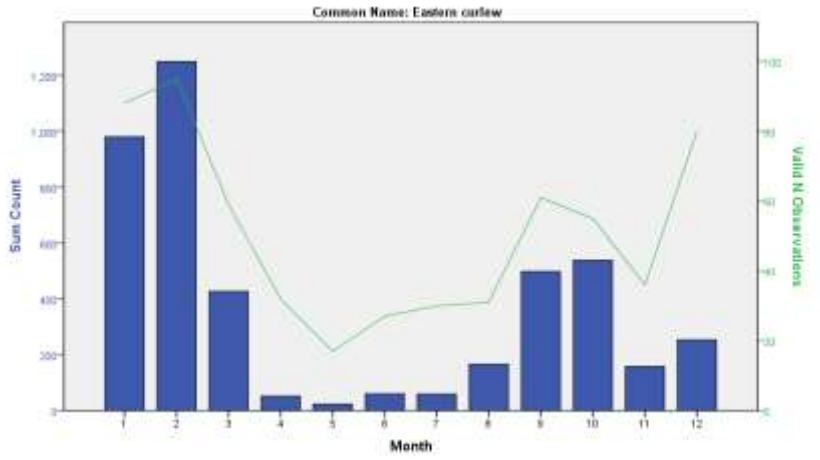
Figure 12 Eastern Curlew – historical records and Habitat Importance Modelling; proposed action area



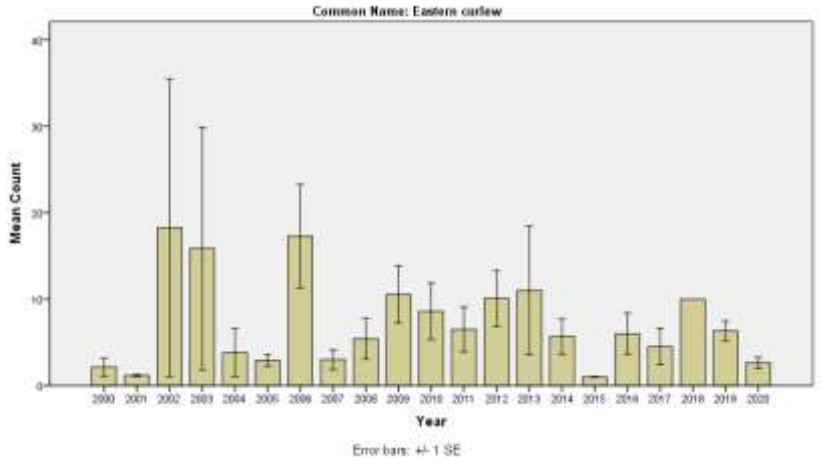
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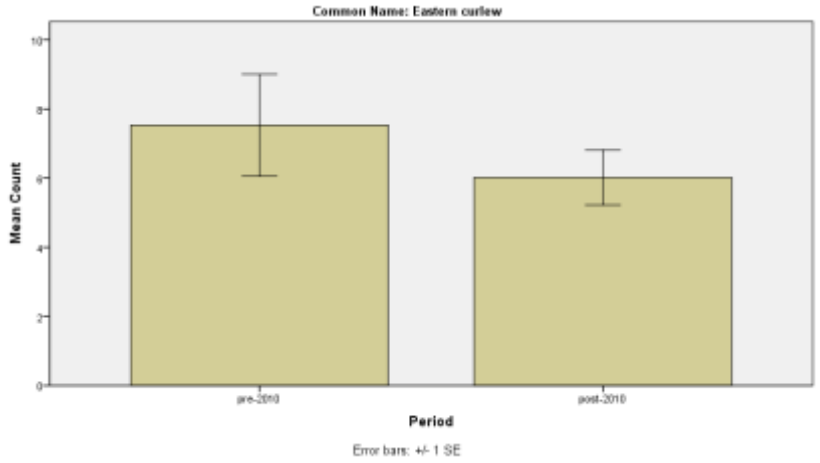
Graph 24 ***Summed counts and numbers of observations per year (all years) – Eastern Curlew***



Graph 25 ***Summed counts and numbers of observations per month (all years) – Eastern Curlew***



Graph 26 ***Mean counts (and Standard Error) per year since 2000 – Eastern Curlew***



Graph 27 ***Mean counts (and Standard Error) before and after 2010 – Eastern Curlew***

3.3.3.2.6 Curlew Sandpiper (*Calidris ferruginea*)

This species typically migrates annually from breeding areas in the Northern Hemisphere to foraging grounds in Australia during its non-breeding season. The Curlew Sandpiper does not breed in Australia (Higgins & Davies 1996). The species visits a broad range of locations in Australia, primarily around the coast but also in smaller numbers at widespread locations inland. Records occur in all states during the non-breeding period, and there are also records during the breeding season, when many non-breeding one-year-old birds remain in Australia rather than migrating north. In Victoria, Curlew Sandpipers are widespread and relatively common in coastal bays and inlets, and are widespread in near-coastal wetlands, and inland in suitable habitats such as the Kerang area, Mildura, and western districts.

Figure 13 and Figure 14 display the species' historical records and the DEECA Habitat Importance Modelling (HIM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.

The global population size of this species was estimated to be 1,350,000 in 2002 (Delany & Scott 2002 as cited in Bamford et al. 2008). No more-recent estimate is known. The global extent of occurrence is estimated at 100,000–1,000,000 km² (BirdLife International 2008). Approximately 13% of the global population uses the East Asian-Australasian Flyway (Bamford et al. 2008). Up to 2008, approximately 115,000 individuals were thought to visit Australia during the non-breeding period (Bamford et al., 2008), but numbers subsequently declined (Garnett et al., 2011). Numbers declined at Corner Inlet in Victoria by 3.4% per year between 1982 and 2011 (Minton et al., 2012), and by 82% across 49 Australia sites between 1983 and 2007. Models suggest that this decline was due to reduced adult survival rates (Rogers and Gosbell, 2006). Time-series data from directly observed summer counts at a large number of sites across Australia indicated a severe population decline of 75.9% over 20 years (7.5% per year; Fuller, pers. comm., 2014). In large part, the observed decline in Curlew Sandpiper numbers across Australia is thought to stem from ongoing loss of intertidal mudflat habitat at key migration staging sites in the Yellow Sea, rather than habitat changes within Australia itself (Murray et al., 2014 cited in DAWE 2021b). However, threats are occurring locally in Australia, such as coastal developments and recreational activities causing disturbance.

The history of observations of the Curlew Sandpiper on the Bellarine Peninsula is presented in Graph 28 to Graph 31. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2015, ALA includes observations up to 2020).

Observations of the Curlew Sandpiper on the Bellarine Peninsula have varied greatly in effort and summed counts (Graph 28). Few records exist prior to 1981, but after that there are regular annual summed counts of large numbers of birds. The highest counts and the highest search effort have been in the two most recent years – 2019 and 2020. In both years, summed counts are >10,000 birds (note that the summed values likely represent multiple counts of smaller numbers of individuals). Records since 1980 present a good understanding of Curlew Sandpiper observations in this area: in most years, moderate to high numbers of birds are reported, while in some years, very high counts are made.

Observations and counts of Curlew Sandpiper on the Bellarine Peninsula show a strongly seasonal pattern (refer to Graph 29). There are reports of this species in every month, but most records by far are from February. The species is generally counted in small numbers between April and November inclusive.

Since 2000, mean annual counts of Curlew Sandpipers on the Bellarine Peninsula have remained relatively consistent (refer to Graph 30). In most years, the average count is of 50 birds or more, and the highest mean count for any year is 2006, with more than 150 birds counted for the average observation. Relatively large standard errors for many years suggest that the numbers of birds counted varies broadly. The population declines since 2008, as reported by Garnett et al. (2011), are not clearly evident in the history of database records for the Bellarine Peninsula.

Mean counts of Curlew Sandpipers on the Bellarine Peninsula in the last ten or so years (post-2010) are slightly smaller than average counts historically (pre-2010) (refer to Graph 31). This suggests that fewer Curlew Sandpipers visit the Bellarine Peninsula today than historically, and may reflect the population declines reported by Garnett et al. (2011).

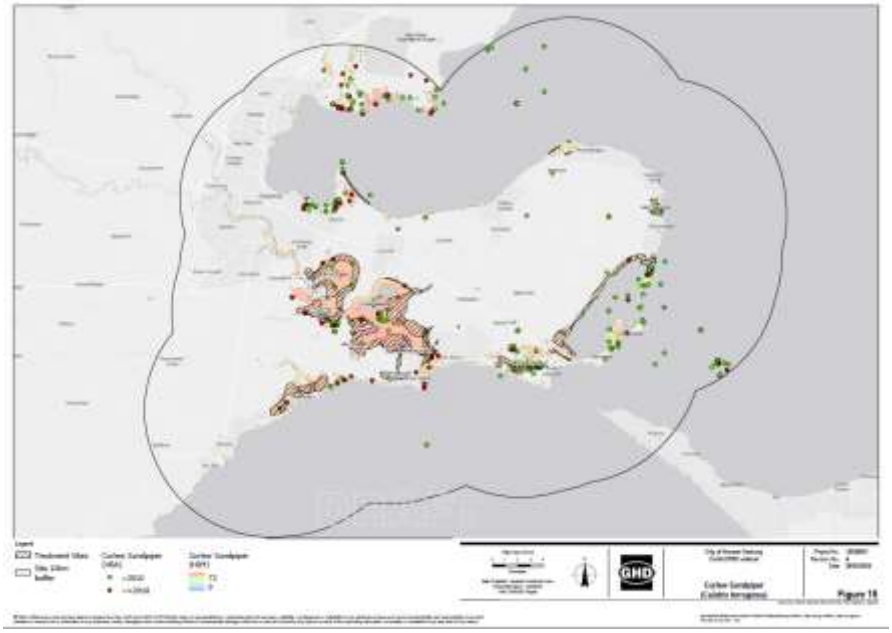
Curlew Sandpipers mainly occur on intertidal mudflats in sheltered coastal areas, such as estuaries, bays, inlets and lagoons, and also around non-tidal swamps, lakes and lagoons near the coast, and ponds in saltworks and sewage farms. They are also recorded inland, though less often, including around ephemeral and permanent lakes, dams, waterholes and bore drains, usually with bare edges of mud or sand. They occur in both fresh and brackish waters. Occasionally they are recorded around floodwaters (Higgins & Davies 1996).

Curlew Sandpipers forage on mudflats and nearby shallow water. In non-tidal wetlands, they usually wade, mostly in water 15–30 mm, but up to 60 mm, deep. They forage at the edges of shallow pools and drains of intertidal mudflats and sandy shores. At high tide, they forage among low sparse emergent vegetation, such as saltmarsh, and sometimes forage in flooded paddocks or inundated saltflats. Occasionally they forage on wet mats of algae or waterweed, or on banks of beachcast seagrass or seaweed. They rarely forage on exposed reefs (Higgins & Davies 1996). In Roebuck Bay, northern Western Australia, they are also said to feed on part of the mudflats that have been exposed for a longer period, foraging in small groups (Tulp & de Goeij 1994).

Curlew Sandpipers generally roost on bare dry shingle, shell or sand beaches, sandspits and islets in or around coastal or near-coastal lagoons and other wetlands, occasionally roosting in dunes during very high tides and sometimes in saltmarsh (Higgins & Davies 1996). They have also been recorded roosting in mangroves in Inverloch, Victoria (Minton & Whitelaw 2000).

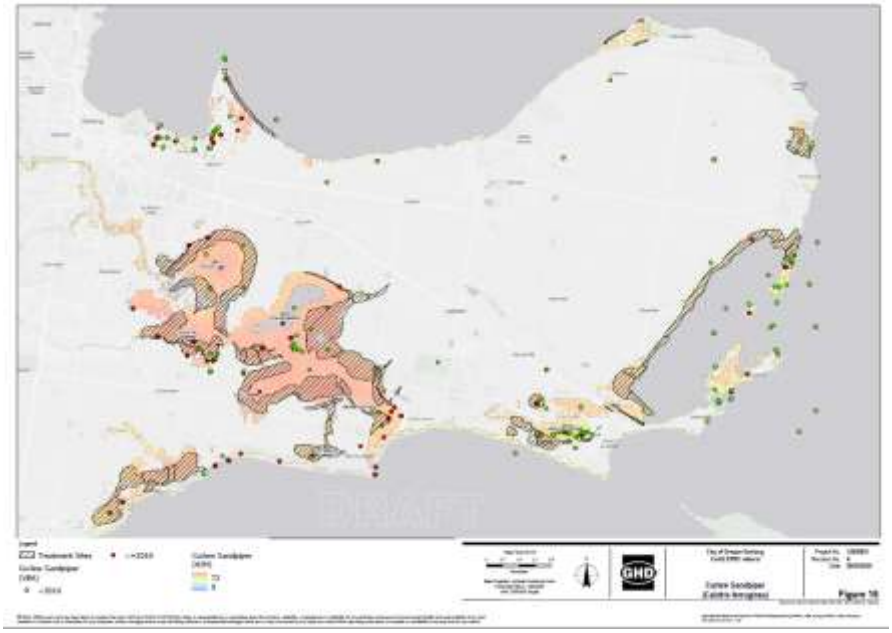
This species forages mainly on invertebrates, including worms, molluscs, crustaceans, and insects, as well as seeds. Outside Australia, they also forage on shrimp, crabs and small fish. Curlew Sandpipers usually forage in water, near the shore or on bare wet mud at the edge of wetlands. On wet mud they forage by pecking and probing. They probe in shallow water, and jab at the edge of the water where a film of water remains on the sand. They glean from mud, from the surface of water, or in drier areas above the edge of the water. They often forage in mixed flocks (Dann 1999b), including with Red-necked Stints.

Figure 13 Curlew Sandpiper – historical records and Habitat Importance Modelling; 10 km search area

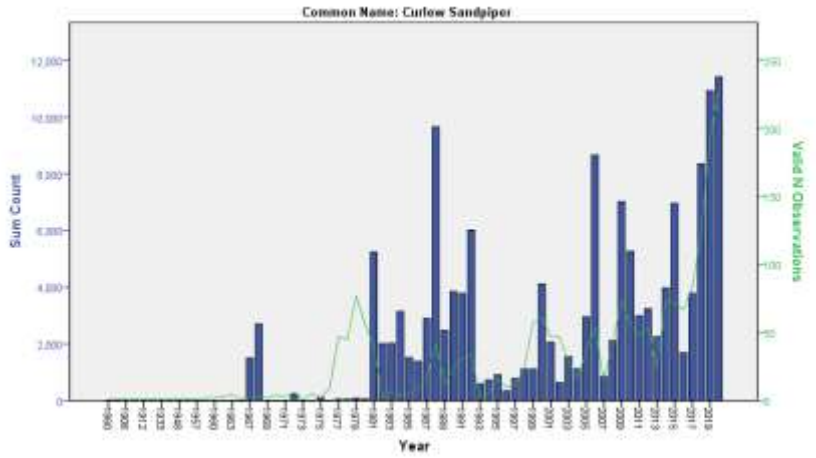


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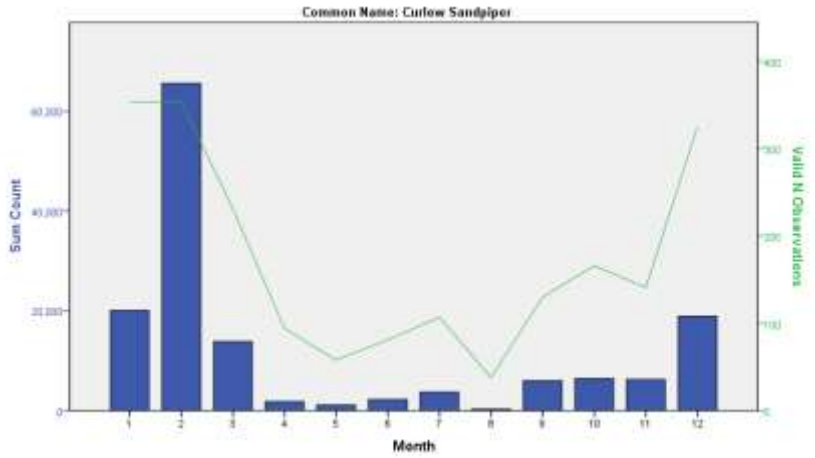
Figure 14 Curlew Sandpiper – historical records and Habitat Importance Modelling; proposed action area



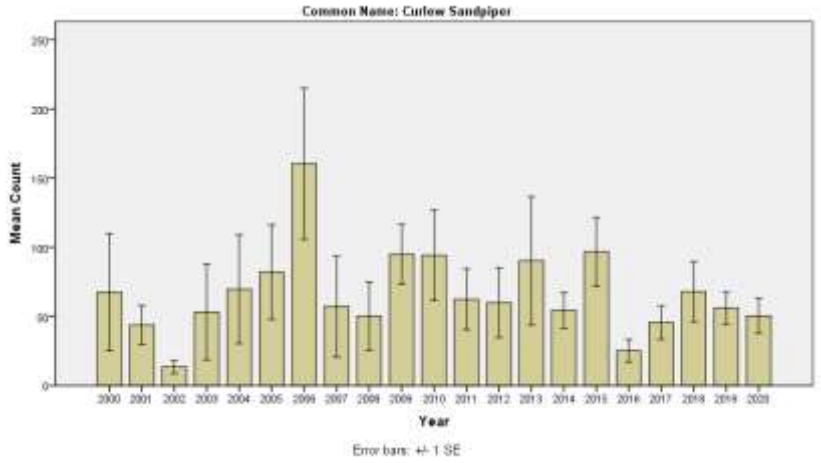
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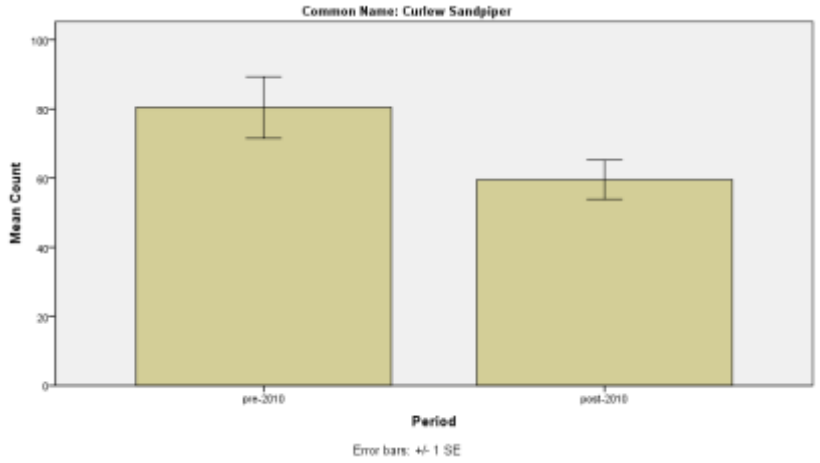
Graph 28 ***Summed counts and numbers of observations per year (all years) – Curlew Sandpiper***



Graph 29 ***Summed counts and numbers of observations per month (all years) – Curlew Sandpiper***



Graph 30 ***Mean counts (and Standard Error) per year since 2000 – Curlew Sandpiper***



Graph 31 ***Mean counts (and Standard Error) before and after 2010 – Curlew Sandpiper***

3.3.3.2.7 Common Greenshank (*Tringa nebularia*)

The Common Greenshank is a large and heavily built shorebird with a long and slightly upturned bill. The species typically migrates annually from breeding areas in the Northern Hemisphere to foraging grounds in Europe, Africa, Asia, Melanesia and Australasia during its non-breeding season (DCCEEW 2024). In Australia, the Common Greenshank occupies all types of wetlands; it is widespread in coastal regions and has one of the widest distributions of any shorebird in Australia (Higgins & Davies 1996; in DCCEEW 2024). In Victoria, the species occurs between Gippsland Lakes and Port Phillip Bay (including the Bellarine Peninsula), with scattered records elsewhere along the coast (Higgins & Davies 1996; in DCCEEW 2024).

The species arrives in northern Australia from August, moving southwards from November onwards (Lane 1987; in DCCEEW 2024). The Common Greenshank may overwinter at a few sites, and the proportion of the population that overwinters in Australia varies between years (Thomas 1970a; in DCCEEW 2024). During non-breeding season, most birds do not seem to move long distances within Australia, although dispersive movements may occur (Higgins & Davies 1996; in DCCEEW 2024). Northward migration occurs from March onward, mostly in April.

The Common Greenshank forages at the edge of wetlands, in soft mud on mudflats and within shallows around the edge of waterbodies often near or among emergent or fringing vegetation such as sedges or saltmarsh. The Common Greenshank is carnivorous – DCCEEW (2024) reports that its diet consists primarily of insects and their larvae (especially beetles), crustaceans, annelids, molluscs, amphibians (del Hoyo et al. 1996), small fish (mullet, clinids and tilapia; Hockey et al. 2005), and occasionally rodents (del Hoyo et al. 1996; BirdLife International, 2021). The species is active day and night.

Common Greenshanks are reported to roost in coastal and inland locations - in estuaries and mudflats, mangrove swamps and lagoons, billabongs, swamps, sewage farms, and flooded crops (BirdLife Australia 2021, in DCCEEW 2024).

This species is listed as threatened mainly due to observed population declines (DCCEEW 2024). These declines are thought to be due to increasing degradation and habitat loss in coastal stopover locations along the migration route, particularly along the coast of the Yellow Sea, China. The Common Greenshank is also listed as Migratory under the EPBC Act.

DCCEEW (2024) reports that there are currently estimated to be 23,700 (range 16,300–33,400) mature individuals in the wild with a continuing declining trend (Clemens et al. 2021). The extent of occurrence (EOO) is estimated at 10,200,000 km2 (range 9,700,000–10,700,000 km2) and area of occupancy (AOO) at 13,000 km2 (13,000–20,000 km2). Both the EOO and AOO are considered stable (Clemens et al. 2021).

Figure 15 and Figure 16 display the species' historical records and the DEECA Habitat Importance Modelling (HIM) for the species within the search area (10 km buffer of the treatment sites) and proposed action area. The HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.

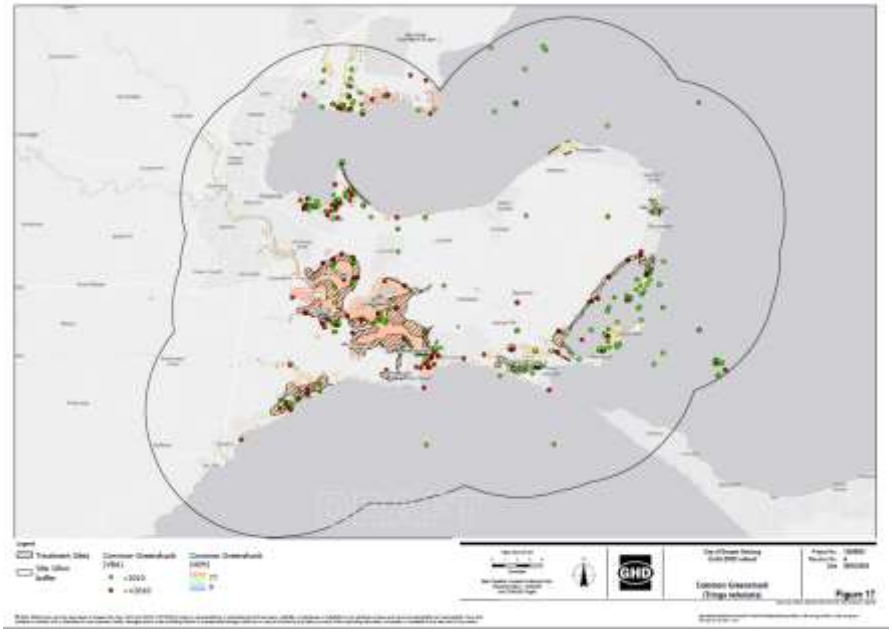
The history of observations of the Common Greenshank on the Bellarine Peninsula is presented in Graph 32 to Graph 35. These graphs are based on VBA data. As for observations of all migratory shorebirds combined (section 3.3.3.3.1), observations of the Common Greenshank on the Bellarine Peninsula appear to have increased with time (refer to Graph 32). There are small numbers of records until the 1980s, then there is a period of consistently larger numbers reported. The reported numbers taper away by 2012, but then increase dramatically after 2013, coinciding with a great increase in survey effort (Valid N Count). Reported numbers of Common Greenshank on Bellarine Peninsula peak in 2016, with more than 2000 birds recorded in that year.

Observations and counts of Common Greenshank on the Bellarine Peninsula show a strongly seasonal pattern (refer to Graph 32). While there are reports of this species in every month, there is a clear increase in numbers as the birds arrive from October onwards, then a decrease in numbers as birds depart between February and April. December to February sees the highest counts of this species.

Since 2000, mean annual counts of Common Greenshank on the Bellarine Peninsula have fluctuated, but the species is recorded in small numbers every year (refer to Graph 34). In many years, the average count is of 15 birds or fewer, but the mean count was higher between 2004 and 2011 and reached as high as 30 or more birds for the average observation in 2006.

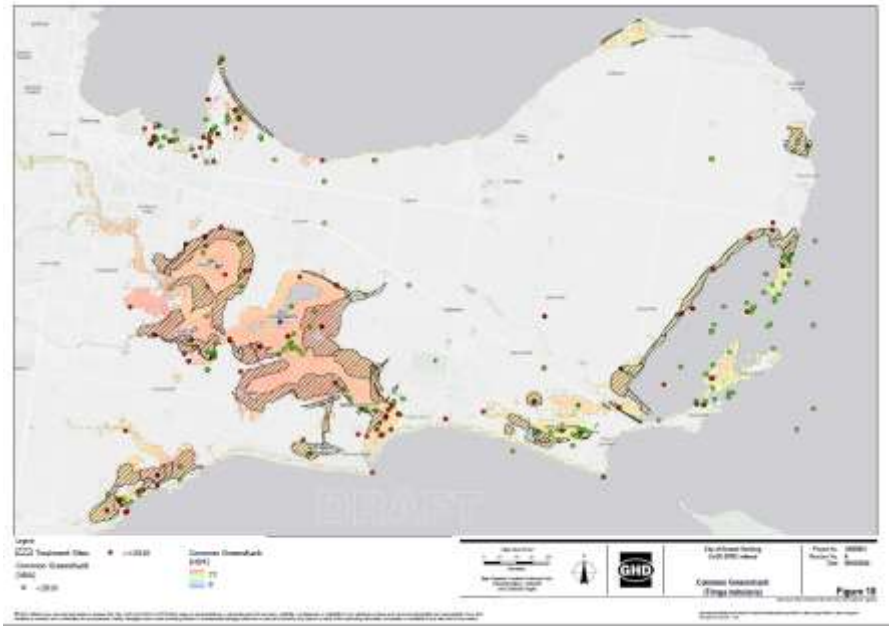
Mean counts of Common Greenshank on the Bellarine Peninsula in the last ten or so years (post-2010) are smaller than average counts historically (pre-2010) (refer to Graph 35).

Figure 15 Common Greenshank – historical records and Habitat Distribution Modelling; 10 km search area

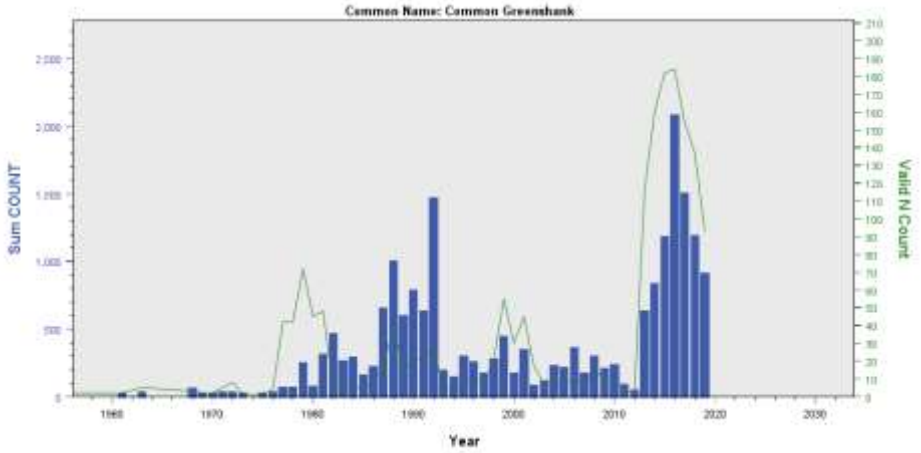


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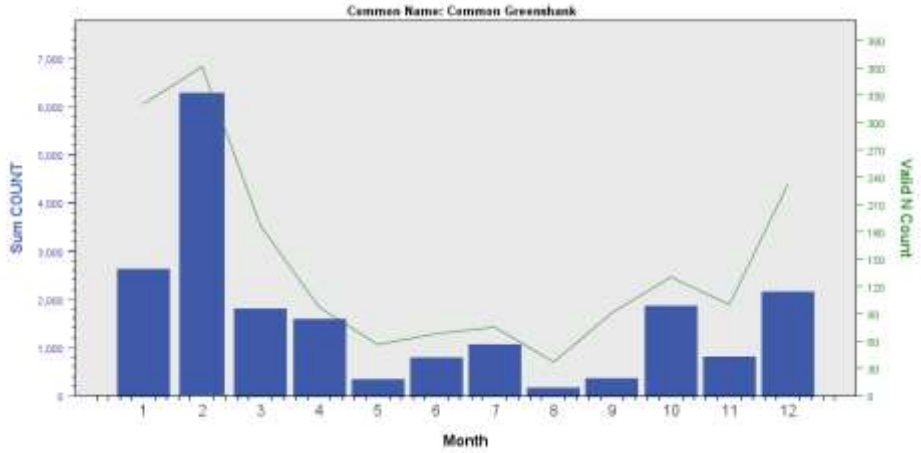
Figure 16 Common Greenshank – historical records and Habitat Distribution Modelling; proposed action area



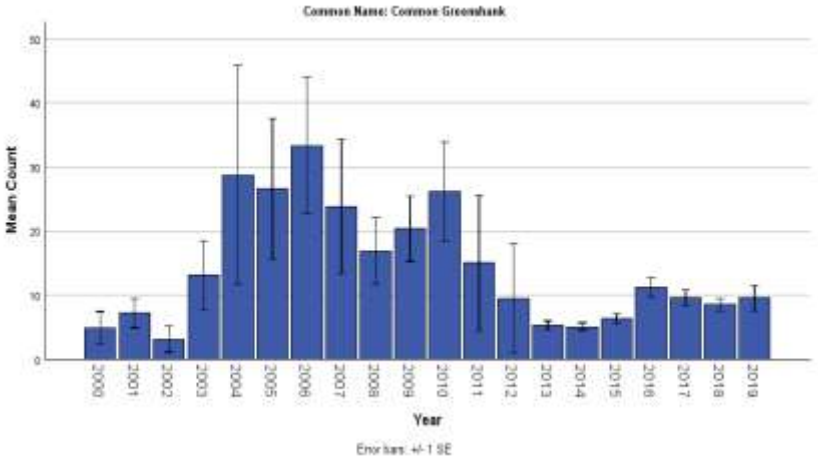
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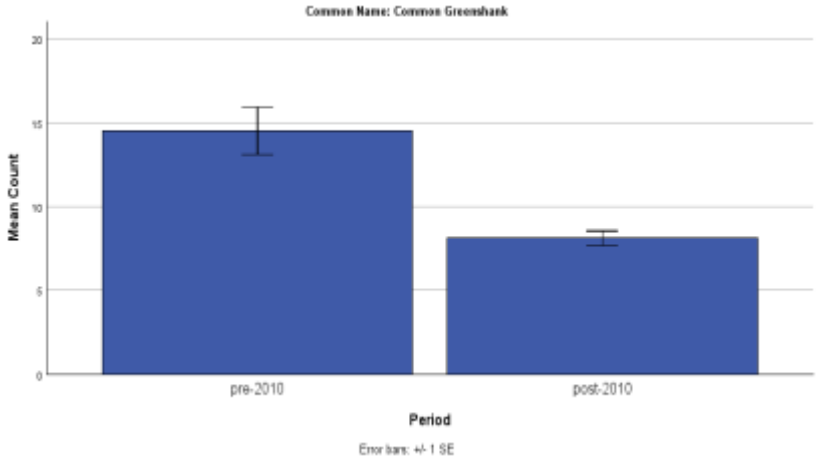
Graph 32 ***Summed counts and numbers of observations per year (all years) – Common Greenshank, Bellarine Peninsula. VBA data for this species stop in 2020.***



Graph 33 ***Summed counts and numbers of observations per month (all years) – Common Greenshank, Bellarine Peninsula***



Graph 34 ***Mean counts (and Standard Error) per year since 2000 – Common Greenshank, Bellarine Peninsula***



Graph 35 ***Mean counts (and Standard Error) before and after 2010 – Common Greenshank, Bellarine Peninsula***

3.3.3.2.8 Sharp-tailed Sandpiper (*Calidris acuminata*)

The Sharp-tailed Sandpiper is a small shorebird that migrates annually from breeding areas in the Northern Hemisphere to foraging grounds in the southern hemisphere. This species spends the non-breeding season in Australia with small numbers occurring regularly in New Zealand also. Most of the population migrates to Australia, mostly to the south-east and the species becomes widespread each year in both inland and coastal locations and in both freshwater and saline habitats. Many inland records are of birds on passage (i.e., during migration) (Cramp 1985; Higgins & Davies 1996). The species becomes widespread in most regions of Victoria, especially in coastal areas, but remains sparse in north-east and north-central Victoria (Higgins & Davies 1996). Birds also occur occasionally inland and on Bass Strait islands (Higgins & Davies 1996).

An estimated 85,000 Sharp-tailed Sandpipers occupy the East Asian-Australasian Flyway (EAAF) (Hansen et al. 2016). During the non-breeding season, approximately 91% of the EAAF population occurs in Australia and New Zealand (Bamford et al. 2008). Thirty-nine 'important sites' have been identified in Australia – an important site is determined using the 1% criterion (i.e., a site is considered 'important' if it is occupied by more than 1% of the bird's total population). Important sites in Australia include Ocean Grove to Barwon Heads, which is estimated to attract and support a population of 1684 birds (Bamford et al. 2008).

In Australasia, the Sharp-tailed Sandpiper is primarily here to make use of foraging habitat. It prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline lakes inland. They also occur in saltworks and sewage farms. They use flooded paddocks, sedgelands and other ephemeral wetlands, but leave when those habitats dry. They use intertidal mudflats in sheltered bays, inlets, estuaries and seashores, and also swamps and creeks lined with mangroves. They tend to occupy coastal mudflats mainly after ephemeral terrestrial wetlands have dried out, moving back during wetter periods. They may be attracted to mats of algae and water weed either floating or washed up around terrestrial wetlands, and coastal areas with much beachcast seaweed. Sometimes they occur on rocky shores and rarely on exposed reefs (Higgins & Davies 1996).

The species forages on seeds, worms, molluscs, crustaceans and insects (Higgins & Davies 1996). It is recorded to eat the following plant seeds: *Paspalum* spp.; clover (*Trifolium* spp.); *Medicago* sp., Lucerne (*M. sativa*); *Ruppia* spp.; goosefoot (*Chenopodium* spp.) and knotweed (*Polygonum* spp.) (Higgins & Davies 1996), and is reported to eat arachnids and dead fish (Barker & Vestjens 1989; Higgins & Davies 1996).

Roosting occurs at the edges of wetlands, on wet open mud or sand, in shallow water, or in short sparse vegetation, such as grass or saltmarsh. Occasionally, they roost on sandy beaches, stony shores or on rocks in water (Higgins & Davies 1996). They have also been recorded roosting in mangroves (Minton & Whitelaw 2000).

Figure 17 and Figure 18 display the species' historical records within the search area (10 km buffer of the treatment sites) and proposed action area. There is currently no DEECA Habitat Importance or Habitat Distribution Modelling for this species.

The history of observations of the Sharp-tailed Sandpiper on the Bellarine Peninsula is presented in Graph 36 to Graph 39. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2015, ALA includes observations up to 2020).

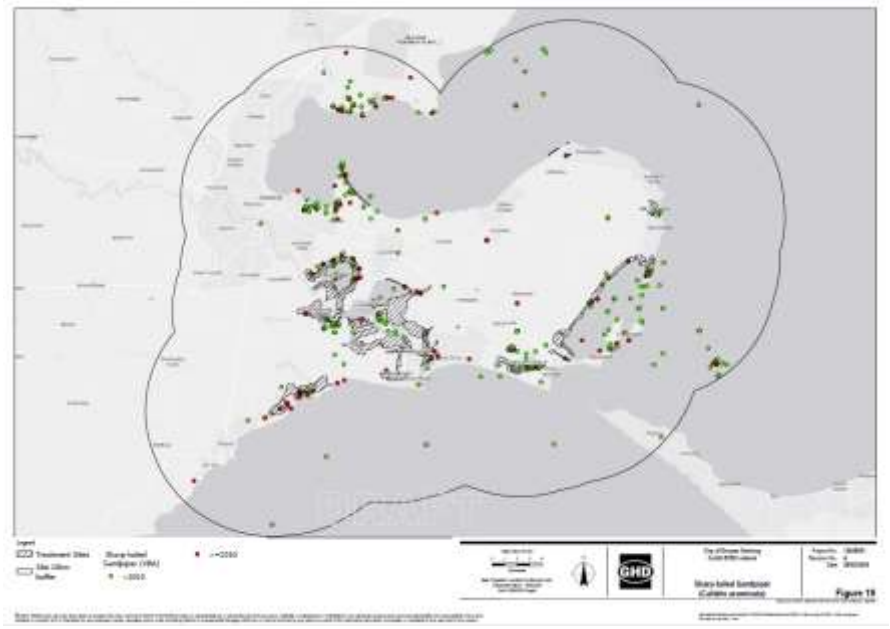
As for observations of all migratory shorebirds combined (section 3.3.3.3.1), observations of the Sharp-tailed Sandpiper on the Bellarine Peninsula appear to have increased with time (refer to Graph 36). There are few records until 1980, then there is a period of consistently small numbers reported until 2004. After 2004, summed counts increase notably, and counts in recent years (2017 – 2020) represent the highest summed counts historically.

Observations and counts of Sharp-tailed Sandpiper on the Bellarine Peninsula show a strongly seasonal pattern (refer to Graph 36). While there are reports of this species in every month, there is a clear increase in numbers as the birds arrive from September onwards, then a decrease in numbers as birds depart before April. December to February has the highest counts of this species.

Since 2000, mean annual counts of Sharp-tailed Sandpipers on the Bellarine Peninsula have fluctuated, but the species is recorded every year (refer to Graph 38). In many years, the average count is of 100 birds or fewer, but mean counts reach as high as 300 birds counted for the average observation in 2005.

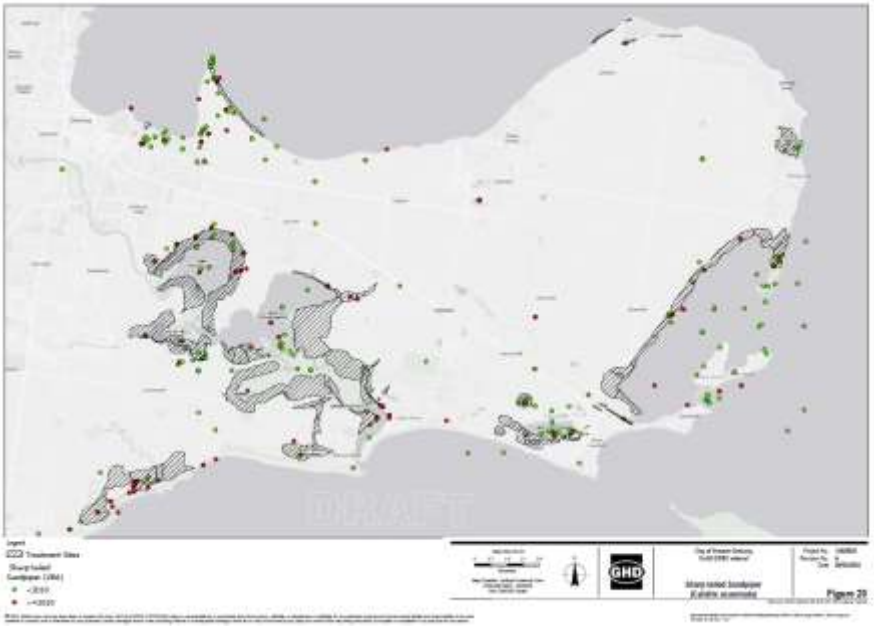
Mean counts of Sharp-tailed Sandpipers on the Bellarine Peninsula in the last ten or so years (post-2010) are slightly smaller than average counts historically (pre-2010), but the difference is unlikely to be significant (refer to Graph 39). This suggests that the numbers of Sharp-tailed Sandpipers that visit the Bellarine Peninsula today are similar to the numbers of birds that have visited historically.

Figure 17 Sharp-tailed Sandpiper – historical records; 10 km search area

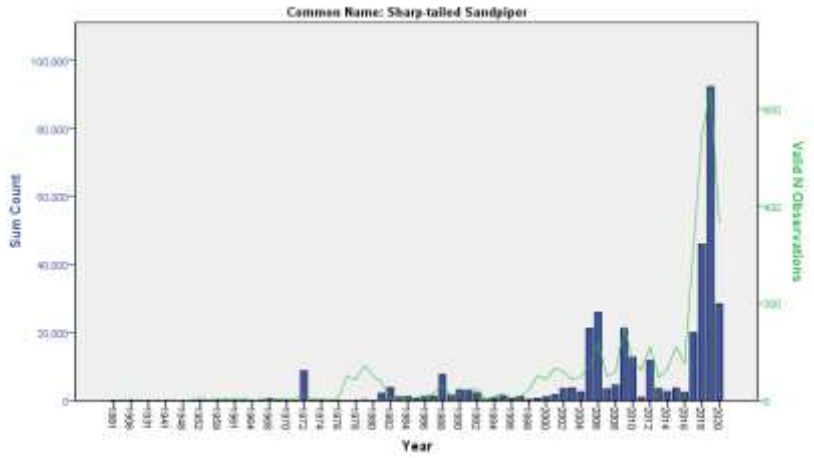


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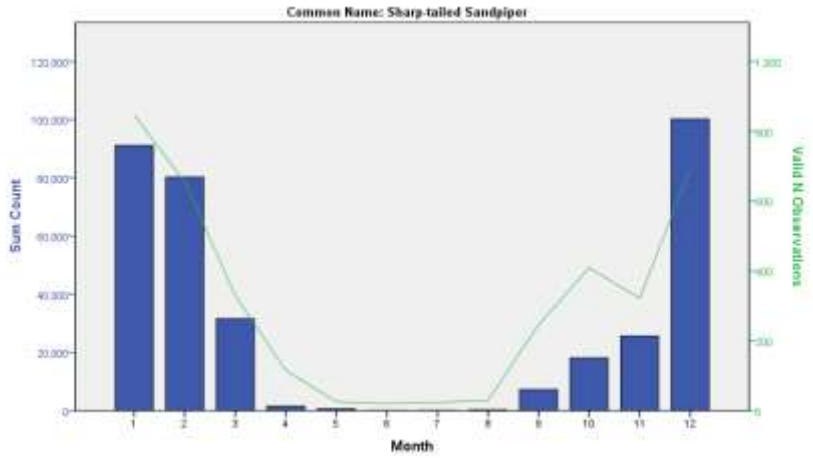
Figure 18 Sharp-tailed Sandpiper – historical records; proposed action area



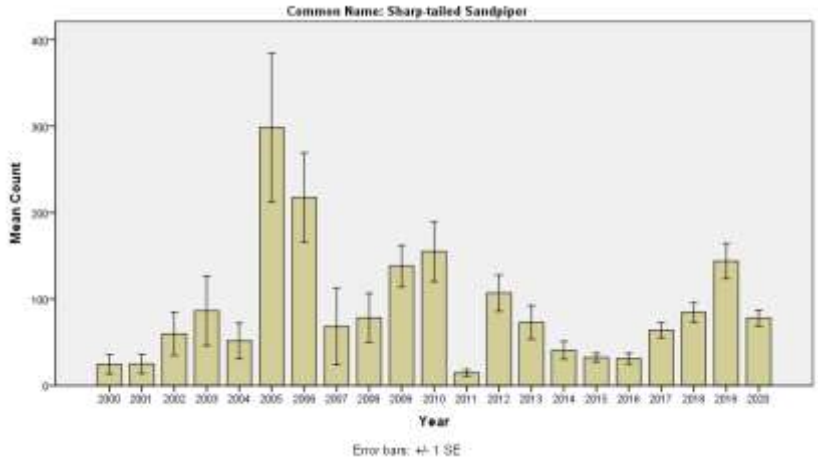
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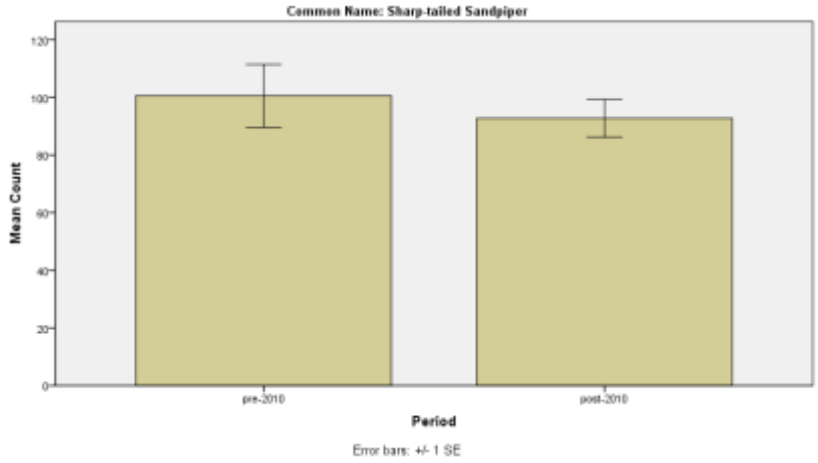
Graph 36 ***Summed counts and numbers of observations per year (all years) – Sharp-tailed Sandpiper***



Graph 37 ***Summed counts and numbers of observations per month (all years) – Sharp-tailed Sandpiper***



Graph 38 ***Mean counts (and Standard Error) per year since 2000 – Sharp-tailed Sandpiper***



Graph 39 ***Mean counts (and Standard Error) before and after 2010 – Sharp-tailed Sandpiper***

3.3.3.2.9 Summary of historical records and modelled habitats within the search area for key threatened species of concern

Table 29 provides a summary for occurrence, VBA records and total area of HIM/HDM habitat for the Orange-bellied Parrot, Blue-winged Parrot, Growling Grass Frog, Australian Grayling, Eastern Curlew, Curlew Sandpiper, Common Greenshank, and Sharp-tailed Sandpiper.

Table 29 Summary of historical distribution of records and modelled habitats for key threatened species of concern within the search area.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/no. records within treatment sites (3)	Total area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered	Non-breeding, migratory marine species, over winters during March – August on mainland. Key known habitats – Lake Connewarre, Swan Bay foreshore habitats, Breamlea Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 20 records (count = 59 birds) Search area = 388 records (count = 4591 birds) Date range = 1857 to 2012	Ground sites = 12.388 ha (0.18 %) Aerial sites = 2465.918 ha (35.23 %) Search area = 6999.164 ha Modelling applied: HIM. Note: the HIM overestimates the area of habitat available for this species within the search area. It includes extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging, perching or roosting.
Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable	Widespread, and potentially occurs anywhere within proposed action area. No breeding records. Likely favoured coastal/wetland habitats – Lake Connewarre, Swan Bay foreshore habitats, Breamlea Flora and Fauna Reserve.	Ground site = 3 records (count = 12 birds) Aerial sites = 133 records (count = 2590 birds) Search area = 441 records (count = 7964 birds) Date range = 1860 to 2020	Ground sites = 26.411 ha (0.03 %) Aerial sites = 3235.449 ha (4.20 %) Search area = 77069.191 ha Modelling applied: HDM. Note: the HDM overestimates the area of habitat available for this species within the search area. The higher-value areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging, perching or roosting.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/no. records within treatment sites (3)	Total area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Growling Grass Frog (*Litoria raniformis*) - Vulnerable	Resident, probably breeding in select areas (e.g. Reedy Lake), found in freshwater habitats. Key known habitats - Reedy Lake, Hospital Swamp, Port Arlington (Port Richard) Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 11 records (count = 42 frogs) Search area = 43 records (count = 342 frogs) Date range 1788 to 2020	Ground sites = 7.856 ha (0.09 %) Aerial sites = 2335.113 ha (26.45 %) Search area = 8828.062 ha Modelling applied: HIM. Note: the HIM overestimates the area of habitat available for this species within the search area. It includes extensive areas of open water and tidal habitat, such as lower Lake Connewarre and the Barwon River estuary, and along the Swan Bay foreshore, where the species is unlikely to occur due to brackish or salt water.
Australian Grayling (*Prototroctes maraena*) - Vulnerable	Diadromous, spending part of its lifecycle in freshwater and at least part of the larval and/or juvenile stages in coastal seas. Adults (including pre spawning and spawning adults) inhabit cool, clear, freshwater streams with gravel substrate and areas alternating between pools and riffle zones. Key known habitats – Reedy Lake and Barwon River upstream of Lake Connewarre.	Ground site = 0 records Aerial sites = 3 records (count = 37 fish) Search area = 52 records (count = 366 fish) Date range 1873 to 1998	Ground sites = 0.079 ha (0.01 %) Aerial sites = 220.666 ha (26.06 %) Search area = 846.855 ha Modelling applied: HIM.
Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory	Non-breeding, migratory species occurs from August through March. Some first-year birds may overwinter. Key known habitats - Swan Bay foreshore, Edwards Point wildlife Reserve. Also Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Barwon River/estuary – Barwon Heads, Stingaree Bay/Point Henry-Geelong.	Ground site = 0 records Aerial sites = 68 records (count = 357 birds) Search area = 471 records (count = 2996 birds) Date range 1960 to 2018	Ground sites = 9.754 ha (0.14 %) Aerial sites = 2497.906 ha (36.61 %) Search area = 6822.525 ha Modelling applied: HIM. Note: the HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/no. records within treatment sites (3)	Total area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory	Non-breeding, migratory species occurs from August through March. Some first-year birds may overwinter. Usually in small to moderate numbers. Key known habitats - Swan Bay foreshore, Edwards Point wildlife Reserve. Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Reedy Lake, Hospital Swamp, Barwon River /estuary – Barwon Heads, Stingaree Bay/Point Henry-Geelong, Lake Murtnaghurt, Queenscliffe Coastal Reserve from Barwon Heads west, Thompson Creek /Breamlea Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 126 records (count = 10,446 birds) Search area = 1344 records (count = 106,857 birds) Date range 1860 to 2021	Ground sites = 8.827 ha (0.12 %) Aerial sites = 2705.567 ha (35.91 %) Search area = 7534.568 ha Modelling applied: HIM. Note: the HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.
Common Greenshank (*Tringa nebularia*) – Endangered, Migratory	Non-breeding, migratory species occurs from August through March. Some first-year birds may overwinter. Usually in small numbers. Key known habitats - Swan Bay foreshore, Edwards Point wildlife Reserve. Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Reedy Lake, Hospital Swamp, Barwon River /estuary – Barwon Heads, Stingaree Bay/Point Henry-Geelong, Lake Murtnaghurt, Queenscliffe Coastal Reserve from Barwon Heads west, Thompson Creek /Breamlea Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 246 records (count = 2523 birds) Search area = 1759 records (count = 18,905 birds) Date range = 1860 to 2019	Ground sites = 9.958 ha (0.12 %) Aerial sites = 2847.625 ha (35.20 %) Search area = 8089.604 ha Modelling applied: HIM. Note: the HIM overestimates the area of habitat available for this species within the search area. Modelled habitat areas include extensive areas of open water, such as in Reedy Lake, Lake Connewarre and in the Barwon River estuary, where the species may fly over but is unlikely to land for foraging or roosting.
Sharp-tailed Sandpiper (*Calidris acuminata*) – Vulnerable, Migratory	Non-breeding, migratory species occurs from August through March. Some first-year birds may overwinter. Sometimes in large numbers. Key known habitats - Swan Bay foreshore, Edwards Point wildlife Reserve. Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Reedy Lake, Hospital Swamp, Barwon River /estuary – Barwon Heads, Stingaree Bay/Point Henry-Geelong, Lake Murtnaghurt, Queenscliffe Coastal Reserve from Barwon Heads west, Thompson Creek /Breamlea Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 207 records (count = 12,222 birds) Search area = 1336 records (count = 99,764 birds) Date range = 1906 to 2021	No HIM or HDM available for this species.

Table notes: 1 - information sourced from SPRAT, further detail provided in body of report. 2 – Known habitats determined from review of VBA, ALA, NatureKit and other information sources listed in 3.3.3 and 3.3.4. 3 – Records determined from review of VBA and/or ALA data. 4 – Area of habitat determined from NatureKit modelled habitat. HIM = Habitat Importance Model; HDM = Habitat Distribution Model. Note - search area = 10 km buffer area of treatment sites. Includes area between treatment sites and within 10 km of each treatment site.

3.3.3.2.10 Other threatened fauna species

In addition to the five species listed by the Department (listed in section 3.3.3.1), and the three additional species named in section 3.3.3.2, the following 15 threatened fauna species (14 birds and one fish) are also known to occur within the proposed action area at least occasionally and so were considered for possible impacts by the proposed action (see Appendix G): For convenience, species are grouped according to key fauna assemblages:

– **Wetland birds**
  - Australasian Bittern, *Botaurus poiciloptilus* - Endangered
  - Australian Painted Snipe, *Rostratula australis* – Endangered

– **Shorebirds/seabirds**
  - Eastern Hooded Plover, *Thinornis cucullatus cucullatus* – Vulnerable
  - Australian Fairy Tern, *Sternula nereis nereis* – Vulnerable

– **Migratory birds/shorebirds**
  - Bar-tailed Godwit (Western Alaskan), *Limosa lapponica baueri* – Vulnerable, Migratory
  - Black-tailed Godwit, *Limosa limosa* - Endangered, Migratory
  - Greater Sand Plover, *Charadrius leschenaultia* – Vulnerable, Migratory
  - Great Knot, *Calidris tenuirostris* – Critically Endangered, Migratory
  - Grey Plover, *Pluvialis squatarola* – Vulnerable, Migratory
  - Lesser Sand Plover, *Charadrius mongolus* – Endangered, Migratory
  - Red Knot, *Calidris canutus* – Endangered, Migratory
  - Ruddy Turnstone, *Arenaria interpres* – Vulnerable, Migratory
  - Terek Sandpiper, *Xenus cinereus* – Vulnerable, Migratory
  - Latham's Snipe, *Gallinago hardwickii* – Vulnerable, Migratory

– **Fish**
  - Yarra Pygmy Perch, *Nannoperca obscura* – Vulnerable

All bird species excluding Australasian Bittern, Eastern Hooded Plover, Australian Painted Snipe and Australian Fairy Tern are also listed as migratory species, and most are shorebirds (not Latham's Snipe).

For a range of reasons, mostly to do with the likelihood of the species being present in the treated habitat during the treatment, these species are less likely to be of concern for the proposed action than the five species discussed above in sections 3.3.3.2.1 to 3.3.3.2.6.

The **Australasian Bittern** is a rare, solitary, species that eats vertebrates (frogs, birds, mammals, fish) and large macro-invertebrates (e.g., crayfish). It inhabits densely vegetated wetlands, including areas that support taller reeds and rushes. These are not typically the areas that are subjected to larvicide treatments as the vegetation prevents the pilot from seeing the water and therefore product would not be applied to these areas.

The **Australian Painted Snipe** is a very rare, nomadic species that prefers larger freshwater wetlands, and occurs singly or in pairs or small groups. This species is mainly crepuscular (active at dawn and dusk), preferring to sit quietly under cover of grass, reeds or other dense cover during day, becoming more active at dawn, dusk and during night. They generally remain in dense cover when feeding, although may forage over nearby mudflats and other open areas such as ploughed land or grassland. The Australian Painted Snipe eats vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates (Marchant & Higgins 1993). This species may turn up at any suitable habitat, but for the most part is unlikely to be present.

The **Australian Fairy Tern** nests in small colonies on sandy spits and beaches above the high-water mark in sheltered bays. This species may occasionally forage for small fish in some of the wetlands or coastal areas in the proposed action area, but is unlikely to be a common visitor.

The **Eastern Hooded Plover** prefers ocean beaches, foraging on the beach and rock platforms, and nesting on the beach above the high-tide mark. This habitat type is not targeted for larvicide treatment. Small numbers of Hood plover are occasionally seen roosting at Lake Victoria, which is one of the proposed treatment sites.

The **Bar-tailed Godwit**, **Black-tailed Godwit**, **Greater Sand Plover**, **Great Knot**, **Grey Plover**, **Lesser Sand Plover**, **Red Knot**, **Ruddy Turnstone** and **Terek Sandpiper** are some of the less common species of migratory shorebird that visit Victorian shores and wetlands from the northern hemisphere each summer. Most species tend to be predominantly coastal, preferring salt-water and estuarine habitats to freshwater habitats. While any of these species may visit some of the treatment sites from time to time, none is expected to be common, except perhaps at Swan Bay. The Swan Bay and Mud Islands area is notable in Victoria as supporting substantial populations of Bar-tailed Godwit, Red Knot and Grey Plover (Rogers et al., 2010). These birds forage in Swan Bay, then return to Mud Islands to roost.

Greater Sand Plovers usually feed from the surface of wet sand or mud on open intertidal flats of sheltered embayments, lagoons or estuaries (Marchant & Higgins 1993), more often on firm sandy flats than on soft muddy ones (Rogers 1999b). During the non-breeding season, they mostly eat molluscs, worms, crustaceans (especially small crabs and sometimes shrimps) and insects (including adults and larvae of termites, beetles, weevils, earwigs and ants) (Barker & Vestjens 1989; Jessop 2003; MacGillivray 1914; McLennan 1917; Serventy 1952a; Thomas 1986; van Tets et al. 1969, 1977 in DotE 2022a). They usually roost on sand-spits and banks on beaches or in tidal lagoons, and occasionally on rocky points (Bamford 1988; Ewart 1973; Pegler 1983; Sibson 1948, 1953 in DotE 2022a), or in adjacent areas of saltmarsh (Gosper & Holmes 2002 in DotE 2022a) or claypans. They tend to roost further up the beach than other waders, sometimes well above high-tide mark (C.D.T Minton, 2002 pers. comm in DotE 2022a). Greater Sand Plovers are generally uncommon to rare in Victoria and on the Bellarine Peninsula.

Lesser Sand Plovers feed mostly on extensive, freshly exposed areas of intertidal sandflats and mudflats in estuaries or beaches, or in shallow ponds in saltworks (Evans 1975; Hindwood & Hoskin 1954; Johnstone & Storr 1998; McGill & Keast 1945; Thomas 1968 in DotE 2022b). They also occasionally forage on coral reefs and on sandy or muddy river margins (Booth 1982; Evans 1975; McGill & Keast 1945; Pegler 1983 in DotE 2022b). At inland sites, they have been recorded foraging in muddy areas around lakes, soaks and bores (Badman & May 1983; Henle 1989; McGill & Keast 1945 in DotE 2022b). They mainly roost near foraging areas, on beaches, banks, spits and banks of sand or shells (McGill & Keast 1945; Pegler 1983 in DotE 2022b). Lesser Sand Plovers are generally uncommon to rare in Victoria and on the Bellarine Peninsula.

The Bar-tailed Godwit usually forages near the edge of water or in shallow water, mainly in tidal estuaries and harbours. They appear not to forage at high tide and prefer exposed sandy substrates on intertidal flats, banks and beaches. The also prefer soft mud; often with beds of eelgrass Zostera or other seagrasses. They rarely forage in grassy or vegetated areas. (Marchant & Higgins 1993). The species usually roosts in small groups on sandy beaches, sandbars, spits and also in near-coastal saltmarsh (Collins et al. 2001).

The Black-tailed Godwit has a primarily coastal distribution in Australia; it is commonly found in sheltered bays, estuaries and lagoons with large intertidal mudflats or sandflats, or spits and banks of mud, sand or shell-grit; occasionally recorded on rocky coasts or coral islets (Department of the Environment 2024b). It may also be found in shallow and sparsely vegetated, near-coastal, wetlands; such as saltmarsh, saltflats, river pools, swamps, lagoons and floodplains. The Black-tailed Godwit is found in all states and territories of Australia, however, the largest populations are found on the north coast between Darwin and Weipa. It is generally found in small numbers elsewhere, and is uncommon on the Bellarine Peninsula. Eleven important sites have been identified in Australia; none of these occurs in Victoria (Department of the Environment 2024b).

The Great Knot typically prefers sheltered coastal habitats, with large intertidal mudflats or sandflats. This includes inlets, bays, harbours, estuaries and lagoons. They are occasionally found on exposed reefs or rock platforms, shorelines with mangrove vegetation, ponds in saltworks, at swamps near the coast, saltlakes and non-tidal lagoons. The Great Knot rarely occurs on inland lakes and swamps (Higgins & Davies 1996). This species may be seen in small groups or large flocks, and there are records on the Bellarine Peninsula, particularly in the Swan Bay area.

The Red Knot mainly inhabits intertidal mudflats, sandflats and sandy beaches of sheltered coasts, in estuaries, bays, inlets, lagoons and harbours; sometimes on sandy ocean beaches or shallow pools on exposed wave-cut rock platforms or coral reefs. They are occasionally seen on terrestrial saline wetlands near the coast, such as lakes, lagoons, pools and pans, and recorded on sewage ponds and saltworks, but rarely use freshwater swamps. They rarely use inland lakes or swamps (Higgins & Davies 1996). The species usually forage in soft substrate near the edge of water on intertidal mudflats or sandflats exposed by low tide. At high tide they may feed at nearby lakes, sewage ponds and floodwaters (Higgins & Davies 1996). Roosting occurs on sandy beaches, spits and islets, and mudflats; also in shallow saline ponds of saltworks (Higgins & Davies 1996). They have been seen roosting on an inland claypan near Roebuck Bay, north-west Western Australia (Collins et al. 2001). They like to roost in open areas far away from potential cover for predators, but close to feeding grounds (Rogers 2001). This species may be seen in small groups or large flocks, and there are records on the Bellarine Peninsula, particularly in the Swan Bay area.

The Grey Plover occurs almost entirely in coastal areas while in Australia, where they usually inhabit sheltered embayments, estuaries and lagoons with mudflats and sandflats, and occasionally on rocky coasts with wave-cut platforms or reef-flats, or on reefs within muddy lagoons (Department of the Environment 2024c). They also occur around terrestrial wetlands such as near-coastal lakes and swamps, or salt-lakes (Department of the Environment 2024c). The species tends to occur in small groups. Twenty important sites have been identified in Australia; two of those are in Victoria: i) Corner and Shallow Inlets (which is also recognised as one of three internationally important sites within Australia), and ii) Swan Bay - Mud Islands, which is within the proposed treatment area (Department of the Environment 2024b). Other than at Swan Bay, there are few records of this species on the Bellarine Peninsula.

The Ruddy Turnstone is widespread in Australia during its non-breeding period. It is found mostly in coastal regions, and strongly prefers rocky shores or beaches (Department of the Environment 2024d). During the non-breeding season, 11 important sites have been identified in Australia, with a further four identified as important staging areas – none of these sites is within Victoria. This species is regularly reported in small numbers along the coast of the Bellarine Peninsula, as it is along much of the Victorian coastline.

The Terek Sandpiper is generally uncommon in Victoria, and there are few records on the Bellarine Peninsula. The species is generally more common in northern coastal Australia. In Victoria, the species has been recorded from Corner Inlet, Anderson Inlet, Westernport Bay and west Port Phillip Bay (Department of the Environment 2024e). Twelve important sites have been identified in Australia; none of these occurs in Victoria (Department of the Environment 2024e).

Latham's Snipe is a medium-sized wader and the largest snipe in Australia. It has a long straight bill, short broad pointed wings, a long tail and short legs (Higgins & Davies 1996). Latham's Snipe usually occurs singly or in small, loose groups (<12 birds) (Driscoll 1993; Higgins & Davies 1996; Naarding 1983), occasionally occurring in larger groups (Higgins & Davies 1996; Naarding 1983; in Department of the Environment 2024a).

Latham's Snipe is a non-breeding migrant to south-eastern Australia. It is not uncommon, and is found in all regions of Victoria except for the north-west (Barrett et al. 2003; Blakers et al. 1984; Emison et al. 1987). In Australia, Latham's Snipe occurs in permanent and ephemeral wetlands. The species favours open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands, around bogs and other water bodies) (Frith et. al. 1977; Naarding 1983; Weston 2006, pers. comm.; in Department of the Environment 2024a). There are numerous records of this species on the Bellarine Peninsula, including within the proposed treatment area.

The **Yarra Pygmy Perch** is a small freshwater fish that occurs in the Barwon River system, including Reedy Lake. A free-swimming species whose entire life cycle is completed in freshwater (Cadwallader & Backhouse 1983). The species is endemic to south-eastern Australia. Populations within the proposed action area are likely to be resident and not generally considered a migratory species. The species typically occurs in slow-flowing or still waters which possess large amounts of aquatic vegetation (particularly emergent vegetation) such as lakes, ponds and slow-flowing rivers. Yarra Pygmy Perch are usually found in small groups, often occurring with the Southern Pygmy Perch, although the Yarra Pygmy Perch appears to prefer slightly stronger flows (Kuiter et al 1996). The diet includes microcrustaceans, molluscs and aquatic insects, such as mosquito larvae (MDBC 2007, Allen 1989). Yarra Pygmy Perch spawn during spring (September to October) at water temperatures of 16–24oC (Kuiter et al. 1996). Some of the habitats occupied by this species within the proposed action, particularly Reedy Lake, may be subjected to larvicide treatments as they could contain mosquito breeding habitat (e.g. still waters). However other habitat for Yarra pygmy perch is not likely to be targeted for mosquito larvicide treatment as the conditions are not suitable for mosquitos (e.g. flowing waters) or where treatment cannot be applied effectively (e.g. areas of dense emergent vegetation).

Table 30 summarises historical records and modelled habitat areas for all 15 threatened fauna species.

Table 30 Summary of historical distribution of records for key species of concern within the search area.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/within treatment sites (3)	Area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Australasian Bittern (*Botaurus poiciloptilus*) - Endangered	Possible breeding resident in small numbers. Freshwater wetlands and, rarely, in estuaries or tidal wetlands. Favouring wetlands with tall dense vegetation. Lake Connewarre Reedy Lake, Thompsons Creek /Breamlea Flora and Fauna Reserve, Point Henry	Ground site = 0 records Aerial sites = 37 records (count = 46 birds) Search area = 90 records (count = 120 birds) Date range 1901 to 2019	Ground sites = 10.609 ha (0.11 %) Aerial sites = 2872.911 ha (30.56 %) Search area = 9399.806 ha Modelling applied: HIM.
Australian Painted Snipe (*Rostratula australis*) – Endangered	Possible rare breeding visitor. Generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. Breeding habitat requirements may be quite specific: shallow wetlands with areas of bare wet mud and both upper and canopy cover nearby. Reedy Lake, Lake Connewarre, Salt Swamp	Ground site = 0 records Aerial sites = 0 records Search area = 10 records (count = 15 birds) Date range 1860 to 2013	Ground sites = 8.797 ha (0.12 %) Aerial sites = 2650.347 ha (37.06 %) Search area = 7151.429 ha Modelling applied: HIM.
Australian Fairy Tern (*Sternula nereis nereis*) – Vulnerable	Non-breeding resident. Nests on sheltered sandy beaches, spits and banks above the high tide line and below vegetation. The bird roosts on beaches At night. Outside the action area – Sand Island maintains a regular breeding population of the species and provides the main roosting habitat in Swan Bay. Coastal areas of Bellarine Peninsula including – Swan Bay and foreshore/Edwards Point wildlife Reserve. Also Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Barwon River – Barwon Heads, Stingaree Bay-Geelong	Ground site = 0 records Aerial sites = 40 records (count = 341 birds) Search area = 855 records (count = 10,844 birds) Date range 1800 to 2019	Ground sites = 5.262 ha (0.09 %) Aerial sites = 2007.577 ha (35.20 %) Search area = 5703.433 ha Modelling applied: HIM.
Eastern Hooded Plover (*Thinornis cucullatus cucullatus*) – Vulnerable	Resident along coastal zone or waterbodies not far from coast. Breeding locations for last 10 years restricted to coastal high energy shore habitats. Usually in small numbers. Coastal Swan Island, Lorne Queenscliffe Coastal Reserve (along coast from Point Lonsdale to Breamlea). Also Lake Victoria/Lonsdale Lakes Wildlife Reserve, Barwon River – Barwon Heads, Lake Murtnaghurt, Thompson Creek/ Breamlea Flora and Fauna Reserve	Ground site = 0 records Aerial sites = 82 records (count = 949 birds) Search area = 955 records (count = 3771 birds) Date range 1959 to 2021	Ground sites = 7.656 ha (0.19 %) Aerial sites = 767.020 ha (18.71 %) Search area = 4099.546 ha Modelling applied: HIM.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/within treatment sites (3)	Area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Bar-tailed Godwit (Western Alaskan) (*Limosa lapponica baueri*) – Vulnerable, Migratory	Non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small to moderate numbers. Swan Bay, Edwards Point wildlife Reserve, Swan Island, Lake Connewarre, Barwon River – Barwon Heads.	Ground site = 0 records Aerial sites = 59 records (count = 1498 birds) Search area = 416 records (count = 19,359 birds) Date range 1907 to 2019	Ground sites = 21.934 ha (0.12 %) Aerial sites = 3121.531 ha (17.39 %) Search area = 17949.466 ha Modelling applied: HDM.
Black-tailed Godwit (*Limosa limosa*) – Endangered, Migratory	Non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small numbers. Reedy Lake, Lake Connewarre, Barwon River – Barwon Heads.	Ground site = 0 records Aerial sites = 29 records (count = 107 birds) Search area = 134 records (count = 363 birds) Date range 1963 to 2019	Ground sites = 9.754 ha (0.12 %) Aerial sites = 2836.258 ha (35.10 %) Search area = 8081.124 ha Modelling applied: HIM.
Greater Sand Plover (*Charadrius leschenaultia*) – Vulnerable, Migratory	Uncommon non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Swan Bay foreshore, Swan Island. Stingaree Bay-Geelong	Ground site = 0 records Aerial sites = 0 records Search area = 50 records (count = 92 birds) Date range 1963 to 2019	Ground sites = 7.909 ha (0.16 %) Aerial sites = 1222.345 ha (24.70 %) Search area = 4948.957 ha Modelling applied: HIM.
Great Knot (*Calidris tenuirostris*) – Critically Endangered, Migratory	Non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small to moderate numbers. Swan Bay foreshore, Swan Island /Edwards Point wildlife Reserve. Also Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Barwon River – Barwon Heads, Stingaree Bay-Geelong, Queenscliffe Coastal Reserve /Breamlea Flora and Fauna Reserve	Ground site = 0 records Aerial sites = 1 record (count = 45 birds) Search area = 185 records (count = 5807 birds) Date range 1968 to 2018	Ground sites = 8.797 ha (0.15 %) Aerial sites = 2160.332 ha (37.33 %) Search area = 5786.857 ha Modelling applied: HIM.
Grey Plover (*Pluvialis squatarola*) – Vulnerable, Migratory	Non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small numbers. Swan Bay, Swan Island /Edwards Point wildlife Reserve.	Ground site = 0 records Aerial sites = 4 records (count = 27 birds) Search area = 285 records (count = 5086 birds) Date range 1860 to 2019	Ground sites = 5.950 ha (0.21 %) Aerial sites = 457.413 ha (16.21 %) Search area = 2822.055 ha Modelling applied: HIM.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/within treatment sites (3)	Area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Lesser Sand Plover (*Charadrius mongolus*) – Endangered, Migratory	Uncommon non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Swan Bay foreshore, Swan Island /Edwards Point wildlife Reserve. Also Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Stingaree Bay-Geelong	Ground site = 0 records Aerial sites = 1 record (count = 4 birds) Search area = 159 records (count = 637 birds) Date range 1970 to 2013	Ground sites = 10.792 ha (0.16 %) Aerial sites = 2133.004 ha (32.47 %) Search area = 6568.980 ha Modelling applied: HIM.
Red Knot (*Calidris canutus*) – Endangered, Migratory	Non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small to moderate numbers. Swan Bay foreshore, Swan Island /Edwards Point wildlife Reserve. Also Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Barwon River – Barwon Heads, Stingaree Bay-Geelong, Queenscliffe Coastal Reserve /Breamlea Flora and Fauna Reserve	Ground site = 0 records Aerial sites = 16 records (count = 212 birds) Search area = 399 records (count = 15,930 birds) Date range 1860 to 2019	Ground sites = 8.478 ha (0.14 %) Aerial sites = 2217.724 ha (37.03 %) Search area = 5988.624 ha Modelling applied: HIM.
Ruddy Turnstone (*Arenaria interpres*) – Vulnerable, Migratory	Uncommon non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small numbers. Coastal areas, Portarlington, Swan Bay, Swan Island /Edwards Point wildlife Reserve, Breamlea Flora and Fauna Reserve.	Ground site = 0 records Aerial sites = 18 records (count = 110 birds) Search area = 570 records (count = 5024 birds) Date range 1906 to 2019	Ground sites = 7.476 ha (0.21 %) Aerial sites = 652.975 ha (18.50 %) Search area = 3529.613 ha Modelling applied: HIM.
Terek Sandpiper (*Xenus cinereus*) – Vulnerable, Migratory	Uncommon non-breeding, migratory species - occurs from August through March. Some first year birds may overwinter. Usually in small numbers. Swan Bay, Swan Island, Lake Connewarre, Barwon River – Barwon Heads.	Ground site = 0 records Aerial sites = 2 records (count = 2 birds) Search area = 31 records (count = 34 birds) Date range 1953 to 2017	Ground sites = 0 ha (0 %) Aerial sites = 232.913 ha (18.30 %) Search area = 1272.541 ha Modelling applied: HIM.
Latham's Snipe (*Gallinago hardwickii*) – Vulnerable, Migratory	Possible non-breeding migratory visitor. Generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and flooded grasslands. Usually in small numbers, often singly. Reedy Lake, Lake Connewarre, Salt Swamp, other freshwater marshes.	Ground site = 1 record (count = 8 birds) Aerial sites = 37 records (count = 125 birds) Search area = 1023 records (count = 7151 birds) Date range 1860 to 2020	No HIM or HDM available for this species.

Species	Species occurrence within proposed action area (1) and key known habitats within proposed action area (2)	Total no. records (VBA) within search area/within treatment sites (3)	Area of HIM/HDM habitat (ha) within treatment sites/ search area (4) (% = percentage of the entire modelled habitat within the 10 km search area)
Yarra Pygmy Perch (*Nannoperca obscura*) – Vulnerable	Resident, probably breeding population. Entire lifecycle within freshwater streams/bodies of water. Recent historical records from 2011 and 2014 from near Ocean Grove Golf Course Creek and Ocean Grove Blue Lake. Older records form Reedy Lake in proposed project area. Outside proposed project area – Many records from Thompson Creek upstream of Breamlea Flora and Fauna Reserve, Waurn Ponds Creek	Ground site = 0 records Aerial sites = 4 records (count = 5 fish) Search area = 94 records (count = 726 fish) Date range 1876 to 2022	Ground sites = 0.603 ha (0.02 %) Aerial sites = 646.904 ha (22.59 %) Search area = 2863.120 ha Modelling applied: HIM.

Table notes: 1 - information sourced from SPRAT. 2 – Known habitats determined from review of VBA, ALA, NatureKit and other information sources listed in 3.3.3 and 3.3.4. 3 – Records determined from review of VBA and/or ALA data. Note - search area = 10 km buffer area of treatment sites. Includes area between treatment sites and within 10 km of each treatment site. 4 – Area of habitat determined from NatureKit modelled habitat. HIM = Habitat Importance Model; HDM = Habitat Distribution Model. Note - search area = 10 km buffer area of treatment sites. Includes area between treatment sites and within 10 km of each treatment site.

3.3.3.3 Description of migratory species and their habitats known or likely to occur within proposed action area

The Department identifies three migratory species (all are migratory shorebirds) in the preliminary documentation request that may be significantly impacted by the proposed action. All three are also listed as threatened. The three species are:

– Eastern Curlew (*Numenius madagascariensis*) – migratory shorebird
– Curlew Sandpiper (*Calidris ferruginea*) – migratory shorebird
– Sharp-tailed Sandpiper (*Calidris acuminata*) – migratory shorebird

A detailed description of the abundance, distribution, ecology and habitat preferences is provided for each of these species in the sections above.

Including the three species listed by the Department, 64 migratory bird species may occur within the proposed action area. These include terrestrial birds (fantails and flycatchers), aerial birds (swifts and needletails), gulls and terns (noddies, jaegers, terns), marine or oceanic birds (e.g., albatrosses, petrels, shearwaters), and 36 species of migratory shorebird (e.g., plovers, sandpipers, etc). Many of these species do not use or visit the treatment areas. Of the 64 migratory species, 31 are considered for this assessment.

The migratory shorebirds (and aligned species such as snipe) are the group most likely to use or visit habitats within proposed treatment areas, so were also considered for the potential for impacts by the proposed action (see Appendix G). Because of the similar habitat use and broad ecological characteristics shared by many of these species, all migratory shorebird species are assessed as a group in section 3.3.3.3.1.

The Department's specific requests for information on select migratory species (Eastern Curlew, Curlew Sandpiper and Sharp-tailed Sandpiper) are met through the detailed information provided in earlier sections for threatened species – all three species are also listed as threatened, as well as migratory.

Additional information is provided here for the Red-necked Stint (*Calidris ruficollis*), which is the most ubiquitous and numerous migratory species that visits southern Australia and the proposed action area, and is therefore considered a suitable species to assess for distribution patterns and habitat use by migratory species.

Table 31 summarises the following information for the Red-necked Stint (species listed also as threatened under the EPBC Act are summarised in Table 29):

– Occurrence type within the proposed action area (e.g. resident, breeding or non-breeding)
– Known habitats within the proposed action area
– Number of records within the search area and number of records within or adjacent to treatment sites
– Note – the HIM habitat mapping is not available for species solely listed as migratory within Victoria. Consequently, the distribution and number of records is used to discuss location and extent of habitat for each species

Table 31 Summary of historical distribution of records for select migratory species of concern within the search area.

Species	Species occurrence within proposed action area (1)	Key known habitats within proposed action area (2)	Total no. records (VBA) within search area/within treatment sites (3)
Red-necked Stint (*Calidris ruficollis*) - Migratory, Marine	Non-breeding, migratory species occurs from August through March. Some first-year birds may overwinter. Common and regular visitor to numerous locations in the proposed action area.	Swan Bay foreshore, Swan Island /Edwards Point wildlife Reserve. Salt Lagoon/St Leonards Wildlife Reserve, Lake Victoria/Lonsdale Lakes Wildlife Reserve, Lake Connewarre, Reedy Lake, Barwon River – Barwon Heads, Stingaree Bay/Point Henry-Geelong, Queenscliffe Coastal Reserve from Barwon Heads west, Thompson Creek /Breamlea Flora and Fauna Reserve	Ground site = 1 record (count = 24 birds) Aerial sites = 285 records (count = 34,441 birds) Search area = 2171 records (count = 401,045 birds) Date range 1903 to 2021

Table notes 1- information sourced from SPRAT, further detail provided in subsequent sections. 2 – Known habitats determined from review of VBA, NatureKit and other information sources listed in 3.3.3 and 3.3.4. 3 – Records determined from review of VBA data. Note - search area = 10 km buffer area of treatment sites. Includes area between treatment sites and within 10 km of each treatment site. HDM/HIM not available for this species.

3.3.3.3.1 All migratory shorebird species

There are 37 shorebird species (listed migratory species) protected as MNES under the EPBC Act that migrate to and from Australia each year (DoE, 2015a). Sixteen of the 37 species are also listed as vulnerable, endangered or critically endangered under the EPBC Act.

Movement patterns

Thirty-six of the 37 EPBC Act listed migratory shorebird species breed in the northern hemisphere (e.g., Alaska, Siberia, eastern Russia, Japan) and migrate annually along the East-Asian-Australasian Flyway (EAAF) to nonbreeding habitats in the southern hemisphere, including Australia. The other species, Double-banded Plover, migrates between Australia and breeding grounds in New Zealand, rather than north-south through the flyway (DoE, 2015a). The majority of the migratory shorebirds that visit Australia are from two taxonomic families, the Sandpipers (Scolopacidae) and the Plovers (Charadriidae) (DoE, 2015a).

Most migratory shorebirds that visit Australia make an annual return journey of many thousands of kilometres between their breeding grounds and foraging grounds via the EAAF. The EAAF extends from breeding grounds in the Russian tundra, Mongolia, Siberia and Alaska southwards through east and south-east Asia, to non-breeding foraging areas in Indonesia, Papua New Guinea, Australia and New Zealand (DoE 2015a, DoE 2015b).

Migratory shorebird species are mostly present in Australia during their non-breeding period, from as early as August to as late as April/May each year. The Double-banded Plover is different and is generally present in Australia from March to September (DoE, 2015a). Shorebirds that migrate from the northern hemisphere reach 'staging areas' in Australia, such as Roebuck Bay in north-western Western Australia, by September. From these staging areas, the birds may disperse to other parts of Australia, typically reaching the south-eastern parts by October.

By March, birds begin to gather at staging areas, once again forming large flocks and feeding almost round the clock to accumulate energy reserves for their northward migration (DoE, 2015b).

Small flocks or individuals of some migratory species may remain in Australia during the winter months, such as first-year birds that lack the experience or physical condition to return to their natal sites until they are older and stronger, often in their second year (DoE, 2015b).

Areas inhabited by migratory shorebirds

After arriving in Australia at the end of their migration journey, birds tend to disperse to a wide variety of coastal and inland habitats within Australia, including:

– Coastal wetlands, estuaries, mudflats, rocky inlets, reefs and sandy beaches, often with mangrove populations
– Inland freshwater wetlands, floodplains and grassland areas, often with ephemeral water sources

Generally, smaller numbers take advantage of ephemeral wetlands across inland Australia, while most use habitats associated with the coastline (DoE, 2015b).

Australia's coastal and freshwater wetlands are important habitat during the non-breeding season as places for migratory shorebirds to rest and feed, and accumulate energy reserves to travel the long distance back to their breeding grounds (DoE, 2015b). Areas commonly used by migratory shorebirds in Australia usually comprise networks of foraging and roosting habitats.

Shorebirds move around within these networks depending on the time of day, availability of resources, levels of disturbance and environmental conditions (DoE, 2015a). That is, individual birds use a wide variety of sites and habitats during their non-breeding foraging season. The majority of migratory shorebirds mostly feed on intertidal sandflats and mudflats and require safe roosting areas to rest during high tide periods. The high energy demands on migratory shorebirds resulting from their migratory lifecycle means that resting is critical when not breeding.

Generally, migratory shorebirds prefer roosting areas in open habitat on slightly elevated ground, so that they remain alert to potential predators (DoE 2015a). Migratory shorebirds at non-tidal wetlands such as inland systems tend to show more dispersive behaviour (DoE 2015a). Within estuarine environments, principal roosting areas include exposed sands at estuary mouths and on adjacent beaches, saltmarshes that are only marginally submerged during high tide, grassy areas adjacent to estuaries, mangroves, nearby freshwater wetlands, claypans, and occasionally, rock groynes and exposed reefs (DoE, 2015a).

Foraging habitat

Many migratory shorebirds have specialised feeding techniques that enable them to feed on specific prey within particular foraging areas. The distribution of prey species, which are generally invertebrates, crustaceans and small fishes, also depends on factors such as sediment type and particle size which influences the shorebirds' foraging habitat selection. In coastal areas, foraging habitats are typically found in soft substrate tidal areas exposed during low tide (DoE, 2015a).

Some Australian inland wetlands and grasslands are also important habitat for migratory shorebirds. As rain-fed systems, many of these inland areas are ephemeral due to variability in climate. For this reason, many inland areas may not be used for several years. However, when these areas receive adequate rain, they can provide extremely productive and important food sources for some migratory shorebirds (e.g., Lake Eyre in northern South Australia) (DoE, 2015a).

Shorebirds on the Bellarine Peninsula

The history of observations of migratory species (all species listed as migratory and observed in the search area) on the Bellarine Peninsula is presented in Graph 40 to Graph 43. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2016, ALA includes observations up to 2021).

Overall counts of migratory species tend to be strongly influenced by counts of the most common species. For migratory species that visit the Bellarine Peninsula, three species are clearly the most common in terms of abundance: Red-necked Stint, Sharp-tailed Sandpiper and Curlew Sandpiper. These species are discussed in sections above (Curlew Sandpiper and Sharp-tailed Sandpiper) and below (Red-necked Stint).

Observations of all migratory species on the Bellarine Peninsula appear to have increased with time (refer to Graph 40). There are few records until 1980, then counts tend to increase progressively until the present time, with occasional years of exceptionally high counts (e.g., 1987, 2006, 2019). Counts of migratory species in recent years (2017 – 2020) represent a period of very high counts, and include the highest summed count historically (2019).

As expected, observations and counts of migratory species on the Bellarine Peninsula show a clear seasonal pattern (refer to Graph 41). While there are reports of migratory species in every month, there is a clear increase in numbers as birds arrive in spring, then a clear decrease as most birds depart in autumn. October to March sees the highest counts of migratory species on the Bellarine Peninsula.

Since 2000, mean annual counts of migratory species on the Bellarine Peninsula have remained relatively consistent (refer to Graph 42). In most years, the average count in any observation is around 50 birds, but typical variation ranges from 20 to 80 birds. The highest mean count for any year is clearly 2006, with a mean of approximately 125 birds counted for the average observation. As noted individually for the Red-necked Stint, Sharp-tailed Sandpiper and Curlew Sandpiper, 2006 appears to be an exceptional year for migratory shorebirds on the Bellarine Peninsula.

Mean counts of migratory species on the Bellarine Peninsula in the last ten or so years (post-2010) are close to the same as average counts historically (pre-2010) (refer to Graph 43). This suggests that the numbers of migratory species that visit the Bellarine Peninsula today are similar to the numbers that visited historically. It is acknowledged that there may be slight variation in the species composition from year to year.

Rogers *et al.*, (2010) studied shorebird movements and habitat use at numerous locations across the *Port Phillip Bay (western shoreline) and Bellarine Peninsula* Ramsar site (which includes areas beyond the Bellarine Peninsula – see section 3.3.4). On the Bellarine Peninsula, the Ramsar areas assessed are the Lake Connewarre area and the Swan Bay area.

Areas of high-value shorebird habitat on the Bellarine Peninsula are identified in Rogers *et al.*, (2010) - the two most important shorebird areas are the Lake Connewarre area and the Swan Bay/Mud Island area. Both of these areas, as for the other important shorebird areas within the broader Ramsar site, are characterized by having tidal flats (for foraging) and inland wetlands (for high-tide roosting and for foraging).

Shorebirds that used the Lake Connewarre area used different areas to forage, but shared roost sites (mainly at the Lake Connewarre delta) (Rogers *et al.*, 2010). Shorebirds preferred to roost close to their foraging grounds, but would commute up to 10 km if necessary (Rogers *et al.*, 2010).

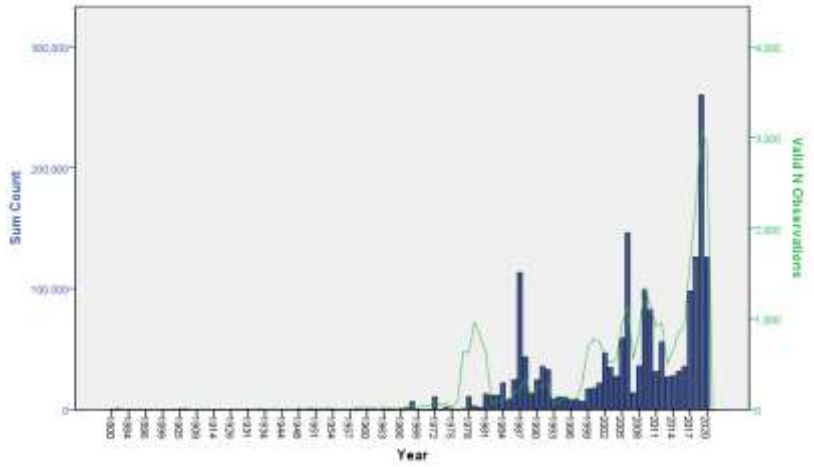
In the Swan Bay area, two areas stood out as particularly important foraging habitat: 1) tidal flats in Swan Bay west of Swan Island, especially those most distant from shore; and 2) tidal flats in the central north of Swan Bay, west of Edwards Point Conservation Reserve (Rogers *et al.*, 2010). Roost sites for shorebirds were identified along the western and southern shorelines of Swan Bay and on Sand Island and Swan Island, Mud Islands, and on the southern tip of Edwards Point.

The Swan Bay and Mud Islands area is notable in Victoria as supporting substantial populations of Bar-tailed Godwit, Red Knot and Grey Plover (Rogers *et al.*, 2010). These birds forage in Swan Bay, then return to Mud Islands to roost.

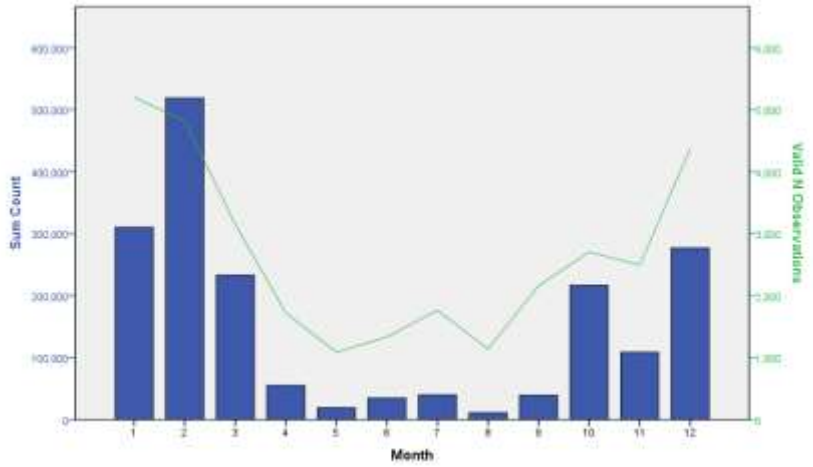
Shorebirds were found to be more site-faithful than thought previously; individuals at one site were much more likely to be found again at that site than at other nearby sites (Rogers *et al.*, 2010).

According to observations by Rogers *et al.*, (2010), at low tide, shorebirds in the area would be expected to be in their foraging grounds, day or night. At high tide, shorebirds would be expected to be in their preferred roost sites.

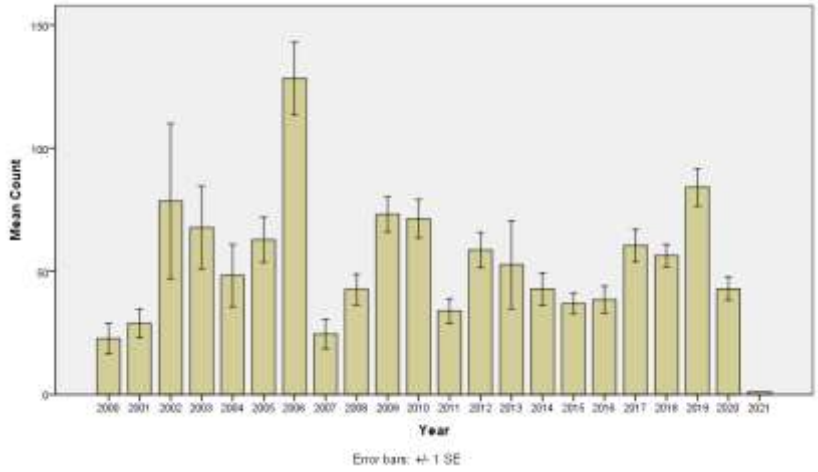
Figure 19 and Figure 20 display the historical records for migratory species within the search area (10 km buffer of the treatment sites) and proposed action area. Species included in these maps are the 16 migratory species identified for the proposed action area and included in this report as threatened or migratory species, namely: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Stint, Common Greenshank, Double-banded Plover, Bar-tailed Godwit, Black-tailed Godwit, Greater Sand Plover, Great Knot, Grey Plover, Lesser Sand Plover, Red Knot, Ruddy Turnstone, Terek Sandpiper, Latham's Snipe.



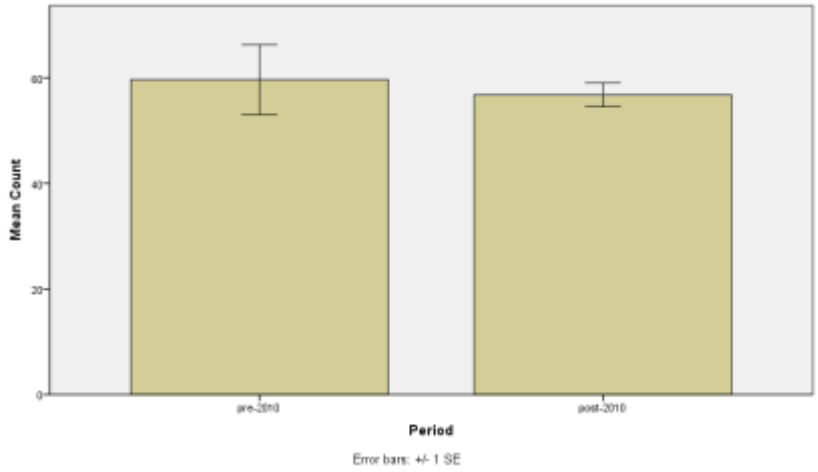
Graph 40 ***Summed counts and numbers of observations per year (all years) – all Migratory species***



Graph 41 ***Summed counts and numbers of observations per month (all years) – all Migratory species***



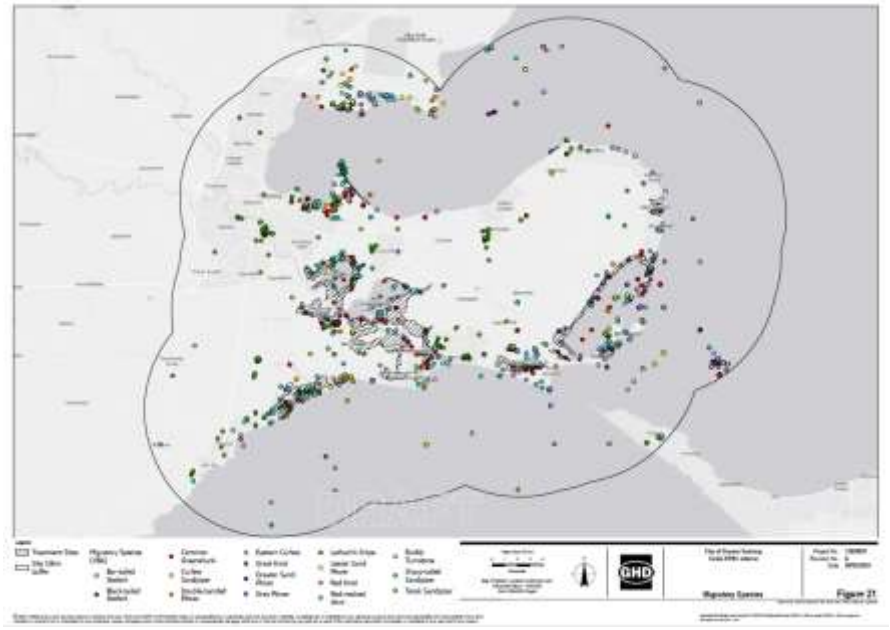
Graph 42 ***Mean counts (and Standard Error) per year since 2000 – all Migratory species***



Graph 43 ***Mean counts (and Standard Error) before and after 2010 – all Migratory species***

Figure 19 Historical records for migratory shorebird species – all records combined; 10 km search area

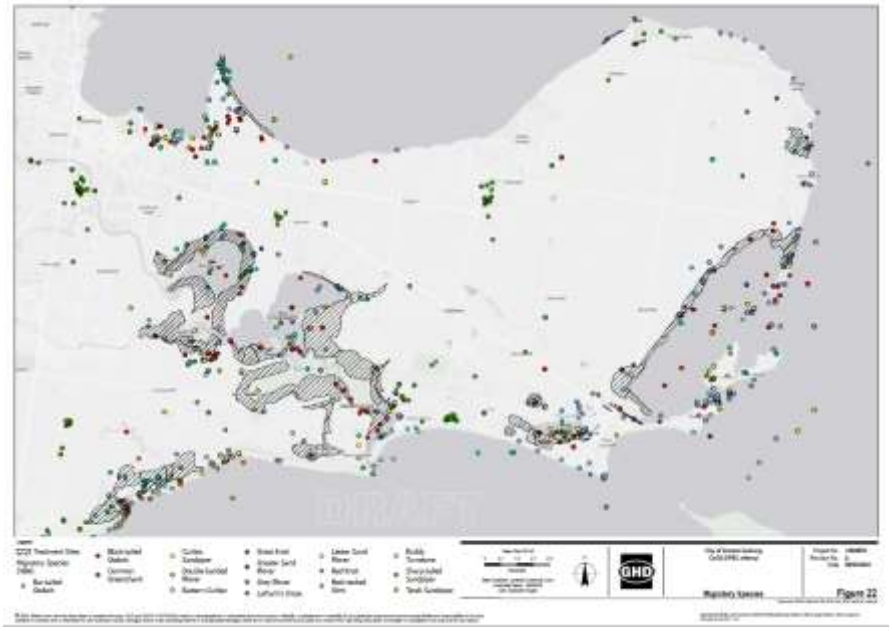
Species included: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Stint, Common Greenshank, Double-banded Plover, Bar-tailed Godwit, Black-tailed Godwit, Greater Sand Plover, Great Knot, Grey Plover, Lesser Sand Plover, Red Knot, Ruddy Turnstone, Terek Sandpiper, Latham's Snipe.



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Figure 20 Historical records for migratory shorebird species – all records combined; proposed action area

Species included: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Stint, Common Greenshank, Double-banded Plover, Bar-tailed Godwit, Black-tailed Godwit, Greater Sand Plover, Great Knot, Grey Plover, Lesser Sand Plover, Red Knot, Ruddy Turnstone, Terek Sandpiper, Latham's Snipe.



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3.3.3.3.2 Eastern Curlew (*Numenius madagascariensis*)

The Eastern Curlew is discussed in section 3.3.3.2.5.

3.3.3.3.3 Curlew Sandpiper (*Calidris ferruginea*)

The Curlew Sandpiper is discussed in section 3.3.3.2.6.

3.3.3.3.4 Sharp-tailed Sandpiper (*Calidris acuminata*)

The Sharp-tailed Sandpiper is discussed in section 3.3.3.2.8.

3.3.3.3.5 Red-necked Stint (*Calidris ruficollis*)

The Red-necked Stint breeds in Siberia and sporadically in north and west Alaska (Higgins & Davies 1996). In its non-breeding season, it migrates in small flocks along the East Asian-Australasian Flyway (EAAF) to southern-hemisphere locations, including Australia.

Prior to 1993, the Australian population of Red-necked Stints was estimated at 353,000 birds (Watkins 1993), which is approximately 75% of the world population estimate at the time (471,000 birds) (Rose & Scott 1997). A decline in the abundance of this species was reported in Australia during the early 1990s, and attributed to poor breeding success (Watkins 1993). The world population may have declined to as low as 315,000 birds (Delany & Scott 2002). Fluctuations in population numbers are typical of migratory birds - populations tend to be lowest prior to the breeding period and greatest just after breeding. More recent counts of this species indicate an increasing population due to successful breeding (Rogers & Gosbell 2006). By 2008, Bamford et al. (2008) estimated that ~260,000 visit Australia during the non-breeding season, which represented over 80% of the global population.

During its non-breeding period, the Red-necked Stint occurs along most of the Australian coastline, with sometimes large aggregations on the Victorian and Tasmanian coasts. It has been recorded in all coastal regions, and found inland in all states when conditions are suitable. The species is mostly found in sheltered inlets, bays, lagoons and estuaries with intertidal mudflats, often near spits, islets and banks and, sometimes, on protected sandy or coralline shores. Occasionally it is recorded on exposed or ocean beaches, and sometimes on stony or rocky shores, reefs or shoals. It also occurs in saltworks and sewage farms, saltmarsh, ephemeral or permanent shallow wetlands near the coast or inland, including lagoons, lakes, swamps, riverbanks, waterholes, bore drains, dams, soaks and pools in salt flats. The species sometimes uses flooded paddocks or damp grasslands, and has even been recorded on dry gibber plains, with little or no perennial vegetation (Higgins & Davies 1996).

The Red-necked Stint roosts on sheltered beaches, spits, banks or islets, of sand, mud, coral or shingle, sometimes in saltmarsh or other vegetation. It occasionally roosts on exposed reefs or shoals (Higgins & Davies 1996). Large numbers sometimes roost on ocean beaches, though it is probably not a preferred habitat and use of this habitat may increase when large numbers of birds are present (C.D.T. Minton 2002, pers. comm.). This species was once recorded roosting ~1.5 km from an inland lake, in close-cropped grass. They also roost among beachcast seaweed or clods of mud or dried cow-pats (Hobbs 1961). During very high tides, they may use sand dunes or claypans. Large numbers (an estimated 7967 birds) were recorded roosting at an inland claypan near Roebuck Bay in north-west Western Australia (Collins et al. 2001).

Foraging habitat includes bare wet mud on intertidal mudflats or sandflats or in very shallow water, mostly in areas with a film of surface water and mostly close to edge of water. During high tides, foraging may occur in non-tidal wetlands. Red-necked Stints may also forage in samphire, generally avoiding beds of seagrass. On Lake Reeve, Victoria, Red-necked Stints have been reported to feed occasionally on algal mats. In Westernport Bay, Victoria, they have been observed foraging on beaches without mangroves. Elsewhere, they have been recorded foraging in flooded paddocks and in a freshly cropped lucerne paddock near lagoons (Higgins & Davies 1996).

The species is omnivorous. It jabs and probes with its bill into the soft substrate for small invertebrates. It also gleans from plants in saltmarsh and water, and sometimes eats grit (Higgins & Davies 1996). It forages on plant seeds (such as from *Ruppia* spp. and *Polygonum* spp.) and on a range of marine worms, molluscs, snails and slugs, shrimps, spiders, beetles, flies and ants. It sometimes feeds in dense flocks that spread out as the tide recedes. The Red-necked Stint often feeds with other shorebird species, especially Sharp-tailed Sandpipers (*Calidris acuminata*) and Curlew Sandpipers (*Calidris ferruginea*) (Higgins & Davies 1996).

All of the recognised ‘important migration sites’ for this species during its non-breeding period are located in Australia. In Victoria, sites of international importance and maximum or average counts (Watkins 1993) include: Corner and Shallow Inlets (20 338), Werribee-Avalon (13 417), Altona (9536), Swan Bay - Mud Islands (7207), Westernport Bay (5783), Gippsland Lakes (5397) and Anderson Inlet (5000).

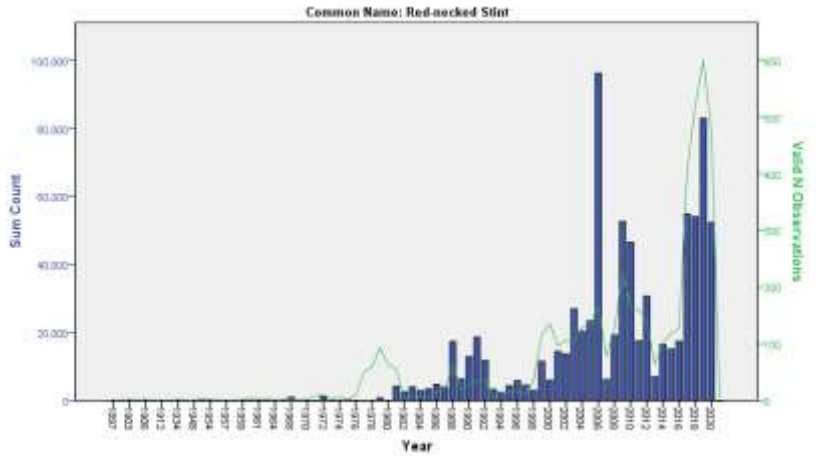
The history of observations of the Red-necked Stint on the Bellarine Peninsula is presented in Graph 44 to Graph 47. These graphs are based on ALA data rather than VBA data, because the ALA data include more observations and observations from more recent years (VBA observations stop in 2015, ALA includes observations up to 2021).

As for Sharp-tailed Sandpipers (section 3.3.3.2.8), observations of the Red-necked Stint on the Bellarine Peninsula appear to have increased with time (refer to Graph 44). There are few records until 1980, then there is a period of relatively small counts reported until the late 1990s. After that, summed counts increase notably, to a peak summed count of approximately 100,000 birds in 2006. As for Sharp-tailed Sandpipers, counts of Red-necked Stint in recent years (2017 – 2020) represent some of the highest summed counts historically.

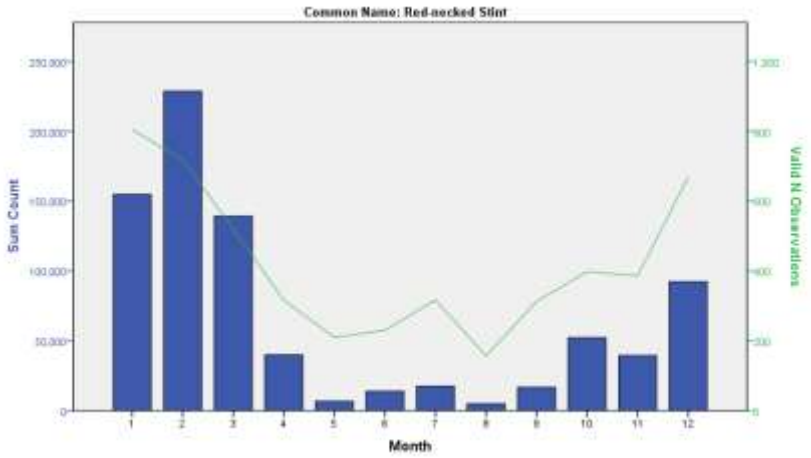
Observations and counts of Red-necked Stint on the Bellarine Peninsula show a strongly seasonal pattern (refer to Graph 45. While there are reports of this species in every month, there is a clear increase in numbers as the birds arrive from September onwards, then a decrease in numbers as most birds (weak, young or old birds may over-winter in Australia rather than migrate that year) depart by April-May. January to March sees the highest counts of this species.

Since 2000, mean annual counts of Red-necked Stints on the Bellarine Peninsula have remained relatively consistent (refer to Graph 46). In most years, the average count is of 100 birds or more, and the highest mean count for any year by far is for 2006, with a mean of nearly 600 birds counted for the average observation. 2006 appears to be an exceptional year for migratory shorebirds on the Bellarine Peninsula. The large numbers of stint in 2006 is also seen for the other two most common migratory shorebirds in this part of Australia: the Curlew Sandpiper (section 3.3.3.2.6) and the Sharp-tailed Sandpiper (section 3.3.3.2.8). For the Sharp-tailed Sandpiper, the peak in numbers spans 2005 and 2006, which is explained by the seasonal peak of that species occurring in December-January. That is, while peak numbers of Red-necked Stints and Curlew Sandpipers centre on January or February of any given year, the peak for Sharp-tailed Sandpiper begins in the December of the preceding year.

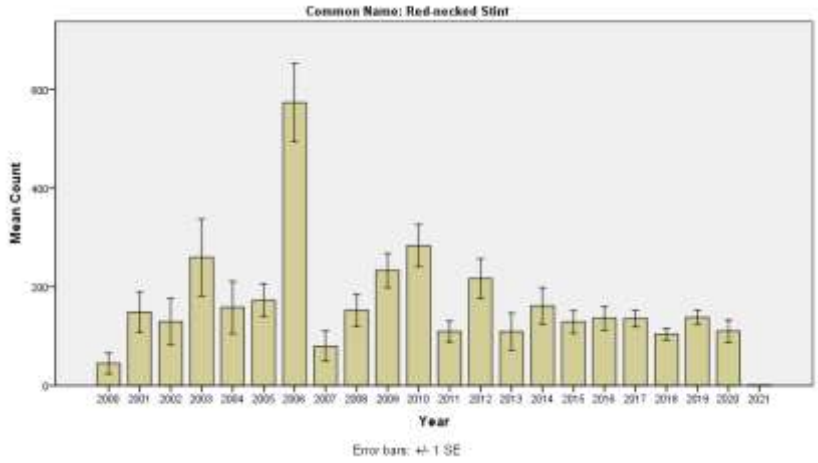
Mean counts of Red-necked Stint on the Bellarine Peninsula in the last ten or so years (post-2010) are smaller than average counts historically (pre-2010) (refer to Graph 47). This suggests that fewer Red-necked Stints visit the Bellarine Peninsula today than historically, but it remains easily the most common of the migratory shorebirds.



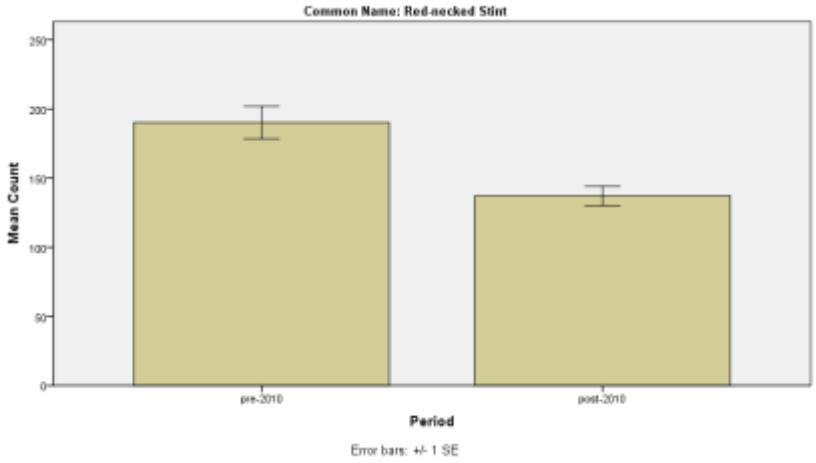
Graph 44 ***Summed counts and numbers of observations per year (all years) – Red-necked Stint***



Graph 45 ***Summed counts and numbers of observations per month (all years) – Red-necked Stint***



Graph 46 ***Mean counts (and Standard Error) per year since 2000 – Red-necked Stint***



Graph 47 ***Mean counts (and Standard Error) before and after 2010 – Red-necked Stint***

3.3.4 EPBC Act listed Ramsar sites

3.3.4.1 Location of the site and area with regard to the proposed action

The *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site is located on the western shoreline of Port Phillip Bay between Melbourne and Geelong and on the Bellarine Peninsula and Mud Islands. The Ramsar site covers 22,650 hectares and comprises six distinct areas: Point Cook/Cheetham, Werribee/Avalon, Point Wilson / Limeburners Bay, Swan Bay, Mud Islands, and the Lake Connewarre complex, as shown in Figure 21. The site includes freshwater wetlands, estuaries, intertidal shorelines, sub-tidal beds, inland saline wetlands and a wastewater treatment facility. Extensive areas of coastal saltmarsh and seagrass occur within the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site.

The sections relevant to the proposed action are Swan Bay and the Lake Connewarre complex.

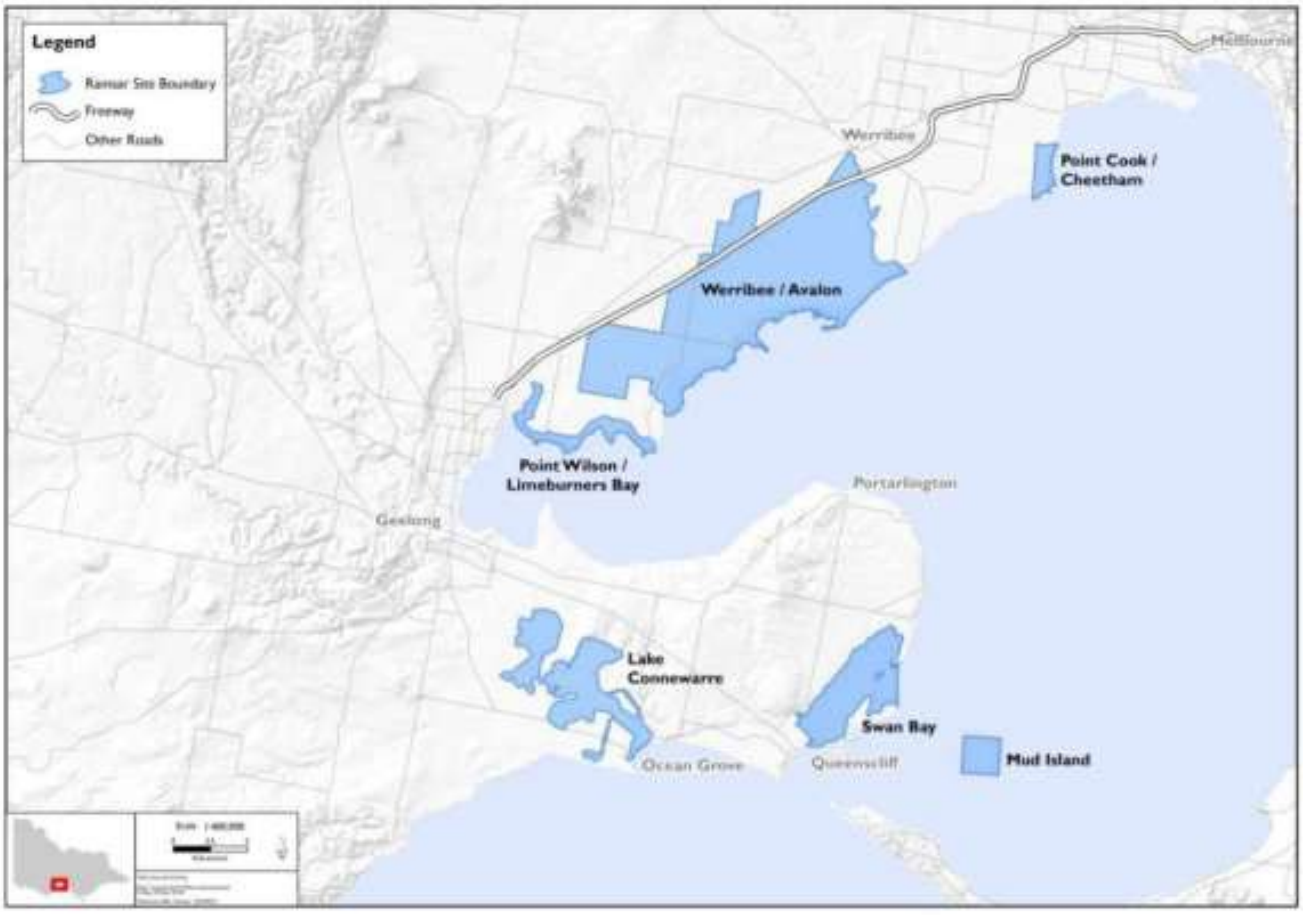


Figure 21 Map of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site (Hale, 2020)

3.3.4.2 Listing criteria and ecological character of the Ramsar site

The Ecological Character Description (ECD) of the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar Site is currently in preparation. To be listed as a wetland of international importance under the Ramsar Convention, a site must meet at least one of the nine listing criteria. At the most recent assessment by Hale in 2020, the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar Site met six of those criteria (See Table 32 – note that some of the species have changed threat categories since DELWP (2018) was prepared). The impact of the proposed action against the criteria listed in the ECD is presented in section 4.

Table 32 Criteria met by the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (Hale, 2020)

Criteria	Justification
2. Supports vulnerable endangered, or critically endangered species or threatened ecological communities	The site regularly supports one wetland dependent ecological community and 13 fauna species listed under the EPBC Act and or IUCN Red List. – Coastal saltmarsh – vulnerable ecological community (EPBC Act) – Australasian bittern (*Botaurus poiciloptilus*) – endangered (EPBC Act and IUCN) – Australian fairy tern (*Sternula nereis nereis*) – vulnerable (EPBC Act) – Bar-tailed godwit (*Limosa lapponica baueri*) – vulnerable (EPBC Act) and near threatened (IUCN) – Curlew sandpiper (*Calidris ferruginea*) – critically endangered (EPBC Act) and near threatened (IUCN) – Eastern curlew (*Numenius madagascariensis*) – critically endangered (EPBC Act) and endangered (IUCN) – Great knot (*Calidris tenuirostris*) – critically endangered (EPBC Act) and endangered (IUCN) – Greater sand plover (*Charadrius leschenaultia*) – vulnerable (EPBC) – Hooded plover (*Thinornis rubricollis rubricollis*) – vulnerable (EPBC Act) – Lesser sand plover (*Charadrius mongolus*) – vulnerable (EPBC Act) – Red knot (*Calidris canutus*) – endangered (EPBC Act) and near threatened (IUCN) – Orange-bellied parrot (*Neophema chrysogaster*) – critically endangered (EPBC Act and IUCN) – Australian grayling (*Prototroctes maraena*) – vulnerable (EPBC Act) and near threatened (IUCN) – Growling grass frog (*Litoria raniformis*) – vulnerable (EPBC Act) and endangered (IUCN)
3. The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site represents the most species rich Ramsar site in the South East Coast (Victoria) Drainage Division with respect to waterbirds when compared to other large marine and costal wetland systems in the bioregion.	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site supports a high diversity of waterbirds, most likely related to the diversity of habitats provided by the site (permanent shallow marine waters, marine subtidal aquatic beds, rocky marine shores, sandy shores, intertidal forested wetlands, intertidal mud, sand or salt flats, intertidal marshes, estuarine waters, seasonal and permanent saline wetlands, permanent and intermittent freshwater marshes and pools, wastewater treatment areas and former saltworks). A total of 130 species of waterbird have been recorded within the site (excluding 24 species that are outside their range or could be considered vagrant). The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site represents the most species rich Ramsar site in the South East Coast (Victoria) Drainage Division with respect to waterbirds when compared to other large marine and costal wetland systems in the bioregion.
4. Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions	Port Phillip Bay (Western Shoreline) and Bellarine Peninsula supports large numbers of migratory waterbirds, breeding of waterbirds and frogs, nursery grounds for fish, supports waterfowl during moulting of their primary flight feathers, and drought refuge for waterfowl and other native species.
5. Regularly supports 20,000 or more waterbirds	Waterbird counts across the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site are very high (mostly due to the large numbers of birds supported by the Western Treatment Plant). Counts of shorebirds have been consistently > 20,000 from 1981 to 2019 (data from BirdLife Australia) and counts of waterfowl are generally > 80,000.

Criteria	Justification
6: Regularly supports 1% of the individuals in a population of one species or subspecies of waterbird	Data provided by BirdLife Australia and from the DELWP Annual Summer Waterfowl Counts, indicate that 15 species meet this criterion: – Australasian shoveler (*Anas rhynchotis*) – Australian fairy tern (*Sternula nereis nereis*) – Australian shelduck (*Tadorna tadornoides*) – Blue-billed duck (*Oxyura australis*) – Chestnut teal (*Anas castanea*) – Curlew sandpiper (*Calidris ferruginea*) – Double-banded plover (*Charadrius bicinctus*) – Hoary-headed grebe (*Poliocephalus poliocephalus*) – Musk duck (*Biziura lobata*) – Pink-eared duck (*Malacorhynchus membranaceus*) – Red-necked stint (*Calidris ruficollis*) – Red-necked avocet (*Recurvirostra novaehollandiae*) – Sharp-tailed sandpiper (*Calidris acuminata*) – Silver gull (*Chroicocephalus novaehollandiae*) – Straw-necked ibis (*Threskiornis spinicollis*)
8: An important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.	Seagrass beds and other habitats within the Ramsar site are known to provide important feeding and nursery habitats for several fish species, including several that are recreationally important. The Barwon River Estuary provides an important migratory route for native fish to travel between fresh and marine waters such as short-finned eels, common galaxias (*Galaxias maculatus*), broad-finned galaxias (*Galaxias brevipinnis*), Australian grayling and pouched lamprey (*Geotria australis*).

3.3.4.3 Summary of the critical components, processes and services that the Ramsar site provides

The Ramsar site has 12 components, processes and services (CPS) that are considered critical to the ecological character of the site. These are briefly described in Table 33 as outlined in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Management Plan (DELWP, 2018) and the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Ecological Character Description (Hale, 2020). Some values have been elaborated upon in table 33 for further context.

Table 33 Values of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (DELWP 2018; Hale, 2020)

Component/process/service	Description
Geomorphology	Connectivity between freshwater and estuarine areas and estuaries and the marine environment are an important process for the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. In particular, this is important in the Lake Connewarre complex where the Ramsar site connects the upper Barwon River catchment with the Barwon River estuary and Bass Strait. This connectivity is important for ecosystem functioning and to a number of migratory fish. The proposed action does not involve removal or modification of any vegetation or fauna habitat; significant impact on this CPS is unlikely.
Hydrology	There are four sub-components that comprise the hydrology of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site; tides, river flows, groundwater and artificial water regimes. The hydrology of the Point Wilson/Limeburners Bay area would comprise of tides and river flows as it is a coastal/marine area, with Hovells Creek also forming part of this area of the Ramsar site. Two critical aspects of hydrology were identified in the latest Ecological Character Description (Hale, 2020): – Interaction between freshwater inflows and tidal exchange in the Lake Connewarre Complex. – Artificial water regimes that maintain the highly productive lagoons of Cheetham Wetlands and the Western Treatment Plant. The proposed action does not involve removal or modification of any vegetation or fauna habitat and the products have low level persistence in water. Significant impact on this CPS is unlikely.
Saltmarsh	Each of the six areas that form the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site contain coastal saltmarsh, with a total area of 1225 hectares within the Ramsar site boundary (Boon et al., 2011 in DELWP, 2018). Saltmarsh occupies the area of the site between seagrass and terrestrial vegetation at higher elevation. Coastal saltmarsh is listed as a vulnerable Version 7: March 2020 33 ecological community under the EPBC Act and is important habitat for fish, when inundated as well as for feeding and roosting waterbirds, when tides are low. The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used is detailed in section 4.2.2.1. Significant impact on this CPS is unlikely.

Component/process/service	Description
Seagrass	Seagrass is an important component of the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site at three areas: Point Wilson/Limeburners Bay; Swan Bay and Mud Islands. There are three species of seagrass in Port Phillip Bay which are a feature within the Ramsar site (Jenkins and Keogh, 2015 in DELWP, 2018): - *Zostera nigricaulis* – occurs only in subtidal areas where exposure to the air is limited. *Zostera muelleri* – generally occurs in the intertidal zone, requiring periods of exposure to maintain health and growth. A third species, Halophila ovalis occurs generally in deeper water and there may be patches around Point Wilson, but there are few deep-water areas within the Ramsar boundary. The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used is detailed in section 4.2.2.1. Significant impact to this CPS is unlikely.
Mangroves	The mangrove areas of Port Phillip Bay comprise a single species, Avicennia marina, and there are small areas of mangrove in Limeburners Bay (4 hectares). The inundated roots and pneumatophores of mangroves provide good habitat for fish and invertebrates and play a role in stabilising the soft sediments in the site. The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used is detailed in section 4.2.2.1. Significant impact to this CPS is unlikely.
Freshwater vegetation	Freshwater vegetation in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is limited largely to areas other than Point Wilson/Limeburners Bay, such as Reedy Lake in the Lake Connewarre Complex. Reedy Lake supports approximately 50 species of freshwater aquatic and semi-aquatic native vascular plants (Yugovic, J. Z., 1985). The Lake Connewarre complex contains both lignum (*Duma florulenta*) shrubland and understories of Australian salt-grass (*Distichlis distichophylla*). The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used is detailed in section 4.2.2.1. Significant impact to this CPS is unlikely.
Fish diversity, abundance and native fish	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site provides a variety of habitats for fish ranging from freshwater species as well as estuarine and marine species in seagrass and saltmarsh habitats. Over 60 species of marine and estuarine fish have been recorded in saltmarsh and seagrass habitats of the Ramsar site. The seagrass areas are home to a large number of pipefish (which are listed as marine under the EPBC Act) the most common of which is the spotted pipefish (*Stigmatopora argus*). Other species include bridled leather jacket (*Acanthaluteres spilomelanurus*), the spot-shoulder weed fish (*Heteroclinus perspicillatus*) and the cobbler (*Gymnapistes marmoratus*). A total of 12 native species of fish have been recorded within the reaches of the Lake Connewarre complex, with the vulnerable Australian grayling (*Prototroctes maraena*) recorded in Reedy Lake and the freshwater reaches of the Barwon River (Hale, 2020; Dahlhaus et al., 2007). The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used in relation to invertebrates is detailed in section 4.2.2.1.1 and 4.2.2.1.2. Table 45 details the risk of exposure for key MNES with relation to product. Significant impact to this CPS is unlikely.
Waterbird diversity and abundance	More than 120 waterbird species have been recorded within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, and the site regularly supports 20 species of waders from the East Asian-Australasian Flyway listed under the international migratory bird agreements JAMBA, CAMBA and ROKAMBA. The Ramsar site supports very large numbers of shorebirds across all six areas. In addition to shorebirds, the site provides habitat for a variety of waterbird groups or guilds including ducks and swans; grebes; large wading birds such as herons, ibis and spoonbills; gulls and fish-eating birds such as cormorants, pelicans and terns. An annual maximum abundance of around 180,000 birds were recorded. The proposed action does not involve removal or modification of any vegetation or fauna habitat; impact of the products proposed to be used in relation to vertebrates is detailed in section 4.2.2.1.1 and 4.2.2.1.2. Table 45 details the risk of exposure for key MNES with relation to product. The collision/disturbance risk impacts to waterbirds is detailed in section 4.2.1.4. Significant impact to this CPS is unlikely.
Waterbird breeding	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is important for waterbird breeding for a wide variety of species. The most significant waterbird breeding location in the site is Mud Islands. Disturbance impact of the drone on waterbird breeding is discussed in section 4.2.1.2.3.1. Significant impact to this CPS is unlikely.

Component/process/service	Description
Threatened species	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site regularly supports threatened species, including 10 species of bird, one frog and one fish species: – Bar-tailed Godwit (*Limosa lapponica bauera*) – Curlew Sandpiper (*Calidris ferruginea*) – Eastern Curlew (*Numenius madagascariensis*) – Great Knot (*Calidris tenuirostris*) – Greater sand plover (*Charadrius leschenaultia*) – Lesser Sand Plover (*Charadrius mongolus*) – Red Knot (*Calidris canutus*) – Australian Fairy Tern (*Sternula nereis nereis*) – Australasian Bittern (*Botaurus poiciloptilus*) – Hooded Plover (*Thinornis rubricollis*) – Orange-bellied Parrot (*Neophema chrysogaster*) – Growling Grass Frog (*Litoria raniformis*) – Australian Grayling (*Prototroctes maraena*). Table 45 details the risk to threatened species, with only 4 species having a medium risk due to indirect exposure to products. Significant impact to this CPS is unlikely.
Intertidal reefs	Rocky reefs comprise a small area within the Ramsar site, around Point Cooke and the Point Wilson / Limeburner's Bay section of the Ramsar site. Within the Ramsar site boundary, they are largely intertidal and typically colonised by mat forming brown algae.
Social and cultural values	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site includes parts of the Port Phillip Heads Marine National Park and the Point Cooke Marine Sanctuary. The Ramsar site is important to at least two indigenous language groups, Mud Islands is part of Country of the Boonwurrung and the remainder of the site is part of Country of the Wathaurong. The site contains the Western Treatment Plant which treats a significant proportion of Melbourne's wastewater and produces recycled water. The site is located close to the large cities of Melbourne and Geelong and is popular for recreation, education, tourism, and scientific research. The proposed action does not involve removal or modification of any vegetation or fauna habitat. Significant impact to this CPS is unlikely.
Provides physical habitat for waterbirds	The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site provides habitats supporting the moulting, foraging and roosting of waterbirds. The Western Treatment Plant supports tens of thousands of waterfowl with permanent lagoons; these permanent lagoons also support the foraging of waterfowl, potentially through the discharge of treated wastewater from the site. The proposed action does not involve removal or modification of any vegetation or fauna habitat. Significant impact to this CPS is unlikely.
Provides nursery habitat for fish	The saltmarshes and seagrass communities within Swan Bay provide nursery habitats for juvenile fish species such as the King George whiting, blue rock whiting, leatherjackets, pipefish tallow-eye mullet and greenback flounder (Jenkins et al. 1997; Crindall and Hindell, 2004). Seagrass populations are emphasised as important to the continuation of the sites ability to support juvenile fish, which are themselves influenced by factors such as water clarity, tidal regime and epiphytic growth (Jenkins and Mckinnon, 2006). The proposed action does not involve removal or modification of any vegetation or fauna habitat. Significant impact to this CPS is unlikely.
Ecological connectivity	The migration of waterbirds and native fish is a critical character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. The site provides pathways for migratory fish and interconnected habitats. The proposed action does not involve removal or modification of any vegetation or fauna habitat. Significant impact to this CPS is unlikely.

3.3.4.4 Existing threats to the matters that may be impacted by the proposed action

In the development of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Ecological Character Description, a risk assessment was completed with the input of scientific experts and local knowledge. Priority threats were identified for each location within the Ramsar site. Table 34 contains list of threats and priority threats that were identified for portions of the Ramsar Site which are within the vicinity of the proposed action (Swan Bay and Lake Connewarre).

Table 34 Priority threats at each location in the Ramsar site (those shaded are identified as the highest priority) (Hale, 2020)

Threats	Swan Bay	Lake Connewarre
Climate change: sea level rise impacting on intertidal vegetation and waterbird habitat	X	X
Climate Change: increased intensity of storms resulting in erosion of shoreline habitats	X	
Toxicants from catchment inflows and stormwater	X	X
Stormwater results in decreased salinity and altered water regimes		X
Urban development: direct habitat removal and loss of buffer	X	X
Invasive species: foxes and cats predating on waterbirds	X	X
Invasive species: salt tolerant weeds impacting saltmarsh and waterbird habitat	X	X
Invasive species: non-native grazing animals (rabbits and deer) impacting vegetation and habitat		X
Recreation: boats, jets skis, kite surfers disturbing waterbird feeding, breeding and roosting	X	X
Recreation: walkers, horse-riding disturbing waterbird feeding, breeding and roosting	X	X
Recreation: vehicles damaging saltmarsh		X
Duck hunting impacts to non-target species		X

The major difference between the 2018 ECD and 2020 ECD for priority threats to the two locations considered within the proposed action is the inclusion of vehicles damaging salt marshes as a high priority; as the proposed action does not involve vehicles accessing saltmarshes, significant impact from this threat to the Ramsar site is negligible.

A Disease Risk Assessment workshop hosted by the University of Melbourne in March 2020 to identify priority disease risks to birds using the *Port Phillip Bay (western shoreline) and Bellarine Peninsula* Ramsar site concluded that the risk of pollutants and contaminants was one of the top three health risks to birds using these sites, and rated as a high risk with high confidence in the risk estimation. The Disease Risk Assessment included heavy metals, insecticides, herbicides and other pesticides, algal toxins, oil spills, medication residues, plastic and rubbish in this risk category (Rachel Pritchard, DELWP, pers. comm. November 2021). No additional information on this workshop could be found online.

3.3.5 Invasive or threatening species and processes

Invasive species are considered a key threat to the values of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. Foxes and cats preying on waterbirds, salt tolerant weeds impacting saltmarsh and waterbird habitat, non-native grazing animals (rabbits and deer) impacting vegetation and habitat are all listed as key threats to the Swan Bay and Lake Connewarre portion of the Ramsar site.

An assessment of the vegetation condition at the Ramsar site undertaken in 2010 (Sinclair 2010) revealed that much of the vegetation assessed within the Ramsar site is degraded, by a range of factors including weed invasion and losses of native species diversity.

The weed and animal pest species known to be present at the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site were described in the Strategic Management Plan for the site in 2003 and have been included below in Table 35 and Table 36. Pest weed species known to be present more broadly within the vicinity of the proposed action have been identified using the Bellarine Peninsula local Landcare group website (Bellarine Landcare Group, 2018) and are provided in Table 37.

A search of the Victorian Biodiversity Atlas (VBA) was undertaken on 31 January 2024 to identify the introduced aquatic and terrestrial fauna species within the vicinity of the proposed action area. Search results were retrieved dating back to 01 January 2013. Of the invasive and/or threatening species known to occur within the vicinity of the proposed action, introduced mosquitofish (*Gambusia holbrooki*) are discussed in further detail (section 3.3.5.1).

Details of the impact due to invasive or threatening species are discussed in sections 4.2.3.4 and 4.2.3.5 respectively.

Table 35 Pest weed species in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (DSE 2003)

Common name	Scientific name
African Box-thorn	*Lycium ferocissimum*
African Thistle	*Berkheya rigida*
Aleppo Pine	*Pinus halepensis*
Apple of Sodom	*Solanum linnaeanum*
Bathurst Burr	*Xanthium spinosum*
Blackberry	*Rubus spp.*
Boneseed	*Chrysanthemoides monilifera*
Bridal Creeper	*Myrsiphyllum asparagoides*
Buffalo Grass	*Stenotaphrum secundatum*
Chilean Needle-grass	*Nassella neesiana*
Great Mullein	*Verbascum thapsus*
Horehound	*Marrubium vulgare*
Hoary Cress	*Cardaria draba*
Kikuyu	*Pennisefum clandesinum*
Myrtle-leaf Milkwort	*Polygala myrtifolia*
Paterson's Curse	*Echium plantagineum*
Prickly Pear	*Opuntia spp.*
Sand Rocket	*Diplotaxis tenuifolia*
Serrated Tussock	*Nassella trichotoma*
Sharp Rush	*Juncus acutus*
Spanish Artichoke	*Cynara cardunculus Datura spp.*
Sticky Ground-cherry	*Physalis viscosa*

Table 36 Pest fauna species in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (DSE 2003)

Common name	Scientific name
Red Fox	*Vulpes vulpes*
Dog	*Canis familiaris familiaris*
Rabbit	*Oryctolagus cuniculus*
Feral Cat	*Felis catus*
European Carp	*Cyprinus carpio*

Table 37 Pest Plants on the Bellarine Peninsula (Source – Bellarine Peninsula Landcare Group, 2009)

Weed Status	Common Name	Botanical Name	Abundance
Regionally Prohibited Weeds	Cape Tulip	*Maraea spp.*	Occasional
	Serrated Tussock(WONS)	*Nassella trichotoma*	Occasional
	St. John's Wort	*Hypericum perforatum*	Occasional
	Wild Garlic	*Allium vineale*	Occasional
Regionally ControlledWeeds	African Boxthorn	*Lycium ferocissimum*	Scattered
	Angled Onion	*Allium triquetrum*	Scattered
	Blackberry (WoNS)	*Rubus fruticosus*	Few
	Boneseed (WoNS)	*Chrysanthemoidesmonilifera*	Occasional
	Caltrop	*Tribulus terrestris*	# Few
	Fennel	*Foeniculum vulgare*	Scattered
	Flax-leaf Broom	*Genista linifolia*	Common
	Great Mullein	*Verbascum Thapsus*	# Occasional
	Gorse/ Furze	*Ulex europaeus*	Common
	Horehound	*Marrubium vulgare*	Few
	Onion Weed	*Aspodelus fistulosus*	Occasional
	Paterson's Curse	*Echium plantagineum*	Scattered
	Soursob	*Oxalis pres-caprae*	Common
	Spiny Rush	*Juncus acutus*	# Occasional
	Sweet Briar	*Rosa rubiginosa*	Few
	Wild Watsonia	*Watsonia meriana var. bulbillifera*	Scattered
Restricted Weeds	Bridal Creeper (WoNS)	*Asparagus asparagoides*	# Common
	Chilean Needle-grass(WoNS)	*Nasella neesiana*	Occasional
Emerging Weeds	Texas Needle-grass	*Nasella leucotricha*	Occasional
Environmental Weeds	African Thistle	*Berkheya rigida*	Scattered
	Arum Lily	*Zantedeschia aethiopiea*	Few
	Agapanthus	*Agapanthus praecox*	# Scattered
	Apple of Sodom	*Solanum Sodom*	Few
	Artichoke Thistle	*Cynara cardunculus*	Occasional
	Bellarine Pea / Myrtle-leaf Milkwort	*Polygala myrtifolia*	# Common
	Blue Periwinkle	*Vinca major*	# Occasional
	Bracelet Honey-myrtle	*Melaleuca armillaris*	Scattered
	Buffalo Grass	*Stenotapaphrum secundatum*	Common
	Cape Ivy	*Delairea odorata*	# Occasional
	Cape Wattle	*Paraserianthes lophantha*	Occasional
	Climbing Groundsel	*Senecio angulatus*	# Occasional
	*Coast Tea-tree	*Leptospermum laevigatum*	Scattered
	Cotoneaster	*Cotoneaster sp.*	# Scattered
	Cretan Trefoil	*Lotus creticus*	# Few
	Dolichos Pea	*Dipogon lignosus*	# Scattered
	English Ivy	*Hedera helix*	# Occasional
	Galenia /Carpet Weed/Blanket Weed	*Galenia pubescens*	Common

Weed Status	Common Name	Botanical Name	Abundance
	Gazania	*Gazania linearis*	# Occasional
Environmental Weeds	Golden Wreath Wattle	*Acacia saligna*	# Scattered
	Italian Buckthorn	*Rhamnus alaternus*	Common
	Kikuyu	*Pennisetum clandestinum*	Common
	Mirror Bush	*Coprosma repens*	# Scattered
	Montbretia	*Crocosmia x crocosmiiflora*	Few
	Monterey Pine	*Pinus radiata*	Scattered
	Olive	*Olea europaea ssp europaea*	# Occasional
	Onion Grass	*Romulea rosea var. australis*	# Occasional
	Pampas Grass	*Cortaderia selloana*	#Occasional
	Perennial Veldgrass	*Ehrharta calycina*	Scattered
	Phalaris	*Phalaris aquatic*	Common
	Sallow Wattle	*Acacia longifolia var. longifolia*	# Scattered
	Sea Spurge	*Euphorbia paralias*	# Scattered
	Sweet Pittosporum	*Pittosporum undulatum*	# Scattered
	Tall Wheat Grass	*Thinopyrum ponticum*	Occasional

Key to Table	
Item	**Description**
#	denotes weeds that are primarily coastal weeds on the Bellarine Peninsula.
*	denotes indigenous in the coastal fringe but a weed beyond this range
Weeds of National Significance (WoNS)	Weeds identified at a National level as threats to Australia's productive capacity and natural ecosystems.
Regionally Prohibited Weed	Declared noxious weed, not widely distributed in the Corangamite Region, but capable of spreading further. Landowners and land managers must eradicate or control these weeds on their land.
Regionally Controlled Weed	Declared noxious weed, widespread and considered important in the Corangamite Region. Landowners are responsible for taking all reasonable steps to control and prevent spread and growth.
Restricted	Trade in these declared noxious weeds and materials containing them is prohibited in Victoria.
Environmental Weeds	Plants that invade natural areas.
Common	Common throughout wide areas of the Bellarine Peninsula
Scattered	Scattered infestations in limited areas of the Bellarine Peninsula
Occasional	Occasional small infestations in limited areas of the Bellarine Peninsula few individuals

Table 38 VBA results for introduced fauna within the study area over the last 10 years

Taxon ID	Scientific Name	Common Name	Count of Sightings	Last Record
4711	*Carassius auratus*	Goldfish	7	23/01/2023
4713	*Cyprinus carpio*	European Carp	318	06/06/2023
4714	*Cyprinus carpio var. mirror*	Mirror Carp	1	03/11/2021
4718	*Rutilus rutilus*	Roach	4	23/01/2023
4771	*Gambusia holbrooki*	Eastern Gambusia	63	23/01/2023
4888	*Perca fluviatilis*	Redfin	5	06/06/2023
10957	*Columba livia*	Domestic Pigeon	32	27/05/2018
10989	*Spilopelia chinensis*	Spotted Dove	277	30/11/2019
10991	*Turdus merula*	Common Blackbird	376	31/12/2016

Taxon ID	Scientific Name	Common Name	Count of Sightings	Last Record
10993	*Alauda arvensis*	Eurasian Skylark	1244	4/08/2021
10995	*Passer domesticus*	House Sparrow	2745	19/11/2019
10997	*Chloris chloris*	European Greenfinch	353	29/11/2016
10998	*Acridotheres tristis*	Common Myna	263	29/09/2020
10999	*Sturnus vulgaris*	Common Starling	266	29/09/2020
11408	*Rattus rattus*	Black Rat	86	08/07/2021
11409	*Rattus norvegicus*	Brown Rat	1	31/01/2016
11511	*Lepus europaeus*	European Brown Hare	30	28/12/2019
11523	*Dama dama*	Fallow Deer	6	18/01/2020
528552	*Vulpes vulpes*	Red Fox	12	24/6/2018
528559	*Carduelis carduelis*	European Goldfinch	1841	22/6/2021

3.3.5.1 *Gambusia holbrooki*

Gambusia holbrooki, commonly known as eastern gambusia, gambusia or mosquitofish, has been recorded in the Lake Connewarre Complex. Of the six species of exotic fish recorded in the Ramsar site, the most concern are the common carp, goldfish and *G. holbrooki* (Dahlhaus and Reeves 2013).

G. holbrooki are highly invasive and capable of tolerating a wide range of environmental conditions. The broad salinity tolerance of mosquitofish allows them to colonise environments such as salt lakes, estuaries, near coastal marine environments (Lloyd, 1987). The salinity LD50 for mosquitofish is more than 58g/L and they can tolerate direct transfers to salinity differences of up to seawater (35 g/L) with few mortalities (Chervinski, 1983).

G. holbrooki and mosquito management

G. holbrooki has been introduced into many wetlands worldwide to control mosquito larvae. The fish was introduced to Australia from North America in 1925 as an exercise in biological control and is now widespread and common in many waterways in south-eastern Australia (Hamer et al. 2002).

In 2003, the NSW National Parks and Wildlife Service published the *G. holbrooki* Threat-Abatement Plan, including an extensive review of the contemporary literature, which indicates that the views on the effectiveness of gambusia as a mosquito control agent vary (NSW National Parks and Wildlife Service 2003). Lake (1971), for instance, stated "I believe their effect on mosquitoes has been negligible". Grant (1978) noted that it was arguable whether gambusia offers better mosquito control than some native fish. Studies in Australia indicate that gambusia is not an effective mosquito predator, with mosquitoes only making up a small part of its diet (Lloyd 1984; Lloyd 1986). In another study in the lower Murray River, only 10% of the diet of gambusia consisted of mosquito larvae, whereas four endemic fish species consumed more mosquitoes (Lloyd 1986; Arthington and Lloyd 1989). Reddy and Pandian (1972) found heavy mortalities of gambusia reared on a diet restricted to mosquito larvae, and the few survivors showed poor growth and delayed maturation (NSW National Parks and Wildlife Service (2003).

Several authors have observed that gambusia may actually encourage mosquito populations by preying on their invertebrate predators (Stephanides 1964; Hoy et al. 1972; Hurlbert et al. 1972; Hurlbert and Mulla 1981). Gambusia are inappropriate for mosquito control in certain habitats such as temporary ponds, waters with dense vegetation and running waters. It is also unlikely to be effective as a predator on cool cloudy days, where drops in temperature and oxygen occur (Lloyd 1986). Where good mosquito larvae control has been reported, the evidence was largely anecdotal or derived from poorly designed experiments (Courtenay and Meffe 1989; Rupp 1996; NSW National Parks and Wildlife Service 2003).

Interactions with other species

Predators of *G. holbrooki* in Australia probably include birds, fish and even spiders (Lloyd 1984). Many of the major predators of gambusia in the USA listed in Swanson et al. (1996) are also possible predators in Australia. Lloyd et al. (1986) noted important fish predators to include species of *Anguilla*, *Mogurnda*, *Gobiomorphus*, *Leiopotherapon* and *Glossamia*, although their impacts on gambusia are not known. Lloyd (1987) noted that water rats *Hydromys chrysogaster* and the fish -eating bat *Myotis adversus* (*macropus*) also apparently fed on gambusia. There have been very few studies of predators of *G. holbrooki* in Australia, but there have been suggestions as to the likely cause of low predation levels (Lloyd 1984). Both native and exotic fish predators avoid *G. holbrooki* as prey when given a choice (Lloyd 1984; Lloyd1990). Reports suggest *G. holbrooki* are considered unpalatable and that native predators may not have evolved behaviours appropriate to the capture of *G. holbrooki* (Lloyd 1984). In inland lakes of NSW, little black cormorants (*Phalacrocorax sulcirostris*) feed mainly on exotic fishes such as carp and *G. holbrooki* (Boulton and Brock 1999). Lloyd (1984) noted that, when exposed to predators, *G. holbrooki* can rapidly develop complex escape and avoidance behaviours (NSW National Parks and Wildlife Service 2003).

The species is an aggressive competitor that potentially out-competes native fish species. *G. holbrooki* is known to attack fish of any size by aggressive fin-nipping, thereby leaving them susceptible to disease (Arthington, 1991). *G. holbrooki* can rapidly increase in population size due to its rapid maturation to breeding age (four weeks in summer) and high survival rate of young (Milton and Arthington, 1983; Lloyd et al., 1986; Lloyd, 1990 cited in Arthington and Loyd 2021).

G. holbrooki have broad feeding habits, and together with a high fecundity, extended breeding season, and tolerance of water conditions, populations of *G. holbrooki* can rapidly expand, outcompeting other species for limited food supplies. This competition is likely to impact juvenile and small bodied fish, such a Southern Pygmy Perch, Yarra Pygmy Perch, various Galaxias spp., Australian Smelt, Flat-headed Gudgeon and Australian Grayling.

Gambusia also preys on frog eggs and tadpoles and appears to differentially affect frog species (Morgan and Buttemer 1996; Pyke and White 1996 and 2000; Komak and Crossland 2000; Pyke 2005 cited in Ecology Australia 2016).

3.4 Summary of MNES values and hydrology for each treatment site

The purpose of this section is to summarise the MNES values known from or likely to occur within each of the 52 (9 ground-based and 43 aerial) treatment sites using the information from sections 3.2 – 3.3. Table 39 and Table 40 include:

– Site number, name and area
– Location regarding Ramsar site
– Brief habitat description
– MNES values including known (e.g. historical records) or potential (e.g. species or habitat) values
– Hydrology – connectivity with other sites other waterways/waterbodies
– Typical treatment area – description of the specific areas within each site that will be treated based on historical treatment patterns

An assessment of the hydrology for each site was undertaken to understand the movement of water between sites and other waterways/waterbodies within the proposed action area. This assessment was undertaken by GHD ecologists using aerial photography and terrain/topographical maps to identify obvious surface water linkages. Additional assessment was undertaken by the City of Greater Geelong Waterway Engineer to validate these findings and comment on the hydrological connectivity of sites via pipes and drains (i.e. stormwater connectivity).

Table 41 displays photographs from January 2022 and March 2024 for some of the ground and aerial sites.

Aerial sites

– Of the 43 aerial sites, 42 are known for or have potential habitat for MNES
– Of the 42 sites, 41 are considered to be of sufficient size, habitat quality, connectivity with adjoining habitats and historical data to support ongoing and regular use by MNES
– The remaining two sites are unlikely to provide a substantial portion of or important habitat for MNES for this project

Ground-based sites

– All 9 ground-based sites are known for or have potential habitat for MNES
– Of the 9 sites, six are considered to be of sufficient size, habitat quality, connectivity with adjoining habitats and historical data to support ongoing and regular use by MNES
– The remaining three sites are unlikely to providse a substantial portion of or important habitat for MNES

Table 39 Summary of habitat type, MNES values and hydrology and typical treatment area for aerial treatment sites

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
2.17	SOUTHERN LAKE VICTORIA	77 #	Yes	Southern portion of Lake Victoria and part of the Lonsdale Lakes Wildlife Reserve adjacent the Lonsdale Links Golf Course. Includes former gravel/stone extraction area. Lake Victoria is a shallow sub-coastal lagoon and forms part of the **Swan Bay** wetland system of shallow marine areas and lagoons considered important **wetland** for **waterbirds** and **waders**. Mapped as EVC 74 - Wetland formation, EVC 858 - Coastal alkaline scrub and EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	Known habitat for threatened and migratory birds including: Hooded Plover, Orange-bellied Parrot, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint.	Freshwater – largely rainfall dependent connected to Swan Bay via artificial channel and series of culverts through the Point Lonsdale Development (artificial pondages/lagoons), then Lakers Cutting. Water level in Lake Victoria is more sensitive to sustained rainfall rather than short intense events. One-way valves at inlet and outlet to 'The Point' waterway to control tidal flushing and ensure one way circulation.	Confined to the periphery of Lake Victoria.
2.4	COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK	13.2	Yes	Part of the larger Lonsdale Lakes Wildlife Reserve, located west of Lake Victoria. A large shallow open ephemeral wetland surrounded by low saltmarsh and alkaline scrub habitat. Mapped as EVC 74 - Wetland formation and EVC 858 - Coastal Alkaline Scrub	No documented MNES. Part of a larger area of habitat including Lake Victoria. Potential foraging/roosting/loafing habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint.	Freshwater – rainfall dependent. No obvious surface water or drain/pipe connection with other waterbodies/waterways.	Confined to the periphery and vegetation areas where mosquitoes breed.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
2.5	COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK	35.2	Yes	Part of the larger Lonsdale Lakes Wildlife Reserve, located west of Lake Victoria. Consists of three open ephemeral wetland/depressions surrounded by low saltmarsh and alkaline scrub habitat. Mapped as EVC 74 - Wetland formation and EVC 858 - Coastal Alkaline Scrub	No documented MNES. Part of a larger area of habitat including Lake Victoria. Potential foraging/roosting/loafing habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint.	Freshwater – largely rainfall dependent. Connected to Lake Victoria via artificial channel. Flow toward Lake Victoria.	Confined to three separate water body peripheries.
2.7	LONSDALE LAKES WILDLIFE RESERVE	30 #	Yes	Part of the larger Lonsdale Lakes Wildlife Reserve, located north of Lake Victoria. Consists of one large open ephemeral wetland surrounded by low saltmarsh and alkaline scrub habitat. Mapped as EVC 74 - Wetland formation and EVC 858 - Coastal Alkaline Scrub	Part of a larger area of habitat including Lake Victoria. Includes known habitat for Hooded Plover, Curlew Sandpiper, Common Greenshank, Freckled Duck, Blue-billed Duck, Caspian Tern, Blue-winged Parrot, and Whiskered Tern. Potential foraging/roosting/loafing habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Sharp-tailed Sandpiper, Double-banded Plover and Red-necked Stint.	Freshwater Lake forming part of the Southeast Bellarine Biolink / Moonahwarri Wetland system discharging to Lake Victoria and Swan Bay. The lake has a very large catchment of mixed farmland and residential areas of Ocean Grove. No clear outfall channel – overland flows, evaporation and infiltration to groundwater all occur. Overtopping of lake to south-west during high rainfall periods can result in prolonged flooding of farmland. Outflow from lake can feed farm dams.	Confined to the periphery of the lake, which changes due to evaporation.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER	3.3	Yes	Part of the Ocean Grove Golf Course. River marsh area consisting of a narrow strip of vegetation fronting Barwon River consisting of moderate to dense coverage of mangrove and saltmarsh. Large area part of the tidal wetlands and creek system part of the Barwon River estuary. Part of the same continuous habitat with 3.8, 3.10, 3.11, 3.12 and 8.18. Mapped as EVC 858 - Coastal alkaline scrub, EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	Within Ramsar site. No other documented MNES. Potential roosting/loafing habitat for wetland and migratory birds, particularly along river frontage /tidal mudflat areas.	Tidal – part of the Barwon River estuary. Ground-based site 3.7 (Ocean Grove Golf Course Creek) flows into 3.1.	Confined to periphery. Not treated typically due to proximity to township.
3.10	PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER	32.8 #	Yes	Large area part of the tidal wetlands and creek system part of the Barwon River estuary. Part of the same continuous habitat with 3.1, 3.8, 3.10, 3.11, 3.12 and 8.18. Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. The estuarine reach of the Barwon River is considered rare in Victoria for its permanent saline flats and its semi-permanent saline salt flats Mapped as EVC 858 - Coastal alkaline scrub, EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic, EVC 140 – Mangrove Shrubland	Within Ramsar site. No other documented MNES. Nearby records in similar habitat for MNES species. Potential foraging/roosting/loafing habitat for wetland and migratory birds. Potential habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. River known habitat for Australian Grayling.	Tidal – part of the Barwon River estuary, fed by a network of tidal flood runners/small channels by two large tributary creeks off Barwon River.	Confined to low-lying pondages either side of the natural water body.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
3.11	PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS	145.3 #	Yes	Large mixed use area consisting of part tidal wetlands and estuarine creek part of the Barwon River estuary, however the majority consists of cleared/modified land for agriculture (e.g. grazing stock). Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. Mapped as EVC 858 - Coastal alkaline scrub, EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	The periphery is within the Ramsar site, however majority of the site is not. No other documented MNES. Nearby records in similar habitat for MNES species. Potential foraging/roosting/loafing habitat for wetland and migratory birds. Potential habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. River known habitat for Australian Grayling	The periphery is largely tidal – part of the Barwon River estuary, fed by a network of tidal flood runners/small channels by two large tributary creeks off Barwon River. However the interior has a network of artificial channels presumably used for drainage	Confined to low-lying pondages.
3.12	PACEY'S HILL WALLINGTON SWAMP	10.9	Yes	Low lying ephemeral swamp divided by Wallington-Ocean Grove Road. Habitat dominated by moderate to dense coverage of low rushes/sedges with fringing scattered mature trees. Both sides of road within private property used for grazing with area on west side of road showing greater signs of disturbance. Mapped as EVC 175 – Grassy Woodland	Adjacent to Ramsar site. No other documented MNES. Potential foraging/refuge/ roosting habitat for wetland birds particularly when inundated. Unlikely to form a substantial or important component of habitat for any migratory shorebird species.	Freshwater – rainfall dependent, possibly receives some stormwater. Not tidal. Area east side of road connects with west side of road via culvert. Small artificial channel through portion of swamp west of road feeds into creek (site 3.8 part of Barwon River Estuary). No obvious surface water connection with other waterbodies/waterways.	Confined to the West side of Wallington road, where a natural depression forms.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	341.9 #	Yes	Large mixed use area with a diverse range of habitats and land uses including the eastern shoreline of Lake Connewarre, the area known as Lake Connewarre Swamp (between the shoreline and farmland) and farmland east of Lake Connewarre. The eastern shorelines and swamp include a diverse range of habitats whereas the farmland appears to be regularly cropped and grazed, although does provide lower quality habitat. Mapped as EVC 858 - Coastal Alkaline Scrub, EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	The eastern shoreline is and swamp are part of the Ramsar site. The majority of the site includes known habitat for a variety of wetland and migratory bird species including Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Lake Connewarre Swamp/eastern shoreline is known habitat for the Orange-bellied Parrot. The lake is known habitat for the Australian Grayling.	The shoreline and most of the swamp area is tidal but also partial influenced by rainfall. Lake Connewarre is a shallow estuarine lagoon. The water quality and plant communities of Lake Connewarre including the site are influenced by daily tidal changes with lake water coming from the sea via the Barwon River. Several constructed drains intersect the farmland draining into the swamp.	Confined to low-lying pondages that form due to tides.
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	25.5	Yes	Low lying ephemeral swamp/natural open drainage line before entering Lake Connewarre. Sparse to moderate coverage of rushes and sedges and also some aquatic vegetation when inundated. Scattered native trees/shrubs and planted trees fringe the waterway. Highly modified in some sections. Surrounded by mixed use land including residential and agriculture with stock access to some parts. Mapped as EVC 3 – Damp Sands Herb-rich Woodland and EVC 175 – Grassy Woodland	Adjacent to Ramsar site. No other documented MNES. Potential foraging/refuge/ roosting habitat for wetland birds. Unlikely to form a substantial or important component of habitat for any MNES species.	Freshwater – rainfall dependent, possibly receives some stormwater. Not tidal. Receives flow from site 3.9 during high rainfall events	Confined to small ponds near the streams and the stagnant pond that leads from site 3.9.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
3.8	OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK	23.1 #	Yes	Large area part of the tidal wetlands and creek system part of the Barwon River estuary. Large area part of the tidal wetlands and creek system part of the Barwon River estuary. Part of the same continuous habitat with 3.1, 3.8, 3.10, 3.11, 3.12 and 8.18. Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. The estuarine reach of the Barwon River is considered rare in Victoria for its permanent saline flats and its semi-permanent saline salt flats Mapped as EVC 858 - Coastal alkaline scrub, EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic, EVC 140 – Mangrove Shrubland	Within Ramsar site. No other documented MNES. Potential foraging/roosting/loafing habitat for wetland and migratory birds. Potential habitat for threatened and migratory birds including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. River, known habitat for Australian Grayling.	Tidal – part of the Barwon River estuary.	Treatment concentrated on the low-lying pondages that form due to tides.
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	14.6	No	Low lying ephemeral swamp/natural open drainage line between Wallington-Ocean Grove Road and Lake Connewarre. Sparse to moderate coverage of rushes and sedges and also some aquatic vegetation when inundated. Scattered native trees/shrubs and planted trees fringe the waterway. Highly modified in some sections. Surrounded by mixed use land including residential and agriculture with stock access to some parts Mapped as EVC 3 – Damp Sands Herb-rich Woodland and EVC 175 – Grassy Woodland	Adjacent to Ramsar site. No other documented MNES. Potential foraging/refuge/ roosting habitat for wetland birds. Unlikely to form a substantial or important component of habitat for any MNES species.	Freshwater – rainfall dependent, receives stormwater from residential areas. Probably flows during high rainfall into site 3.14 east of Lake Connewarre via several culverts. No other obvious surface water connection with other waterbodies/waterways.	Confined to vegetated areas either side of the gully.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
4.12	SALT LAGOON IBBOTSON ST WEST SIDE	84.6 #	Yes	A shallow and highly-saline lagoon located near the sea. It is surrounded by saltmarsh vegetation and has an associated salt meadow (EVC 02 – Coastal Saltmarsh/Mangrove Shrubland and EVC 858 Coastal Alkaline Scrub).	The lagoon is home to 41 different species of waterbirds, 16 of which have special conservation status or are listed as protected. The lagoon also provides potential habitat for Orange-bellied Parrots. Additionally, it is important for Common Greenshanks to spend the winter there after migrating from Europe and Asia (Conservation Volunteers n.d.).	– Shallow, saline lagoon acting as receiving waterbody for ~3km^2 catchment. There are two basins, with relict beaches, spits and islands occurring in both basins. There is no obvious former tideway to connect the lagoon to Port Phillip Bay, but there are two sites where such a connection seems likely. One is at the southeastern edge of the lagoon where there is a low sandy ridge only 40 meters wide separating the lagoon from the bay, and the other is a marshy area north of Dossetor Road (Agriculture Victoria 2018).	Confined to the periphery of the lagoon, particularly the southern and northern edges.
4.1	SWAN BAY NORTH, MARSH BEHIND HOUSES CLIFF ST - LOWER BLUFF	40.9 #	Yes	Part of the Edwards Point Wildlife Reserve including coastal shrubland/woodland, dune and saltmarsh wetlands. EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Ramsar Wetland Known for threatened and migratory species including: Orange-bellied Parrot, Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Double-banded Plover, Red-necked Stint, other migratory birds	Predominantly tidal, also receives stormwater runoff from surrounding residential area. No formal stormwater system in adjoining residential area – surface flows only, no concentrated outfall	Confined to the inlet coming from Cliff street. Water only treated at the very North periphery.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
4.6	SWAN BAY NORTH, PT EDWARDS RESERVE	47.8 #	Yes	Part of the Edwards Point Wildlife Reserve. A long sand spit between Swan Bay and Port Phillip Bay with a diverse range of habitat types including rare coastal woodlands and grasslands, foreshore, tidal mudflat, dune and saltmarsh with ephemeral wetlands/lagoons. The inland lagoons are not tidal and periodically dry out. Large areas of moderate to dense rushes and sedges fringe the lagoons and also glasswort scrublands. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Known habitat for the Orange-bellied Parrot. The site does not appear to support suitable habitat for the Growling Grass Frog, and lacks permanent sources of freshwater with a reasonable cover of aquatic/semi-aquatic plants.	Foreshore areas including the mudflats of Swan Bay area tidal. However majority of site including inland lagoons are freshwater – rainfall dependent.	Confined to low-lying pondages, aerial treatments avoid walking trails.
5.1	PORT ARLINGTON, PT RICHARDS MARSH SWAMP FORESHORE	2	No	Site occurs within the Portarlington (point Richards) flora and fauna reserve. The 62 ha reserve was originally allocated for the conservation of southern brown bandicoots and is one of the largest areas of native bushland and ephemeral wetlands on the Bellarine Peninsula. Site consists of ephemeral swampy wetlands with one large open water body which appears deep and two smaller shallow waterbodies surrounded by low lying vegetation located along the edge of a housing estate. Mapped as EVC 3 – Damp Sands Herb-rich Woodland.	Known habitat for Growling Grass Frog, and Southern Brown Bandicoot and multiple migratory, wetland and threatened bird species including Sharp-tailed Sandpiper and Latham's Snipe.	Rainfall and possibly ground water dependent ephemeral wetland. Multiple stormwater outfalls from residential areas. Discharges to Port Phillip Bay via drain through private land to west and site 5.2	Cannot access site on foot due to vegetation. Low-lying water to the West that dries out.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
5.3	PORT ARLINGTON, PITS AND PIPES SURVEILLANCE (BOAT RD)	0.8	No	A low lying ephemeral swampy marsh area with open water. Appears to be modified with small drain. Water appears to fluctuate in depth. Possibly used as a stormwater reservoir. Scattered planted native trees/introduced trees and shrubs fringe the waterbody. The narrow open drain from the waterbody to Point Richards Road consist of tall rushes and sedges all rushes/sedges.	No documented MNES. May provide some loafing. Roosting and foraging habitat for migratory and wetland bird species. Considered low quality habitat for MNES given location and habitat types. Unlikely to form a substantial or important component of habitat for any MNES	Freshwater - receives water from surrounding parkland/recreation reserve and rainfall. Small drain – not sure of hydrology into bay via culvert under road	Confined to the drain that flows into body of water.
7.1	SWAN BAY NORTH, KNIGHTS RD	31.0	Yes	Located on private and crown land south of Knights Road between Queenscliff Road and Swan Bay. Includes a small section of the Swan Bay foreshore, saltmarsh and mudflat habitats and several ephemeral depressions/wetlands. Part of the continuous foreshore habitat with 14.3, 14.4, 7.2, 7.3, 7.5. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic.	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Known habitat for the Orange-bellied Parrot. The site does not appear to support suitable habitat for the Growling Grass Frog, and lacks permanent sources of freshwater with a reasonable cover of aquatic/semi-aquatic plants.	Foreshore areas including the mudflats of Swan Bay are tidal. Some of the depressions closer to the foreshore appear to be linked via small tidal channels. Other parts of site including larger depressions/wetlands away from foreshore are freshwater – rainfall dependent.	Confined to low-lying pondages, aerial treatment never applied to open water body that connects to Marine National Park.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
7.2	SWAN BAY - NYE RD WETLANDS	25.9	Yes	A strip of the western foreshore and mudflat habitat of Swan Bay located on private and crown. The majority of the site is within the Swan Bay - Edwards Point Wildlife Reserve. Includes areas of saltmarsh and mudflats and small depressions/wetlands. Part of the continuous foreshore habitat with 14.3, 14.4, 7.1, 7.3, 7.5. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 Coastal Dune Scrub/Coastal Dune Grassland Mosaic.	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Known habitat for the Orange-bellied Parrot. The site does not appear to support suitable habitat for the Growling Grass Frog, and lacks permanent sources of freshwater with a reasonable cover of aquatic/semi-aquatic plants.	Foreshore areas including the mudflats of Swan Bay are tidal. Some of the depressions closer to the foreshore appear to be linked via small tidal channels. Other parts of site including ephemeral depressions/wetlands away from foreshore are freshwater – rainfall dependent.	Confined to tidal pockets that do not recede easily, along the periphery of Swan Bay.
7.3	SWAN BAY - IBBOTSON ST	30.1 #	Yes	Part of the Edwards Point Wildlife Reserve including coastal shrubland/woodland and ephemeral saltmarsh wetlands. Large areas of moderate to dense rushes and sedges within and fringing the coastal saltmarsh wetlands. Continuous habitat with sites 4.3, 4.5, 4.6, 7.3 and 7.4. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	Ramsar Wetland No other documented MNES. Known habitat for migratory bird species. Nearby records in continuous habitat for multiple threatened and wetland species. Foraging/refuge/ roosting habitat for wetland and migratory birds.	Foreshore areas including the mudflat areas of Swan Bay area tidal. However inland lagoons are freshwater – rainfall dependent. May receive tidal flow during king/peak high tides.	Confined to the periphery and pockets of water formed due to tides and rainfall.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	161.4	Yes	A long 5.7 km strip between 100 to 120 m wide of the western foreshore and mudflat habitat of Swan Bay located on private and crown land. The majority of the site is within the Swan Bay - Edwards Point Wildlife Reserve. Includes diverse array of habitats including extensive saltmarsh, mudflats and small ephemeral depressions/wetland habitats. Site includes the Swan Bay jetty. The northern portion of the site includes artificial channels/drains that appear to be connected to Swan Bay Part of the continuous foreshore habitat with 14.3, 14.4, 7.1, 7.2, 7.3. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Known habitat for the Orange-bellied Parrot. The site does not appear to support suitable habitat for the Growling Grass Frog, and lacks permanent sources of freshwater with a reasonable cover of aquatic/semi-aquatic plants.	Foreshore areas including the mudflats of Swan Bay are tidal. Some of the depressions closer to the foreshore appear to be linked via small tidal channels. Other parts of site including ephemeral depressions/wetlands away from foreshore are freshwater – rainfall dependent.	Confined to the low-lying pondages that form due to tides and the periphery of Swan Bay.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT	45.2	Yes	Site includes eastern portion of Lake Murtnaghurt and the inactive channel (paleochannel) extending from the lagoon northwards for c. 2.7 km through site 8.9. Former channel now ephemeral drainage consists of low lying open swampy depressions fringed with planted and mature remnant trees and shrubs, low lying swampy marsh areas, sedgeland, glasswort shrubland and tussock grassland. Constructed drains and surrounding cleared agricultural land. Mapped as EVC 858 – Coastal Alkaline Scrub and EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic (see site 8.4 for additional detail)	The channel is part of the Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Common Greenshank and Red-necked Stint. Known habitat for the Orange-bellied Parrot. Limited potential habitat (e.g. one stormwater fed freshwater pond) for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat.	Narrow 2.7 km paleochannel extending from the lagoon northwards to the main tidal channel of the lower Barwon River. It would appear to have support backflows from the Barwon River Estuary under high tidal influence or possibly from rainfall-induced flood events. However, the Lagoon is effectively isolated from the River by a levee c. 2.0 km to the north and by the Barwon Heads Road unless these barriers are flooded out (EA 2008)	Confined to low-lying pondages that form due to rainfall.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.13	LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)	22.7 #	Yes	Located in the southern section of Lake Connewarre a shallow estuarine lagoon – continuous habitat with sites 8.14, 10.7 3.13, 8.18 Habitat includes coastal saltmarsh, swampy areas with sedges and rushes. Possibly also areas of samphire shrubland and glasswort herbland, tussock grasslands. Appears to be separated by a levy with vehicle access from site 8.14. Surrounded by farmland on the west, and south. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 192 – Seasonally Inundated Sub-saline Herbland,	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Curlew Sandpiper and Double-banded Plover. Records nearby in same habitat for the Orange-bellied Parrot. Unlikely to support Growling Grass Frog habitat.	Part of a shallow estuarine lagoon. The water quality and plant communities of Lake Connewarre including site 8.13 are influenced by daily tidal changes with lake water coming from the sea via the Barwon River.	Confined to the depressions that formed due to previous use of land.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.14	LAKE CONNEWARRE, BACKWATERS	44.4 #	Yes	Located in the southern section of Lake Connewarre and includes an area known as the island and a large lagoon separated from the main waterbody by levies which appear to provide access to the island. Continuous habitat with sites 8.13, 10.7 3.13, 8.18. The ephemeral lagoon is surrounded by coastal saltmarsh, swampy areas with sedges and rushes. Possibly also areas of samphire shrubland and glasswort herbland, tussock grasslands. Farmland immediately abuts the lagoon to the south. A sparse layer of trees and shrubs cover the island. Where the island meets the foreshore of the lake habitat includes coastal saltmarsh and swampy areas Mapped as EVC 192 – Seasonally Inundated Sub-saline Herbland, EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 858 – Coastal Alkaline Scrub	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Curlew Sandpiper and Double-banded Plover. Records nearby in same habitat for the Orange-bellied Parrot. Unlikely to support Growling Grass Frog habitat.	The lagoon is ephemeral and may be rainfall dependent. However it may also receive some tidal flow via culverts under the levy banks via site 8.13. The foreshore areas of the island are part of a shallow estuarine lagoon. The water quality is influenced by daily tidal changes with lake water coming from the sea via the Barwon River.	Confined to the periphery of Lake Connewarre and the smaller water body.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.18	SALT SWAMP, BACK OF LAKE CONNEWARRE	452.5 #	Yes	Part of the greater Lake Connewarre complex including Salt Swamp – continuous habitat with sites 8.14, 8.13, 10.7 3.13 Salt Swamp located in the western portion of the site, is an extensive, coastal saltmarsh consisting of a diversity of habitats including glasswort herbland, Wilsonia herbland, samphire shrubland, tussock grasslands and sedgeland. Several large ephemeral shallow lagoons Experiences prolonged inundation after major flooding of the Barwon River. Surrounded by farmland on the west, south and east. The Barwon estuary is to its north. The eastern portion of the site is part of the Barwon River estuary floodplain – consisting of coastal saltmarsh and small sections of mangrove along the river and flood runners. Also large ephemeral shallow lagoons, tidal flood runners, swampy depressions. Mapped as EVC 192 – Seasonally Inundated Sub-saline Herbland, EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 858 – Coastal Alkaline Scrub	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Records on site and nearby in same habitat for the Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	The area known as Salt Swamp is largely freshwater dependent, relying on major flood events. The eastern section of the site is influenced by tidal inputs from the Barwon River. The middle portion of the site is possibly a combination of both given the distance and lack of obvious surface water connection to the river.	Confined to the periphery of Lake Connewarre and low-lying pondages.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.2	BARWON HEADS, REAR 90 CARR ST SALTMARSH AND DRAINS and OLD TURKEY FARM, MARSH AND PONDS, BARWON RIVER	40.7 #	Yes	Low lying ephemeral marshy areas/wetlands and natural drains as part of the Barwon River estuary. Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic with nearby EVC 140 – Mangrove Shrubland	Within Ramsar site. Includes records for Common Greenshank, Caspian Tern, Eastern Curlew, Fairy Tern, Curlew Sandpiper, Latham's Snipe. Numerous records for threatened and migratory birds nearby within same continuous habitat. Potential foraging/roosting/loafing habitat for wetland and migratory birds.	Partially tidal – part of the Barwon River estuary. Also influenced by rainfall.	Confined to the pondage that forms. Requires access through private property.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.4	REAR OF SCHOOL - LAKE MURTNAGHURT PERIPHERY	73.6	Yes	Lake Murtnaghurt, is a large shallow, ephemeral wetland (c. 81 ha). It comprises two enclosed depressions, elongated west-east and separated by a low ridge (sites 8.4 west and part of 8.1 east). The western portion forms part of the Lake Connewarre State Game Reserve, which is included in the Ramsar site. The eastern section is owned by the Barwon Heads Golf Course, however biodiversity values are spread across the lake. Supports a diverse range of high quality habitats including Coastal Saltmarsh Shrubland/Herbland, Estuarine Sedgeland/Grassland, Saline Aquatic Meadow and mudflats. Two freshwater ponds occur – one spring-fed pond in the western portion and one derived freshwater pond fed by stormwater runoff in the eastern portion. Lower lying ephemeral areas/depressions fill with sufficient rainfall. Surrounded by two golf courses to the east and west, farmland to the north and coastal sand dunes to the south. Mapped as EVC 858 – Coastal Alkaline Scrub and EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	Ramsar Wetland Known habitat for a variety of wetland and migratory bird species including Sharp-tailed Sandpiper, Curlew Sandpiper, Common Greenshank and Red-necked Stint. Known habitat for the Orange-bellied Parrot. Limited potential habitat (e.g. one spring fed freshwater pond) for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat.	The lagoon is largely freshwater dependent – fed by a natural spring, rainfall and stormwater from the surrounding golf course and residential areas. Formally connected by a narrow 2.7 km paleochannel extending from the lagoon northwards to the main tidal channel of the lower Barwon River. It would appear to have support backflows from the Barwon River Estuary under high tidal influence or possibly from rainfall-induced flood events. However, the Lagoon is effectively isolated from the river by a levee c. 2.0 km to the north and by the Barwon Heads Road unless these barriers are flooded out (EA 2008)	Confined to the small pondages that form due to rainfall. Larger waterbody is never treated due to proximity to golf course.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	20.9	Yes	Site consists of the Barwon Heads levy bank ponds and drains forming long artificial ephemeral wetlands, along the length of the levy bank. Shallow ponds fringed with scattered planted and mature remnant trees and shrubs, low lying swampy marsh areas, constructed drains and cleared agricultural land. Mapped as EVC 858 – Coastal Alkaline Scrub and EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	A small portion of the former channel connecting Barwon River to Lake Murtnaghurt is part of the Ramsar site. No other documented records for MNES. Potential habitat for some wetland and migratory bird species. Unlikely to form a substantial or important component of habitat for any MNES species.	Largely freshwater – rainfall dependent however may fill during major flood from Barwon River events to prevent flooding of Barwon Heads south of levy.	Confined to the point where the levy connects to the Barwon River north of Taits Rd due to tidal flooding.
8.9	BARWON HEADS, JIRRAHLINGA - PONDS AND WETLANDS	16.6 #	Yes	Part of a modified natural ephemeral drainage system connecting Barwon River to Lake Murtnaghurt. Located adjacent the Jirrahlinga Wildlife and Koala Sanctuary. Consists of low lying open swampy depressions fringed with planted and mature remnant trees and shrubs, low lying swampy marsh areas, constructed drains and cleared agricultural land. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 858 - Coastal alkaline scrub	Within Ramsar site. No other documented MNES. Potential foraging/roosting/loafing habitat for wetland and migratory birds, albeit limited to the vegetated and swampy areas.	Largely rainfall dependent. Partially influenced by receiving water from Barwon River upstream of Barwon Heads via small channels that are regulated by culverts and other infrastructure.	Confined to entry pits and water that lies in depressions.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	92 #	No	Part of the Breamlea Flora and Fauna Reserve/Breamlea Coastal Reserve – continuous with sites 9.2, 9.3, 9.4, 9.5, 15.8. The majority of the site consist of saltmarsh, sedgeland and large patches of dense reeds/rushes. Several ephemeral ponds are scattered through the site. Possible samphire shrubland and tussock grasslands The site is bounded by Breamlea Rd the coast, Black Rock Water Plant and farmland. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 132 – Plains Grassland and EVC 1 - Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint. Similar and same habitats within other parts of the reserve include known records for: Hooded Plover, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	Freshwater – rainfall dependent. May connect with site 9.2 via small culvert under Breamlea Road. No other obvious surface water connection to other waterbodies.	Confined to the low-lying pondages and peripheries of larger water bodies. No product applied to the open water.
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	23.9 #	No	Part of the Breamlea Flora and Fauna Reserve/Breamlea Coastal Reserve – continuous with sites 9.2, 9.3, 9.4, 9.5, 15.8. The majority of the site consist of low lying saltmarsh, sedgeland and small areas of dense reeds/rushes. Possible samphire shrubland and tussock grasslands The site is bounded by Breamlea Rd, Blackgate Rd and Thompsons Creek. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 – Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint, Hooded Plover, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	Probably influenced by both rainfall and tidal events. Probably inundated for periods as a result of flooding from upper catchment of Thompsons Creek. Parts may also receive inundation during peak tides. There are also several smaller channels/flood runners that receive flow during high tide. May connect with site 9.1 via small culvert under Breamlea Road.	Confined to the low-lying pondages and peripheries of larger water bodies. No product applied to the open water.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	15.2 #	No	Part of the Breamlea Flora and Fauna Reserve/Breamlea Coastal Reserve – continuous with sites 9.1, 9.2, 9.4, 9.5, 15.8. Large area with diverse range of habitats including saltmarsh and estuarine Thompsons Creek. The majority of the site consist of low lying saltmarsh and sedgeland. Samphire shrubland and tussock grasslands Bounded by Thompson Creek and Blackgate Road. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 – Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint, Hooded Plover, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	Receives tidal flows from Thompsons Creek and potentially stormwater from nearby Breamlea residences. May also become inundated for periods as a result of flooding from upper catchment of Thompsons Creek. Mouth of Thompsons Creek periodically closed due to longshore sediment transport. Results in sustained inundation of saltmarsh	Confined to the low-lying pondages and peripheries of larger water bodies. No product applied to the open water.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
9.5	BREAMLEA SALTMARSHES BLACKGATE RD	57.1 #	No	Part of the Breamlea Flora and Fauna Reserve/Breamlea Coastal Reserve – continuous with sites 9.1, 9.2, 9.3, 9.4, 15.8. Large area with diverse range of habitats including saltmarsh and estuarine Thompsons Creek. The majority of the site consist of low lying saltmarsh, sedgeland and small areas of dense reeds/rushes. Several small ephemeral ponds/depressions occur. Possible samphire shrubland and tussock grasslands Bounded by Thompson Creek and Blackgate Road. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic and EVC 1 – Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint, Hooded Plover, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	Probably influenced by both rainfall and tidal events. Probably inundated for periods as a result of flooding from upper catchment of Thompsons Creek. Parts may also receive inundation during peak tides.	Confined to the low-lying pondages and peripheries of larger water bodies. No product applied to the open water.
10.7	LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD	17.0	Yes	Narrow strip of the northern foreshore area of Lake Connewarre. This part of the foreshore includes saltmarsh, glasswort herb/shrubland, and sedgeland with small sections of mudflat on receding tide. Mapped as Mapped EVC 858 - Coastal Alkaline Scrub and EVC 175 – Grassy Woodland, however the latter EVC is incorrect.	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot.	Foreshore areas is part of a shallow estuarine lagoon. The water quality and plant communities of Lake Connewarre including site are influenced by daily tidal changes with lake water coming from the sea via the Barwon River.	Confined to the periphery of Lake Connewarre and away from local houses.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
10.8	REEDY LAKE PERIPHERY	817.5 #	Yes	Site includes Reedy Lake and Hospital Swamp. Reedy lake is a large shallow intermittent freshwater marsh dominated by Typha, Phragmites and sedges and several less abundant macrophytes. The wetland is fringed by low saline herbfields, with predominantly cleared rural–residential land at higher elevation (Billows 2007). Includes 16 ecological vegetation communities (EVCs), such as coastal saltmarsh, herbfields, sedgelands, open water (semi emergent/macrophyte communities) and reed beds (Loyd et al 2012) Hospital Swamp located in the south-western portion of the Reedy Lake system south of Barwon River. It is a reedy marsh dominated by Phragmites and areas of open water. Salinity is variable, from fresh to brackish depending on the control of freshwater inflows from the Barwon River and local hydrogeology. A narrow zone of saltmarsh fringes the wetland at higher elevation (Billows 2007).	Known habitat for a variety of wetland and migratory bird species including Common Greenshank, Curlew Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Reedy Lake is known habitat for the Growling Grass Frog and one of the few sites within the project area within current and historical records for the species.	Reedy Lake is connected to Lake Connewarre by the Barwon River. Water levels within the lake are artificially altered to replicate a more natural cycle (Parks Victoria, 2010). Hospital Swamp - Since the entitlement was established in 2011, the CCMA has continued to implement the historical wetting and drying regime.	Confined to the periphery of Reedy Lake and the depressions that have naturally formed.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	36.5 #	No	Part of Point Henry Foreshore Reserve. Connects with 11.6 (Former Alcoa wetlands) and part of the Point Henry Foreshore Reserve. The site is a long linear strip of coastal habitat surrounded by recreational and former industrial and agricultural land on the landward Contains many small ephemeral saline ponds – lagoons of various depths fringed by low saltmarsh vegetation. Also many ephemeral depressions/pans which are often dry and only hold water for a short period following rainfall. Large areas of low saltmarsh and low shrubs dominate areas between waterbodies. One large deep artificial lagoon part of water reclamation/treatment, however lacks fringing or emergent vegetation. Mapped as EVC 858 - Coastal alkaline scrub	Known habitat for migratory bird including Sharp-tailed Sandpiper, Red-necked Stint, Common Greenshank. Eastern Curlew, Curlew Sandpiper and Orange-bellied Parrot records nearby in similar habitats.	Most of the site is tidal, with non-tidal areas relying on rainfall. The ponds/lagoons north of Windmill Road are tidal fed, through a small network of tidal flood runners and most likely contain a depth of fluctuating saline water for most of the year. South of Windmill Road there is no obvious connection with the bay, however higher tides may push seawater into this area. There is also a large artificial drain that runs parallel to coast along west boundary of site south of Windmill Rd appears to drain site into bay. Shallow highly ephemeral depressions characterize the area between the drain and the reclamation lagoon.	Confined to the tidal pondages that form.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
11.6	PT HENRY, ALCOA WETLANDS - LAGOONS	9.7 #	Yes	Former Alcoa wetlands. Part of Point Henry Foreshore Reserve. Small ephemeral saltmarsh ponds of various depths fringed by thick reeds/rushes. Ponds bounded by walking tracks and scattered mature shrubs and occasional tree. Some ponds appear to have depth whereas others appear shallow/dry. One large deep artificial lagoon part of water reclamation/treatment. Some low lying open ephemeral saltmarsh depressions. Mapped as EVC 858 - Coastal alkaline scrub	Numerous records for threatened and migratory birds within site and nearby in similar habitat. Potential foraging/roosting/loafing habitat for wetland and migratory birds, including: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. Possible habitat for Orange-bellied Parrot.	North of Point Henry Pier is rainfall dependent and may receive water via seepage through dunes. South of the pier, the larger deep lagoon receives water from reclamation project. Small natural tidal channel provides flow to salt marsh areas. No obvious drains/pipes to Port Phillip Bay or other waterbodies.	Confined to the foreshore area, road beyond pier is closed behind gate.
11.8	GEELONG, DRAIN BEHIND ANIMAL HEALTH LAB	4.8 #	No	Private property (CSIRO) including open swampy saltmarsh area with two small ponds and other low lying depressions.	Numerous records for threatened and migratory birds within site and nearby in similar habitat. Foraging/roosting/loafing habitat for wetland and migratory birds, including: Common Greenshank and Red-necked Stint. Potential habitat for other migratory species and Orang-bellied Parrot	Most of site ephemeral, rainfall dependent – small pond may hold water all year round pending rainfall. Linear drain along eastern boundary of AAHL is stormwater outfall to Stingaree Bay for parts of East Geelong and Newcomb. Ephemeral wetland to north of AAHL is on CSIRO owned land. Not hydraulically connected to drain during low-normal flow conditions. Channel discharging to bay to the west of wetland.	Treatment confined to small pond and following any depressions holding water following heavy rainfall

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
14.1	PT LONSDALE, MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	7.2 #	Yes	Narrow but long strip of low lying coastal saltmarsh along the edge Lakers Cutting. Approximately half of the site is located between the Bellarine Rail line and the Bellarine Highway, opposite the Point Lonsdale. Habitat located between Lakers Cutting/Swan Bay and rail line of better quality. EVC 858 - Coastal alkaline scrub and EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	No documented MNES for site however, many records in close proximity and in similar habitat. Habitat between bay and rail line considered moderate quality. Other habitats low quality for MNES.	Predominantly freshwater – rainfall dependent, possibly stormwater Ephemeral - No obvious surface water connection with other waterbodies/waterways. The areas that occur along the shoreline of the bay ae tidal.	Confined to the water that runs along the depression either side of Murray Road.
14.3	SWAN BAY BURNT PT END OF FELLOWS RD	72.9	Yes	Large area at the south-west end of Swan Bay with diversity of habitats including coastal foreshore, saltmarsh and tidal mudflats. Tussock grassland/sedgeland fringe the rear lagoons/depressions on slightly higher ground than saltmarsh habitats. Large area of coastal saltmarsh with several large shallow lagoons/depressions. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic, and EVC 858 – Coastal Alkaline Scrub.	Known habitat for Orange-bellied Parrot and migratory bird including Red-necked Stint, Common Greenshank. Multiple nearby records for other migratory bird species including Sharp-tailed Sandpiper, Eastern Curlew, Curlew Sandpiper.	Receives water from Yarram Creek, forming part of a small estuary system. Influence by both tide and rainfall, predominately tidal with network of tidal flood runners feeding saline water into/out of lower lying saltmarsh ponds/channel.	Confined to the periphery and low-lying pondages that form due to tides. Vegetated areas sometimes treated if stagnant water present.
14.4	SWAN BAY BURNT PT END OF FELLOWS RD	30.8 #	Yes	A continuation of site 14.3. Predominantly low lying dense saltmarsh habitat located between coastal woodlands and some Mangrove habitat along the shoreline the bay. Several lower lying areas with small depressions. Tip Island contains a lagoon/depression surrounded by vegetation. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	No documented MNES however multiple nearby records for many migratory shorebird species. Potential habitat for Orange-bellied Parrot	Lower lying areas appear to be tidal fed by smaller tidal flood runners. Also influenced by rainfall and higher tides	Confined to the periphery of Swan Bay. No treatments occur on the side closest to houses.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Brief habitat description	MNES	Hydrology	Location of treatment within each site (Typical treatment area)
14.8	PT LONSDALE, CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY	2.7 #	Yes	Low lying narrow area consisting of ephemeral drain/ swamp with limited habitat/opportunities for MNES. Located south of Yarram Creek Lane along the Bellarine Rail line/Bellarine Rail Trail. EVC 858 - Coastal alkaline scrub	No documented MNES. Considered low quality habitat for MNES. Unlikely to form a substantial or important component of habitat for any MNES.	Freshwater – rainfall dependent, possibly stormwater Small artificial channel connects to low lying swampy area on west side of Fellow Road then into Lakers Cutting-Swan Bay via culvert with under Fellows Road. Possibly connected to 1.1 via culvert under Yarram Creek Lane.	Confined to depressions that have formed due to prior use.
15.8	BREAMLEA TIDAL WETLAND LAKES (4 LARGE)	176.1	No	Also known as the Karaaf Wetlands - coastal saltmarsh complex that adjoins the Thompson Creek estuary at the western end of the Breamlea Flora and Fauna Reserve at Breamlea Large area with diverse range of habitats including saltmarsh and estuarine. The site consist of low lying saltmarsh, glasswort herb/shrubland, sedgeland and small areas of dense reeds/rushes. Site contains many shallow ephemeral ponds/depressions. Possible samphire shrubland and tussock grasslands. Surrounded by coastal dunes to the south, Thompson Creek to the east, residential area/golf course and farmland to the west and farmland to the north. The site is intersected by Point Impossible Rd. Mapped as EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic, EVC 858 – Coastal Alkaline Scrub and EVC 1 – Coastal Dune Scrub/Coastal Dune Grassland Mosaic	Known habitat for a variety of wetland and migratory bird species including Common Greenshank and Red-necked Stint, Hooded Plover, Sharp-tailed Sandpiper, and Double-banded Plover and Orange-bellied Parrot. Limited potential habitat for the Growling Grass Frog. Species considered unlikely to occur given lack of records and limited potential habitat	The wetlands are drained by naturally formed tidal channels that feed into a larger tidal creek, known as Mullet Creek. The confluence of Mullet Creek and Thompson Creek occurs approximately 450 m from the mouth of the estuary (Billows 2006). On extremely low tides Mullet Creek is almost completely drained. An old ford is situated 440 m upstream of the culvert on Mullet Creek. Constructed drainage channels dissect through the northwest and central parts of the wetland (Billows 2006).	Confined to where water forms stagnant pockets of water due to tides and rainfall. Majority of site is owned by Surf Coast Shire.

Table 40 Summary of habitat type, MNES values and hydrology for ground based treatment sites

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Habitat description	MNES values	Hydrology	Location of treatment within each site (Typical treatment area)
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	2.93	No	Site is located between Lake Victoria and Point Lonsdale township. Consists of a large artificial stormwater lake and remnant vegetation including costal woodlands and saltmarsh surrounding a natural ephemeral lakes. Mapped EVC 858 - Coastal alkaline scrub and EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	No documented MNES however adjoins Lonsdale Lakes Wildlife Reserve/Lake Victoria with nearby Common Greenshank, Red-necked Stint and Sharp-tailed Sandpiper records. Considered potential foraging/roosting/loafing habitat for threatened and migratory bird species.	Predominantly freshwater – rainfall/stormwater dependent Most likely receives rainfall collected from site 1.7 via drainage network. Does not flow into Lake Victoria – ephemeral lakes downstream of stormwater lake appear to act as evaporation basins.	Confined to pondages that appear as location is not tidal. Emily's pond is the main area of concern.
1.7	PT LONSDALE, PITS & PIPES SURVEILLANCE	0.04 #	No	Site located within the township of Point Lonsdale west of Fellowship Road and consists of concrete drains, pits and pipes. Site does not provide suitable habitat for MNES.	No documented MNES. Considered low quality habitat for MNES. Highly unlikely to form a substantial or important component of habitat for any MNES.	Predominantly freshwater – rainfall/stormwater dependent No obvious surface water or drain/pipe connection with other waterbodies/waterways. Drainage pipes are isolated and directed to 1.4.	Confined to side entry pits along the streets. Incline to the North prevents water from leading into Swan Bay.
3.2	OCEAN GROVE NATURE RESERVE	1.52 #	No	The site consists of a small ephemeral artificial water body (known as the nature reserve lake) within the within the much larger habitat area of the Ocean Grove Nature Reserve. Mapped EVC 175 – Grassy woodland	Known overwintering habitat for the Swift Parrot. The lake may provide temporary refuge/foraging habitat for threatened waterbirds. Unlikely to provide suitable habitat for Growling Grass Frog.	Freshwater – rainfall dependent. No obvious surface water or drain/pipe connection with other waterbodies/waterways.	Confined to the artificial water body

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Habitat description	MNES values	Hydrology	Location of treatment within each site (Typical treatment area)
3.7	OCEAN GROVE GOLF COURSE CREEK	0.67	Yes	Narrow ephemeral creek lined with trees/shrubs and sparse aquatic/semi-aquatic vegetation Creek appears to contain small pools which may provide refuge when not flowing. Starts at Wallington Road, and passes through golf course intersecting several holes before entering Barwon River. EVC 858 - Coastal alkaline scrub and EVC 74 – Wetland formation	No documented MNES. Nearby records for Eastern Curlew on golf course. Potential habitat for wetland birds and temporary refuge for migratory bird species. Unlikely to form a substantial or important component of habitat for any MNES	Predominantly freshwater – rainfall/stormwater dependent, however the lower reach closer to Barwon River Estuary may also receive tidal flow.	Confined to the open drain at the road.
5.2	PORT ARLINGTON, RAMBLERS RD PORT MARSH	5.84	No	Site consist of a small portion of the foreshore/beach of Point Richards and low lying ephemeral swampy marsh within 100 m of the foreshore within private property along from Ramblers Road. Mapped as EVC 3 – Damp Sands Herb-rich Woodland, although likely to also include EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic	Known habitat for migratory bird species including Red-capped Plover. Likely to provide loafing, roosting and foraging habitat for multiple threatened and migratory birds species.	Tidal along foreshore area. Ephemeral wetland possibly influenced by several factors including rainfall and saltwater seepage through dunes. Drain linking foreshore wetland to Portarlington Flora & Fauna Reserve (5.1)	Confined to the drain leads from street and pockets that form due to weather.
8.11	BARWON HEADS, SHEEPWASH TIDAL WETLANDS, BARWON RIVER	3.23	Yes	This site consists of a narrow strip of river frontage reserve along the Barwon River Estuary between the Barwon River boat ramp/launch and river boardwalk parallel to River Parade in Barwon Heads. Includes walking tracks/elevated board walks and a small section of low lying ephemeral marshy area/wetlands adjacent the river. Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. Mapped as EVC 302 - Coastal Saltmarsh/Mangrove Shrubland Mosaic with nearby EVC 140 – Mangrove Shrubland	Within Ramsar site. No other documented MNES. Numerous records for threatened and migratory birds nearby within similar habitat. Potential foraging/roosting/loafing habitat for wetland and migratory birds, albeit limited to a small portion of the overall site located west near the elevated boardwalk including: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. River known habitat for Australian Grayling.	All low lying areas likely to support mosquito habitat are tidal – part of the Barwon River estuary.	Confined to the drains that flow from the residential streets.

Site no.	Site description	Site area (ha)	Within or adjacent to Ramsar site	Habitat description	MNES values	Hydrology	Location of treatment within each site (Typical treatment area)
8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD, BARWON RIVER	2.53	Yes	This site consists of a narrow strip of river frontage reserve along the Barwon River Estuary – adjoin site 8.11. Includes walking tracks and a small section of low lying ephemeral marshy area/wetlands adjacent the river. Species-rich saltmarsh and sub-saline marsh vegetation in the lower reaches of the Barwon estuary. Mapped as EVC 858 - Coastal Alkaline Scrub	Within Ramsar site. No other documented MNES. Numerous records for threatened and migratory birds nearby within similar habitat. Potential foraging/roosting/loafing habitat for wetland and migratory birds, albeit limited to a small portion of the overall site located west near the elevated boardwalk including: Eastern Curlew, Curlew Sandpiper, Sharp-tailed Sandpiper, Common Greenshank, Double-banded Plover and Red-necked Stint. River known habitat for Australian Grayling.	All low lying areas likely to support mosquito habitat are tidal – part of the Barwon River estuary.	Confined to the pondages that form from weather.
8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH (LAKE MURTNAGHURT)	4.55	Yes	Site partially located in grounds of the Barwon Heads Primary School, with a small portion including the eastern end of Lake Murtnaghurt. The vegetation within the school grounds and adjoining land consists of maintained open grassy areas with a small patch of tall shrubs with depressions that may retain water. The portion within the lake consists of a low lying swampy area. Mapped as EVC 858 – Coastal Alkaline Scrub and EVC 302 – Coastal Saltmarsh/Mangrove Shrubland Mosaic	Historical records for Southern Brown Bandicoot (c. 1960). No other documented MNES however nearby records within Lake Murtnaghurt for a variety of migratory and wetland bird species	Ephemeral - rainfall dependent. Stormwater outfall from Hopgood Place / Barnett Close. Flow to/from Murtnaghurt Lagoon and N-S channel (sites 8.1, 8.4, 8.9). Water levels / salinity influenced by groundwater	Confined to depressions following rainfall
14.11	PT LONSDALE, CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	1.10	No	Low lying narrow area alongside the Bellarine Highway with limited habitat/opportunities for MNES. Located between the Point Lonsdale housing development /Bellarine Highway and Bellarine Rail line/Bellarine Rail Trail. EVC 858 - Coastal alkaline scrub	No documented MNES. Considered low quality habitat for MNES. Unlikely to form a substantial or important component of habitat for any MNES.	Freshwater – rainfall dependent, possibly stormwater. No obvious surface water or drain/pipe connection with other waterbodies/waterways.	Works have made it unnecessary to treat as there is a new development. Ground treatments mainly.

Table 41 Site photos – ground sites (provided by City of Greater Geelong January 2022)

Site no. and name	Photos – typical treatment area within site
1.4 PT LONSDALE, SANTAMONICA STORMWATER LAKE	
3.7 OCEAN GROVE GOLF COURSE CREEK	

Site no. and name	Photos – typical treatment area within site
5.2 RAMBLERS RD PORT MARSH	  
14.11 CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	 

Table 42 Site photos – aerial sites (provided by City of Greater Geelong March 2024)

Site no. and name	Photos – typical treatment area within site
2.17 SOUTHERN LAKE VICTORIA	

Site no. and name	Photos – typical treatment area within site
2.5 COLLENDINA NORTH SALT LAKE AT EAST OF CARAVAN PARK	        

Site no. and name	Photos – typical treatment area within site
2.7	    

Site no. and name	Photos – typical treatment area within site
4.6	

Site no. and name	Photos – typical treatment area within site
	 
4.12	     

Site no. and name	Photos – typical treatment area within site
	     

Site no. and name	Photos – typical treatment area within site
	
8.18	

Site no. and name	Photos – typical treatment area within site
8.2	

Site no. and name	Photos – typical treatment area within site
10.8	

Site no. and name	Photos – typical treatment area within site
	

Site no. and name	Photos – typical treatment area within site
	     

Site no. and name	Photos – typical treatment area within site
	    

4. Impact assessment

As described, the City has recently reviewed its program, and particularly its delivery method, as the use of helicopters is no longer feasible due to their availability and cost. The City is now proposing the use of an agricultural drone to complete the aerial delivery of mosquito control product to treatment sites. Switching to the use of drones has brought about a rationalisation of treatment sites and treatment frequencies to better reflect the potential treatment area of the project, and to make projections with regard to the seasonal application rate of larvicide. This development makes the program more efficient, flexible and effective at responding to potential future areas of mosquito breeding concern compared to the program described in the original referral. Most importantly, the use of agricultural drones to deliver targeted and smaller payloads of larvicides will reduce the overall volume of mosquito control product applied to the project area, including the Ramsar site and sites of value to listed threatened and migratory species.

This section addresses the information requirements listed by DCCEEW in the Preliminary Documentation request, with regard to the use of drones instead of helicopters including disturbance, collision risk and the application of larvicides.

4.1 Purpose

The preliminary documentation must include an assessment of potential impacts (including direct, indirect, facilitated and cumulative impacts) that may occur as a result of all elements and project phases of the proposed action on listed threatened species, migratory species and the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site (the relevant MNES).

Consideration of impacts should address the potential for the proposed action to impact either directly or indirectly, listed threatened species and migratory species or their habitat in areas adjacent or downstream to the proposed action area. Consideration of impacts should also address the potential for impacts from the proposed action where it occurs outside the Ramsar site, to impact the Ramsar site, either directly or indirectly.

The impact assessment must include, but not be limited to:

a. an assessment of the direct and indirect impacts to MNES as a result of the proposed action.

i. *helicopter disturbance* (amended to include drone disturbance)

ii. collision risk (amended to include collision risk using drones)

For application of the larvicides Bti and S-methoprene:

iii. direct ingestion of or exposure to pesticide products

iv. potential direct and indirect impacts over the expected timeframe of use of the larvicides, including cumulative, multigenerational and food chain effects, on MNES, including listed species, migratory species and Ramsar site impacts

v. potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (eg freshwater turtles, water dragons)

vi. potential for metabolism and degradation of active ingredients and adjuvants, and subsequent impacts to MNES from metabolites and degradants

b. an assessment of the likely duration of impacts to MNES as a result of the proposed action and if they will persist once the program finishes and how long it will take for recovery

c. any relevant monitoring data, describing impacts on target and non-target species and ecosystems, including any supporting statistical analyses

d. an assessment of the frequency of impacts and whether repeated impacts over a prolonged period are likely to be significant

e. discussion of the risk of introduction and spread of disease during the proposed project on MNES, including amongst wild bird populations

f. details on whether any impacts are likely to be unknown, unpredictable or irreversible

g. *for the Port Phillip (Western Shoreline) and Bellarine Peninsula Ramsar Site, the impact assessment must also include but not be limited to:*
    i. *potential direct and indirect impacts on listed migratory and threatened species*
    ii. *potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (freshwater turtles)*
    iii. *potential for indirect impacts on other biodiversity values*
    iv. *discussion of impacts should include but not be limited to those impacts associated with water quality (i.e. on water dependent ecosystems), and changes to the physico-chemical nature of the site (contaminants and pollutants including leaks or spills arising from improper handling of mosquito control agents, edge effects, habitat fragmentation, loss of connectivity, dust, noise, environmental weeds, pathogens and pest animals).*

Consideration of impacts must not be confined to the immediate area of the proposed action but must also consider the potential of the proposed action to impact on adjacent or downstream areas that are likely to contain populations of or habitat for listed and/or migratory species.

Application of larvicides (S-methoprene and Bti) on MNES

When discussing the direct and indirect impacts from the application of larvicides (S-methoprene and Bti) on MNES, the above impact assessment should be informed by:

a. *a robust systematic literature review on effects of Bti and S-methoprene*
b. *information on impacts of similar programs elsewhere, where available.*

The systematic literature review on the effects of larvicides must include, but not be limited to:

a. *Procedures and processes that follow known and accepted literature review guidelines and protocols (e.g. PROSPERO, PRISMA, MESH terms, Cochrane, etc).*
b. *details of how the literature review was carried out (methodology), including but not limited to:*
    i. *the questions that the review sought to answer*
    ii. *what literature was included in the review and why*
    iii. *what literature was excluded from the review and why*
    iv. *how many items were finally selected for review*
c. *information on the limitations of the literature review* (these limitations are separate to the profession limitations discussed in section 1.3 of GHD [2017])
d. *critical consideration of studies that investigate similar pesticide use patterns (application rates, formulations, frequency over a 10 to 15-year period) preferably in similar environments*
e. *consideration of studies investigating multigenerational and endocrine disrupting effects, and indirect effects such as the disruption of diet/food chain effects*
f. *consideration of degradants and metabolites, i.e. are there any major degradants or metabolites of the active ingredients and adjuvants and if so, what are their potential effects*
g. *a list of references cited or otherwise referred to in the review.*

Full justification of all discussions and conclusions based on the best available information, including relevant conservation advices, recovery plans, threat abatement plans and guidance documents, should be included if applicable. Assumption, limitations, and uncertainties should be concisely reported. Departmental documents regarding listed threatened species can be found at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

When considering whether or not an action is likely to have a significant impact on a matter of national environmental significance it is relevant to consider all adverse impacts which result from the action, including direct, indirect and offsite impacts.

4.2 Review of potential impacts

A review was undertaken to identify potential impacts that may be relevant to the proposed action. The review considered:

- The potential impacts described in the previous referral (2005/32) and measures outlined in the conditions of approval for the referral
- The potential impacts presented in the preliminary documentation request
- A review of the DCCEEW EPBC Act referrals list (http://epbcnotices.environment.gov.au/referralslist/), searching for projects involving a similar application of mosquito management programs near to or involving MNES such as Ramsar wetlands, listed threatened species or communities or migratory species. The review included an analysis of the key impacts, decisions and outcomes for each referral
- The findings of a literature review completed by GHD on behalf of the City of Greater Geelong to understand the potential direct and indirect impacts on MNES from the use of two larvicide products (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) for the proposed action (refer Appendix F - GHD 2022, Literature review on the effects of Bti and S-methoprene. Unpublished report to the City of Greater Geelong, July 2022).
- The findings of a literature review completed by GHD on behalf of the City of Greater Geelong to understand the potential direct and indirect impacts on MNES from the use of drones for the proposed action (refer Appendix H - GHD 2024, Literature review – Potential direct and indirect impacts on MNES from the use of drones. Unpublished report to the City of Greater Geelong, March 2024)

The impact assessment process also incorporated the following desktop and field survey assessment reports (Appendix J):

- GHD 2023 - Migratory shorebird monitoring and drone disturbance trials in April 2023. Unpublished report to the City of Greater Geelong, October 2023.
- GHD 2021 - Desktop assessment of Orange-bellied Parrot, history of habitat use in proposed action area. Unpublished report to the City of Greater Geelong, December 2021
- GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020
- GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019
- GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018

Sections 4.2.1 – 4.2.3 describe the key activities associated with the proposed action, the relevant MNES (see section 3.3.3), and assess the potential for impacts on those MNES. For each impact, the following was considered:

- Type of impact (e.g. direct/indirect)
- Timing of impact (e.g. time of year and where relevant interval between treatments)
- Frequency of impact (e.g. how often each season and how often over the course of the six-year program)
- Duration of impact (e.g. duration of an aerial treatment, treatment period of each season)
- Spatial extent of impact (e.g. spatial extent of impact on a site)

For the impact assessment, MNES were placed into broad, closely aligned fauna groups where appropriate:

- Wetland Birds – Australasian Bittern and Australian Painted Snipe
- Resident Shorebirds/seabirds – Eastern Hooded Plover, Fairy tern
- Parrots – Orange-bellied Parrot, Blue-winged Parrot
- Migratory Birds/Shorebirds – Eastern Curlew, Curlew Sandpiper, Common Greenshank, Greater Sand Plover, Great Knot, Lesser Sand Plover, Red Knot, Bar-tailed Godwit, Black-tailed Godwit, Grey Plover, Sharp-tailed Sandpiper, Red-necked Stint, Ruddy Turnstone, Terek Sandpiper, Latham's Snipe
- Frog – Growling Grass Frog

– Fish – Australian Grayling and Yarra Pygmy Perch

4.2.1 Drone disturbance and collision risk

4.2.1.1 Description of activity

The City proposes to use one or more drones to treat up to 43 sites each season with Bti or S-methoprene products (see section 2.4.3). The area of the 43 sites totals 3,257.31 ha, of which up to 681.13 ha may be treated each season. Within the 43 sites, aerial treatments will be applied to areas suitable for mosquito breeding, including the shallow fringes of large natural wetlands (e.g. Reedy Lake), low lying shallow areas inundated from rainfall and to a lesser extent, areas that may be periodically inundated by king tides before receding. Aerial treatments are not applied to deep open waterbodies, or deep densely vegetated (e.g. tall rushes/sedges) waterbodies or areas subject to daily tidal inundation (e.g. tidal mudflats) as these areas are not suitable for mosquito breeding.

Aerial treatments will be applied using a drone from 15 August to 15 March each season from 2024 through to the end of 2030 (six years). Aerial treatments will not be undertaken at any site between 16 March and 14 August inclusive. Low-level aerial treatments (below 40 m) may only occur between 16 August and 14 March in Lake Connewarre (sites 3.13, 8.13, 8.14, 8.18 and 10.7) and between 16 November and 14 March in Swan Bay (sites 4.6, 7.1, 7.2, 7.3, 7.5, 14.3, and 14.4) to limit the disturbance to the Orange-bellied Parrot created by aerial treatments.

– When applying larvicide, the drones are likely to fly at a height of 10-15 m above the ground, depending on weather conditions such as wind and swath width (10-15 m^2), flying back and forth across a site to apply the product effectively. Prior to application, drones can approach sites from a greater height (maximum flight height is 100 m above the ground). Prior to the application of each product, a reconnaissance site (passover) may be undertaken, then the product will be applied. Larvicide product is primarily applied to areas with surface water, as this is the best use of the product. Larvicide is not deliberately applied to ‘dry’ areas (without surface water) or areas that are flowing or subject to daily tidal action (e.g., Barwon River/estuary, Swan Bay, Lake Connewarre, parts of Reedy Lake, Thompsons Creek, Lake Victoria), as such areas typically lack suitable habitat for mosquito breeding. The use of drones compared to helicopters will minimise the incidental product that may be deployed in some ‘dry’ and tidal areas within a site due to their close proximity to surface water containing mosquito breeding habitat (for example, a patch of dry area between surface waterbodies, or fringing dry shoreline areas surrounding a waterbody, or the fringing shoreline of Swan Bay or Lake Connewarre).
– Not all areas considered suitable mosquito breeding habitat will be subject to larvicide application. For example, larvicide application would not occur where a site contained areas of dense vegetation over water (e.g. dense reed beds, emergent aquatic vegetation) that prevented the drone pilot or City of Greater Geelong Mosquito Management Officer from being able to see the water. In such cases, the product would not be applied to these areas as this would be a waste of product.

Specifications of the foldable quadcopter drone likely to be used for larvicide application are as follows (refer to: https://www.xagaustralia.com.au/p100-pro):

– Dimensions: propeller folded – 1095 mm wide x 893 mm long x 883 mm tall, propeller unfolded – 2927 mm wide x 2868 mm long x 883 mm tall
– Total Weight (Excluding Battery and excluding larvicide and associated equipment): 46 kg
– Maximum Take-off Weight with full hopper and battery: 110 kg
– Maximum Operating Speed: 13.8 m/s

To understand and predict patterns of treatments of sites, the City has provided the following information:

– Drone flights will occur between morning and early afternoon (e.g. generally between the hours of 9 am – 4 pm). Flights will not occur during the early morning or late afternoon (e.g. near sunrise or near sunset)
– The time required for the treatment of each site will vary according to water inundation, level of breeding and site area. A treatment is expected to take less than 60 minutes for small sites (e.g. <33 ha; n=37), and from 40 mins up to 140 minutes for larger sites (e.g. > 33 ha; n = 6). This is based on treating the entire seasonal treatment area at once, which is not the intention of the program.

– When a site is treated, flight time for treatment within that day will vary (historical range 1 – 6 hrs, average 2 hrs). The maximum flight time for a treatment period at any given site at any given time is approximately 60 minutes. A typical treatment period could take 2-3 hours, noting that the drone will stop to reload product and swap batteries at the launch site between landing and take-off. Because the drone is smaller than the helicopter and carries a smaller larvicide load, it would require more refills (i.e., return to base) than a helicopter does to treat the same area. Therefore, treatment of a specific area within a site may take longer overall using a drone than using a helicopter. As the drone is smaller and is capable of flying lower, its treatment swath is narrower. This results in more passovers within a site than would be required by a helicopter. For example, site 3.13 (341.9 ha) may require more drone passovers within a season than it would with a helicopter (e.g. 20 drone flights compared with 8 or so helicopter passes, given the broader swath of helicopter) because of the larger treatment area, while site 8.7 (20.9 ha) may require fewer (e.g. three drone flights) due to being smaller. However, because the drone is smaller, lower, slower and more manoeuvrable than a helicopter, it has the potential to treat a site with more precision, resulting in less product redundancy or wastage.
– Maximum flight time is also restricted by factors external to the proposed action including battery life, weather, how long the drone is permitted to fly within the airspace of the project area and other aircraft traffic
– Number of treatment periods (days) each season will vary (historical range 4 to 29 non-consecutive days per season, average = 13). A typical treatment season will most likely consist of 6 to 8 non-consecutive treatment days.
– A single treatment period will never aim to treat the entire area of a site. Areas proposed for treatment typically form a small portion of the entire site, and are selected specifically to target potential mosquito breeding habitat (refer to Table 17).

Section 2.4.8 provides a summary of how often (frequency) a site is expected to be treated and therefore how often it is likely to be exposed to aerial disturbance each season. Of the 43 aerial sites:

– 20 sites will receive no more than one treatment per season, meaning there is a gap of at least six months, and possibly greater than 10 months, between treatments for these sites
– 23 sites may receive two or more treatments per season, with a gap between treatments varying between seven to 14 days, depending on product type. On the basis of historical observations, the need for multiple treatments of a site per season is expected to occur every two to three years, due to environmental conditions that influence mosquito breeding.

Aerial treatments are only conducted during the day and are subject to strict weather and tide conditions. Wind conditions must be below 30 km/h to ensure both safety and appropriate application of product. After application, wind speed and direction affect how the product moves once within the aerial site and must also be accounted for in the days after a treatment. Rain forecast will delay application as rain could wash product out of the intended treatment area. Incoming high tides above 1.5 metres will force a reschedule of an aerial treatment, as any product applied immediately prior to a high tide has the potential to be washed outside of the intended treatment area.

A range of launch sites will be used for the drone operation, and all take-off, landing and reloading of larvicide product will be completed at launch sites. It should be noted that the drone does not land at any of the treatment sites, or hover for any extended period (e.g. more than two seconds) at any location other than the launch site.

The expected level of noise emitted by the drone will vary. Similar sized quadcopter drones are reported to emit between 78 – 60 dBA, as measured from the ground with the drone flying between 2 - 120 m above the ground (Wilson et al. 2022, Weimerskirch et al. 2018). In comparison the rated operational overflight noise level of the helicopter most often used for the previous aerial deployment (Jet Ranger 206B) was 93 - 99 dBA within the cockpit. This results in a significant decrease in the environmental noise pollution for a drone in comparison to a helicopter. Furthermore the Helicopter Association International (HAI) reports that the sound level of a helicopter flying at 152 m is approximately 87 dB and at 304 m, the sound level drops to 79 dB, noting that dB has not been adjusted to human hearing thresholds, while dBA has.

To understand the level of noise created by the drone, the City will use a sound meter (Bruel & Kjaer 2245) to determine the sound pressure levels measured in the logarithmic decibel (dB) scale relative to a reference value. Due to noise levels varying depending on the weight and flight speeds, the sound meter will be used to provide data on the weight and speed variations, to better inform any additional adaptive mitigation measures that may be required for aerial treatments.

4.2.1.2 Literature review of potential impacts

A literature review was completed to understand the potential direct and indirect impacts on MNES from the use of drones for the deployment of mosquito control products by the City (see Appendix F). A full list of references cited in section 4.2.1.2 is provided in Appendix F.

Drones are increasingly being used in areas where they may interact with wildlife, and this presents a number of challenges when considering how drone use might impact nearby wildlife. For this project, the interaction between birds and drones is a key concern since they share the same airspace. The primary aim of the literature review was to inform an assessment of potential impacts on MNES. The literature review considered the following key questions:

– What are the potential direct and indirect impacts of drone use on MNES?
– What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)?

4.2.1.2.1 What are the potential direct and indirect impacts of drone use on MNES?

Generally, the literature reviewed provided an overview of potential disturbance to animals from drones in a range of contexts and locales, but few studies were found that specifically focus on impacts on MNES. No studies identified that explore the impacts of using drones to apply mosquito treatments referred to specific MNES; most studies involving animals and drones were focussed on ecological monitoring.

The most relevant study reviewed was by Wilson et al. (2023) which explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. The key findings from this study are that the extent of disturbance from drones varies depending on the species being disturbed. The Eastern Curlew, a species of concern for the proposed action, was more susceptible to drone disturbance than other migratory shorebirds, such as the smaller, closely related Whimbrel (migratory species). When mixed flocks were present, birds often followed the behaviour of the species most susceptible to disturbance (i.e., if Eastern Curlew took flight, then so did the Bar-tailed Godwit, which is another large migratory shorebird). The study also highlighted that disturbance increased significantly with decreased distance between birds and drone, a finding consistent with other literature (Kaldor 2019; Vas et. al. 2015). With regard to repeated disturbance from drones, there are conflicting findings within the literature. Wilson et al. (2023) found that repeated approaches by drones significantly reduced bird disturbance, possibly indicating short-term habituation. On the contrary, Kaldor (2019) suggests that repeated disturbance (not only from drones, but other disturbance) can result in changed behaviour and may cause birds to permanently leave an area.

Other studies that looked at drone impacts on MNES include a study in France by Vas et. al (2015). This study looked at the response of the Common Greenshank (also a species of concern for this project) to drones and reported that most birds did not respond to an approaching drone that was more than 30 m above ground. Another study from Italy by Valle and Scarton (2019) had a similar finding, where Common Redshanks (another EPBC Act-listed migratory species, but rare in Australia) were disturbed only when the drone was very close (i.e., about 10 m) to the nesting bird or nest (note: Common Redshanks and most other migratory shorebird species do not nest or breed in Australia). Additionally, Weimerskirch et al. (2018) found that seabirds (i.e., petrels, albatross, penguins) generally did not react to approaching drones that were at 50 m or more altitude, whereas at 10 m altitude, most species showed strong behavioural postures of stress.

The key piece of information within the grey literature was from a report for the Moreton Bay Foundation by Wilson et al. (2022), who explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. This report explores and further discusses aspects of the research conducted as part of the published literature by Wilson et al. (2023).

Another study on shorebirds and other birds in the UAE by Benjamin (2017) found that drone height and speed were important factors in determining the likelihood of shorebirds being flushed. Interestingly, body size was also found to be important in determining likelihood of flushing, with smaller shorebirds (i.e., sandpipers, plovers) 33 times more likely to flush than larger birds (i.e., gulls and herons).

The DCCEEW website provides an article by Eric J. Wohler, from Birdlife Australia (Tasmania), that discusses the potential impact of drones (among other disturbance sources) on shorebirds and terns. However, the article considers a range of human disturbance threats on birds and acknowledges that there are substantial knowledge gaps with regards to the impacts of drones on these birds and that caution is warranted, as disturbance of shorebirds and terns at any time (i.e., nesting, roosting or feeding) is likely to have adverse effects.

4.2.1.2.2 What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species?

The literature reviewed provides an overview of potential disturbance to animals (particularly birds) from drones in a range of contexts and locales. There were numerous studies, both locally (i.e., within Australia) and internationally, that explore the disturbance impacts of using drones for ecological monitoring and the potential to mitigate impacts on animals (particularly birds).

As would be expected, most studies identified that birds and other taxa are disturbed by drones (McEvoy et al. 2016; Bech-Hansen et al. 2020; Bevan et al. 2018). However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors that are typically observed in most studies, including:

– The type and size of drone (i.e., quadcopter vs fixed-wing models; large vs small)
– The distance between the drone and the animal and the drone flying speed
– The species of animal and the composition of the flock (in mixed-flock situations)
– The habitat and behaviour of animal (i.e., nesting or foraging)

Another important consideration is not only the response of birds to drones but what birds do after being disturbed by drones (i.e., do they return to the same location or do they fly to different areas). One study that considered this (Mapes et al. 2020) found that following substantial drone disturbance, terns and other colonial nesting birds flew out in a semi-circle over water and then returned.

Although the primary focus of the literature is on drone impacts on birds, Bevan et al. (2018) also showed that other taxa (sea turtles and saltwater crocodiles) were disturbed by drones. In particular, saltwater crocodiles showed a range of behaviours when approached by a drone that was flying below 50 m altitude, whereas sea turtles generally showed no disturbance behaviours from drones at 20-30 m altitude. In the same study, terns were consistently disturbed by approaching drones flown below 60 m altitude, thus strengthening the notion that there is variability in species-specific responses to drones.

Most studies agree that if drone use around wildlife is undertaken carefully and with consideration to the species that may be impacted, then drone-related disturbance is likely to be of relatively low-risk, when considering the impact of existing techniques (Lyons et al. 2018; McKellar et al. 2021). Hodgson and Koh (2017) provide best practice principles for minimising unmanned aerial vehicle (drone) disturbance to wildlife.

4.2.1.2.3 Key outcomes

4.2.1.2.3.1 Are birds and/or other animals disturbed by drones?

Most studies identified that birds and other taxa are disturbed by drones (McEvoy et al. 2016; Bech-Hansen et al. 2020; Bevan et al. 2018). However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors, which are discussed below.

The type and size of drone

Evidence from the literature indicates the type of drone influences the level of disturbance (for birds, at least), and that quadcopter model drones (i.e. the drone for this project) are less likely to disturb birds than fixed-wing drones (McEvoy et al. 2016; Lyons et al. 2018). A common suggestion made by some authors is that fixed-winged drones more resemble the shape of an aerial predator (i.e., raptor) (McEvoy et al., 2016; Egan et al., 2020). Drone size also appears to be an important factor in disturbing birds, with larger drones (i.e., 605 mm diagonal span) more likely than smaller drones (ranging between 213 – 354 mm diagonal span) to induce flight (Wilson et al. 2023).

The distance between the drone and the animal

Most studies investigating the effects of drone disturbance on animals assess the point at which the focal animal (i.e., a flock of birds) detects an approaching drone. Wilson et al. (2023) concluded that disturbance generally increases with decreased distance between the drone and the animal. This finding is consistent with other studies that found greater disturbance responses when a drone was flown closer to Common Redshank, seabirds and shorebirds (Valle and Scarton 2018; Weimerskirch et al. 2018; Benjamin 2017). Some studies show that the drone launching location is important, with increased distance between the launch location and animal location resulting in less disturbance (McEvoy et al. 2016). The angle of approach may also be a contributing factor in disturbance.

In France, Vas et al. (2015) found that birds (flamingos, mallards and Common Greenshank) reacted most when the drone was directly overhead while approaching the birds. However, when the drone was not directly overhead, there was little significant reaction from the birds.

The species of animal and the composition/size of the flock (in mixed-flock situations)

Variability in species' response is prevalent throughout the literature. Many studies identify that different species and taxa respond differently to drone disturbance. Wilson et al. (2023) found the Eastern Curlew (a large shorebird) to be extremely sensitive to drone-induced disturbance and could not be approached from above by a drone from any tested height (up to 120 m). However, the closely related Whimbrel (a large shorebird, but smaller than the curlew) was less sensitive to drone-induced disturbance and could mostly be approached to 80 m without disturbance (Wilson et al. 2022). Other smaller migratory shorebirds tested in that same study (e.g. Great Knot) could be approached to within 50 m before being disturbed (Wilson et al. 2022).

Conversely to Wilson et al. (2022), a study from the UAE by Benjamin (2017) found that smaller shorebirds were 33 times more likely to be flushed by a drone than larger shorebirds, but did acknowledge that flushing from one or more members of birds in a group can elicit flushing behaviour of other birds that may not have flushed individually. Benjamin (2017) also considered that group size may influence bird flushing behaviour, with birds occurring in groups more likely to flush than birds that were alone (but this was potentially confounded by bird body size – birds on their own tended to be larger than birds in groups).

The habitat and behaviour of animal (i.e. nesting or foraging)

Many of the reviewed studies focussed on the response of animals during a specific period of their life cycle (e.g., the breeding season). Geldart et al. (2022) found that ducks did not leave their nests in response to drone disturbance, a finding consistent with that found by Weimerskirch et al. (2018) in penguin breeding colonies, even when drones approached as close as three metres. It is possible that species-specific responses vary depending on the timing of drone disturbance within an animal's life cycle stage (i.e. adults more inclined to take flight when not nesting). Wilson et al. (2022) proposed that the impacts from drone disturbance on migratory shorebirds may be more severe closer to the period of migration, when the birds' energy levels are particularly important.

4.2.1.2.3.2 What type/nature of response do birds and/or other animals show to drones?

Do animals return to normal behaviour/back to same habitat after drone disturbance?

Most of the reviewed studies focussed on whether animals (particularly birds) were disturbed by drones and when the disturbance occurred (i.e., at specific distances). Few studies explore the behavioural response of birds following disturbance by drones, presumably because this can be difficult to quantify (i.e., particularly in large flocks). Kaldor (2019) identified that repeated disturbance of birds (from a range of human disturbances, not just drones) can result in changed behaviour and may cause birds to permanently leave an area. That study also highlighted for birds that response to disturbance is species-specific, with some flying much farther away than others. Problematically, a bird's behaviour when they land again is often modified, with birds showing increased vigilance. Increased time for vigilance means less time for feeding activity and this can result in reduced condition (Kaldor 2019).

When considering drone disturbance, it is prudent to compare this disturbance with disturbance caused by other survey methods and approaches and also the disturbance background that wildlife encounters in the absence of drones. Background disturbances may include birds of prey, introduced predators and pets (i.e., cats, foxes, dogs), humans, wind and other birds. When considering this background disturbance, it is important to understand if additional disturbance caused by drones will have substantial costs for a particular species.

No approach for animal observation or monitoring (or for larvicide treatment, as for this project) is likely to be entirely free of some sort of disturbance. Many authors contend that, when compared with more traditional survey methods (i.e., humans walking transects), drones often had less disturbance on birds (Valle and Scarton 2018; McKeller et al. 2021).

Species-specific responses (flocks influenced by most susceptible species)

An important finding from a recent study was that, in mixed-flock situations, some species may serve as sentinel species for others. Wilson et al. (2023) found that flight response to drones by the Eastern Curlew is often followed by flight responses by other species. However, this effect appears to vary depending on species. For example, Black Swans rarely took flight at the same time as Eastern Curlew, whereas Bar-tailed Godwit almost always did (Wilson et al. 2023). This finding was also consistent with findings from a study in the UAE with regards to shorebird flushing behaviour in response to drones (Benjamin 2017). Therefore, in mixed-flock situations, the species composition of the flock may contribute to specific species' disturbance responses to drones.

4.2.1.2.4 Knowledge gaps

4.2.1.2.4.1 Species-specific responses to drones for MNES

While this literature review has provided some insight into the likely responses of some MNES to drone disturbance, it has also highlighted that there is considerable species-specific variability in responses to drone disturbance, even amongst closely related species such as the Eastern Curlew and Whimbrel (Wilson et al. 2022). This presents a significant challenge when assessing impacts of drone disturbance on species for which there is currently no information available, such as MNES species: Orange-bellied Parrot (*Neophema chrysogaster*), Growling Grass Frog (*Litoria raniformis*), Australian Grayling (*Prototroctes maraena*) and Sharp-tailed Sandpiper (*Calidris acuminata*).

For aquatic and semi-aquatic species such as the Australian Grayling and Growling Grass Frog, there was no literature found or reviewed that provided insight into how these species may be impacted by drones. However, given the size, behaviour and microhabitats occupied by these species, it is expected that the response of these species to drones would be minimal. For example, unlike birds, frogs and fish do not occupy the same space as drones (i.e., not using the airspace, so no risk of collision) and frogs in particular are generally less mobile and occupy smaller home ranges than most birds. Drone disturbance would not result in frogs or fish leaving their home range and is unlikely to have a substantial energetic cost on frogs or fish. In response to drones, frogs and fish would be expected to, at most, temporarily change microhabitat use (i.e., swim away, hop into water, burrow into vegetation) or behaviour (i.e., cessation of calling by frogs during a drone pass over) which frogs and fish are expected to regularly undertake in response to other disturbance (i.e., predators, humans).

4.2.1.2.4.2 How does drone disturbance impact on bird behaviour and physiology in the long term?

Most studies in the reviewed literature focus on the initial behavioural response of birds to drones, with little exploration of the longer-term behavioural and physiological impact of drone disturbance on birds. Longer-term impacts are likely to be dependent on the magnitude, duration and frequency of drone disturbance, for which there is little to no information within the literature. Most studies assess drone-related disturbance as a brief snapshot in time, which fails to capture the potential longer-term implications for species where drones are a regular source of disturbance. Benjamin (2017) posits that shorebirds may be subject to physiological effects that are not visible, such as increases in heart rate, basal metabolism or release of stress hormones. These effects could have important deleterious impacts on some species, such as migratory shorebirds. Wohler (2018) concluded that the impacts of drones on shorebirds and terns are unclear and that caution is warranted, as disturbance of shorebirds or terns at any time (i.e., nesting, roosting or feeding) is likely to have adverse effects.

4.2.1.2.4.3 Drone collisions with birds

No research was uncovered in this literature review that reported on or explored the potential for bird collisions with drones. A number of factors, such as those discussed above (i.e., take off location, drone altitude, drone size), may influence bird collision risk and further investigation is warranted about whether drones are likely to pose a significant risk to birds due to collision. It is noted that no collisions or near-collisions were observed during drone and helicopter disturbance trials conducted for this study (GHD 2018, GHD 2019, GHD 2020, GHD 2023).

4.2.1.2.4.4 Are MNES likely to be significantly impacted by drone disturbance?

A key finding from Wilson et al. (2023) in Moreton Bay, Queensland, was that the Eastern Curlew (threatened and migratory under the EPBC Act) was highly susceptible to drone disturbance and could not be approached vertically by a drone from any tested height (up to 120 m). However, in the same study, other migratory shorebirds such as the Bar-tailed Godwit, Whimbrel and Great Knot would tolerate a drone approaching to closer distances without disturbance (up to 50 m for Great Knot, but 75 m and 80 m for the Bar-tailed Godwit and Whimbrel respectively). Other MNES, such as the Common Greenshank, tolerated an approaching drone at 30 m high with no reaction recorded 87% of the time (Vas et al., 2015). Another study by Benjamin (2017) found that shorebirds were less likely to be flushed by a drone approaching at heights greater than 15 m and travelling at slower speeds. Therefore, it is considered most likely that the impact of drones on avian MNES is likely to be species-specific and dependent on the nature of interaction with the drone (i.e., height of the drone, speed of the drone, angle of approach, number of fly overs, where the drone took off, size of the drone, flock composition).

4.2.1.3 Review of monitoring studies to understand the potential impact

The following desktop and field survey assessments were designed to understand the potential impacts of aerial disturbance and risk of collision to fauna within the treatment areas:

– GHD 2023 - Migratory shorebird monitoring and drone disturbance trials in April 2023. Unpublished report to the City of Greater Geelong, October 2023.
– GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020
– GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019
– GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018

Up to 2021, aerial treatment was done using helicopters, so GHD (2018), GHD (2019) and GHD (2020) report on disturbance caused by a helicopter. The proposed aerial treatment method is now the use of drones, and GHD (2023) reports on disturbance caused by a drone. See Appendix J for all reports. Key findings are outlined below. Even though helicopters are no longer proposed for use, the findings relating to helicopter disturbance are retained here as they provide important discussion on localised and larger scale impacts from aerial treatment.

4.2.1.3.1 Summary of migratory shorebird monitoring within the proposed action area 2018-2020

An examination of onboard video footage (helicopter) of CoGG aerial larvicide treatments was undertaken by GHD Senior Ecologist Craig Grabham from November and December 2016 and January and February 2017. The footage was collected by CoGG to assist with understanding the potential impacts of aerial operations on migratory shorebirds present during the time of the survey. The footage was reviewed with the aim of: i) identifying the presence/absence of migratory shorebird species; and ii) determining if the shorebird species were disturbed by the aircraft.

In 2018, 2019 and 2020, surveys were undertaken by GHD Senior Ecologist Dr Richard Retallick to help understand bird disturbance resulting from aerial larvicide application. For each survey, bird assessments were undertaken i) prior to a flyover event (a simulated larvicide application), ii) during the event, and iii) after the event at sites that are typically included in the treatment areas. For each phase of the assessment, observations recorded included bird species and abundance, and behaviour (e.g., foraging, roosting, preening, fleeing, re-settling). The aim was to focus observations on migratory shorebirds as a result of interactions with the helicopter during simulated treatment flyovers, and was done at an appropriate time of year to detect migratory shorebirds in Victoria (between October and March). However, given the general scarcity of shorebirds at most sites at the time of assessment, observations were made of all birds listed as Migratory under the EPBC Act (i.e., including terns, etc.), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc.).

In March-April 2023, a similar survey was undertaken by GHD Senior Ecologist Dr Richard Retallick using a drone rather than a helicopter.

2016-2017 video footage

No migratory shorebirds listed as MNES were identified when the aerial video footage was reviewed. Unfortunately, the poor quality of footage and narrow field of view prohibited confident identification of species that were observed, which were largely identified as larger wetland bird species (e.g. Australian Shelduck, Black Swan and Egrets). Smaller species (e.g. Welcome Swallow and White-fronted Chat) were identified but these observations were confirmed from stationary footage and not from the helicopter in flight over treatment sites.

It may be possible or even likely that migratory shorebirds flew from the area when the helicopter was in proximity and flew out of the field of view of the camera prior to the flyover. Most birds were observed in flight by the time the helicopter passed through the area (see results Table 2, GHD 2018, Appendix J), hence it was difficult to determine if the absence of smaller birds (i.e. migratory shorebirds) is a true indication of absence or is a result of the disturbance created by the helicopter, or the quality of the footage and field of view of the camera. If not true absence, then it could also be a combination of all factors.

No observations of bird strike or near misses were observed or reported during the monitoring.

Disturbance survey summary - 2018

Generally, shorebirds and wetland birds are easily and frequently disturbed, and by a range of potential sources. During the 2018 assessment, numerous observations were made of birds being disturbed by sources other than the helicopter. Sources of disturbance included people (including birdwatchers, e.g., walking), loud noises, wayward golf balls, dogs, foxes, swamp harriers, whistling kites, low-flying helicopters, etc. The result was similar to what was consistently observed at all sites during the helicopter flyovers – birds took to the sky, then tended to resettle at or near the original location soon after the disturbance source had gone. When disturbed, birds tended to group up (usually in species-specific groups), then land as a tight group, then commence spreading out again, once re-settled. Some birds re-settled some distance away, then made their way back to the original location in smaller groups over the following period. Each major disturbance (i.e., when all birds flee) appeared to reset the distribution of birds at the site. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these sites. On-ground observations made during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter, and often took to the sky well in advance of the helicopter flying over. This may explain why no migratory shorebirds were identified from the 2016-2017 aerial video footage.

No observations of bird strike or near misses were observed during the monitoring.

Disturbance survey summary - 2019

The observations reported for the 2019 surveys strongly resembled those reported in 2018 (GHD 2018). The numbers of migratory shorebirds in 2019 were lower than in 2018 and limited to two sites only. This is likely due to the conditions being far drier in 2019 than in 2018 – wetlands were scarcer in 2019.

Generally, shorebirds and wetland birds are easily disturbed, and by a range of potential sources, including people (including birdwatchers), loud noises, wayward golf balls, dogs, foxes, birds of prey and low-flying aircraft. During the 2018 and 2019 assessments, observations were made of birds being disturbed by sources other than the helicopter. The result was similar to what was consistently observed at all sites during the helicopter flyovers – birds took to the skies, then tended to resettle at or near the original location soon after the disturbance source had gone. As was noted in 2018, disturbed birds tended to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Each major disturbance (i.e., when all birds flee) appeared to reset the distribution of birds at the site. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these sites. On-ground observations made here during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter.

One of the most interesting observations made during the 2019 survey period was of a small group of Sharp-tailed Sandpipers (migratory) at Swan Bay Jetty. These birds were remarkably unfrightened by the presence of the observers and were barely disturbed by the helicopter flyover.

No observations of bird strike or near misses were observed during the monitoring.

Disturbance survey summary - 2020

The observations presented for the 2020 survey bear strong resemblance to those reported in earlier years of monitoring (GHD 2018, GHD 2019). The numbers of migratory shorebirds in 2020 were lower than in 2019, which in turn were lower than in 2018. This is likely due to prevailing conditions at the sites and elsewhere but may also reflect the survey timing with respect to the shorebird season. March is the tail end of the shorebird season in Victoria, and many shorebirds may have commenced their return migration to the northern hemisphere before the surveys began. That said, there were continued reports of 30+ Curlew Sandpipers across southern Victoria (including the Bellarine Peninsula) well into late March 2020 (eBird.org).

Generally, shorebirds and wetland birds are easily disturbed, and are routinely disturbed by a range of sources, including people (including birdwatchers), loud noises, wayward golf balls, dogs, foxes, birds of prey and low-flying aircraft. During the assessments each year, observations have been made of birds being disturbed by sources other than the treatment helicopter. The results were consistent to observations at all sites during the helicopter flyovers, in that birds took to the skies, then tended to resettle at or near the original location soon after the disturbance source had gone. Disturbed birds tend to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these species and these sites.

On-ground observations made here during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter. Black Swans and Australian Pelicans were the exceptions – generally, they took notice of the helicopter (i.e., raised heads), but did not take flight.

This assessment considered the potential disturbance to the birds due to the helicopter operations only. From this assessment and similar assessments in 2018 and 2019, it appears likely that larvicide application by helicopter results in short-lived disturbance of migratory shorebirds (and other species) at sites where they are present. The disturbance does not appear to be major or extraordinary for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly.

Larvicide application by helicopter is likely to meet with variable conditions with respect to birds. Wet conditions in March 2020, yet dry conditions in March 2019, are likely to have influenced waterbird, shorebird and wetland bird distributions and abundances generally, such that birds are not consistently in locations where the helicopter flies. Consequently, the effect of treatments/applications is likely to vary accordingly in terms of bird disturbance.

No observations of bird strike or near misses were observed during the monitoring.

Disturbance survey summary – 2023 - Drone

The drone was observed to disturb birds. However, the drone's radius of disturbance was far smaller than that observed for a helicopter in previous years (e.g., GHD 2020), such that birds generally were disturbed only when the drone was relatively close (generally within 25 m) and flying towards them (i.e., the birds were in the direct flight path). Most birds that were disturbed tended to re-settle in the immediate area very quickly. Some birds appeared to be relatively unconcerned at all by the presence of the drone. There was no consistent evidence that species counts or abundances reduced on or after day 2 (i.e., the day after the drone flyover) as a result of the drone flyover. Disturbance caused by the drone generally appeared to be less intense, less extensive and less prolonged than disturbance caused by the helicopter.

Aside from the differences in scale (i.e., the drone creates a smaller disturbance area than the helicopter does), the observations presented in this report bear strong resemblance to those reported in earlier years of monitoring during helicopter trials (GHD 2018, GHD 2019, GHD 2020). Generally, wetland birds at these sites (including migratory shorebirds) are easily disturbed, taking to the skies or walking and swimming away, then re-settling at or near the original location soon after the disturbance source had gone. Disturbed birds tended to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Birds at these sites are also routinely disturbed by a range of sources other than the drone, including people (including birdwatchers), loud noises, dogs, foxes, birds of prey. Movements of birds into, around and out of these sites appears to be normal and typical of these species and these sites.

From this assessment and similar assessments in 2018, 2019 and 2020, it appears likely that larvicide application by helicopter or drone would result in localised and short-lived disturbance of wetland birds (including migratory shorebirds) at sites where they are present. The disturbance observed did not appear to be major or extraordinary for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance, particularly for migratory shorebirds, remains unknown.

No observations of bird strike or near misses were observed during the monitoring.

4.2.1.4 Assessment of impact

The key fauna groups/species of concern regarding collision risk and disturbance caused by aerial treatment are migratory shorebirds, resident shorebirds, waterbirds and to a lesser extent the Orange-bellied Parrot and Blue-winged Parrot. These species are susceptible because they use habitats in treatment sites (e.g. wetland and foreshore) and are likely to be present and exposed to noise and movements from the drone for all or parts of the aerial application period. The primary concern is the displacement of large flocks of birds, disturbance of nesting and breeding resident shorebirds and waterbirds and disturbance to the Critically Endangered Orange-bellied Parrot. Furthermore, some species may be susceptible to collision causing injury or death.

Collision risk

No collision events or near miss events were recorded from the studies undertaken by GHD in 2018, 2019, 2020, and 2023. Furthermore, no collision or near miss events have been reported to date to the City by the helicopter contractors engaged to undertake aerial treatments within the proposed action area since 2010. No other Australian studies assessing the disturbance of aircraft or drones to birds reported collisions or near misses.

As reported in GHD 2018, 2019, 2020 and 2023, the majority of birds have been observed moving away from the aircraft as it approaches, reducing the risk of collision.

Furthermore, no research was uncovered in the literature review (GHD 2024) that reported on or explored the potential for bird collisions with drones. However, it was suggested that a number of factors, such as those discussed above (i.e., take off location, drone altitude, drone size), may influence bird collision risk, and further investigation is warranted about whether drones are likely to pose a risk to birds due to collision.

The lack of reported collision events and near misses to date within the proposed action area is possibly also due to a number of aspects of the existing aerial treatment program including: the timing of flights (e.g. not during early morning or late afternoon), short flight duration for typical treatment period (e.g. 2-3 hours), absence of back-to-back (multiple consecutive day) treatment periods for same sites and low frequency of treatments for many sites. Furthermore, the conditions of the previous referral regarding low level flight restrictions at key sites for the Orange-bellied Parrot have possibly reduced the opportunity for disturbance and collision with the species and other listed bird species discussed (e.g. aerial treatments were not undertaken at Swan Bay or Lake Connewarre between 15 March and 15 August. Low-level aerial treatments were restricted to 16 August and 14 March at Lake Connewarre sites and between 16 November and 14 March at Swan Bay sites to limit the disturbance to the Orange-bellied parrot).

Birds are likely to view a helicopter or drone as a potential threat (i.e., a predator), so they are more likely to fly away from rather than towards the object. If that object moves slowly, then the risk of accidental collision (i.e., a bird makes a mis-judgement and flies into the path of a drone or helicopter) reduces further.

Another important factor to consider is the awareness of the drone pilot not wanting to collide with a bird for safety, financial and environmental reasons. The combination of all these considerations contributes to the lack of collision events and near misses to date. Whilst the possibility of bird-drone collision cannot be ruled out, it is considered unlikely for the proposed program.

Drone disturbance

GHD surveys during simulated aerial application 2018, 2019, 2020 and 2023 showed that birds disturbed by the helicopter or drone tended to resettle at or near the original location soon after the disturbance source had gone.

A key point of difference between the drone and the helicopter is the radius of disturbance – the drone's radius of disturbance was far smaller than that observed for a helicopter in previous years (e.g., GHD 2020), such that birds disturbed by the drone generally were disturbed only when the drone was relatively close, and most birds re-settled in the immediate area very quickly. Some birds appeared to be relatively unconcerned at all by the presence of the drone. There was no consistent evidence that species counts or abundances reduced on or after day 2 (i.e., the day after the drone flyover) as a result of the drone flyover. Disturbance caused by the drone generally appeared to be less intense, less extensive and less prolonged than disturbance caused by the helicopter.

Aside from the differences in scale (i.e., the drone creates a smaller disturbance area than the helicopter does), the observations presented in the GHD (2023) drone study bear strong resemblance to those reported in earlier years of monitoring during helicopter trials (GHD 2018, GHD 2019, GHD 2020) – see *Disturbance survey summary – 2023 - Drone* in section 4.2.1.3.1 above. From the assessment of drones and similar assessments of helicopter use in 2018, 2019 and 2020, it appears likely that larvicide application by drone would result in localised and short-lived disturbance of wetland birds (including migratory shorebirds) at sites where they are present. The disturbance observed did not appear to be major or extraordinary for the birds; on-ground observations found that most, if not all, birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly.

Because the drone is smaller than the helicopter and carries a smaller larvicide load, it would require more refills (i.e., return to base) than a helicopter does to treat the same area. Also, because the drone is smaller and flies lower, the area it treats with each flyover is narrower, which means it requires more repeated sweeps over a site than a helicopter would to treat the same area. Therefore, treatment of an entire site may take longer overall using a drone than using a helicopter, and birds at a wetland site may experience disturbance over a more prolonged period (hours rather than minutes). However, because the drone is smaller, lower, slower and more manoeuvrable than a helicopter, it has the potential to treat sites with more precision, resulting in less product redundancy or wastage; it may require less larvicide than the helicopter does to effectively treat the same area.

If use of the drone results in a longer duration of stress and/or more repeated flying over a site, then it may result in higher and greater disturbance for birds than the occasional once-only passover by a helicopter. Birds may re-settle nearby after one disturbance or even two, but there is likely to come a time when the disturbance is too great and the birds decide not to remain at that location. However no species is reliant on, or forages entirely within a treatment site within the proposed action area. Most species are known to use multiple treatment sites and multiple other alternative habitat areas within or nearby the proposed action area.

On the basis of field observations and literature review, MNES bird species disturbed by the drone would not be expected to abandon the proposed action area for remainder of that season. Similarly, species disturbed by the drone at treatment sites on Lake Connewarre, Reedy Lake, Lake Victoria and Swan Bay may temporarily relocate to other parts of the site or other sites within the proposed action area with suitable habitat.

As acknowledged, the proposed aerial treatment program includes activities that may occasionally disturb some species for short periods of time each season, which in turn may temporarily displace individuals from treatment sites. Section 3.3.3.2 (Table 29 and Table 30) provides a detailed breakdown of the number of historical records of each species and habitat modelled for the aerial treatment sites and for areas outside the treatment sites within a broader search area including the Bellarine Peninsula. For example:

– Orange-bellied Parrot: approximately 2,465 ha of modelled habitat within aerial sites, with an additional 4,534 ha of habitat within search area
– Curlew Sandpiper: approximately 2,705 ha of modelled habitat within aerial sites, with an additional 4,829 ha of habitat within search area
– Australian Painted Snipe: approximately 2,650 ha of modelled habitat within aerial sites, with an additional 4,501 ha of habitat within search area

There are substantial areas of available habitat for migratory birds, wetland birds, Blue-winged Parrot and Orange-bellied Parrot within the proposed action area, and general locality located outside and beyond the treatment sites. Therefore, if birds are temporarily displaced by drones, there are many nearby opportunities that offer equivalent habitat.

For the proposed action, several other factors are likely to help reduce potential impacts, including: the timing of flights (e.g. not during early morning or late afternoon), short treatment period duration (e.g. historical range 1-6 hrs, with a typical treatment period of 2-3 hrs), absence of back-to-back (multiple consecutive day) treatment periods at same sites, low frequency of treatments for many sites (e.g. the area of the 43 aerial treatment sites totals 3257.31 ha of which up to 681.13 ha may be treated each season) and maintaining restricted timing of low level flights at key sites (see Table 43) for the Orange-bellied Parrot.

Prior to this project proposing the use of drones, disturbance to Orange-bellied Parrots by helicopter noise, particularly young birds at mainland release sites (aerial or ground-based) was identified as a potential impact by DELWP (now DEECA). Young birds are reportedly highly susceptible to noise disturbance during the release period (which may last a few weeks) (Rachel Pritchard, DELWP, pers. comm., November 2021). It is highly unlikely that future releases will occur earlier than April each year due to the breeding cycle of the species. As noted in Table 43, the treatment of aerial sites using helicopter (now drone) will cease before April each year.

The absence of aerial treatments from 15 March – 15 August each year will also serve to avoid the period when the Blue-winged Parrot is most common within the project area (see section 3.3.3.2.2).

Table 43 Aerial treatment program and species occurrence within proposed action area

Proposed activity/species occurrence in proposed action area	Key dates	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Low level treatment Lake Connewarre site	16 Aug - 14 March												
Low level treatment Swan Bay sites	16 Nov - 14 March												
Aerial treatment other sites	-												
Orange-bellied Parrot presence	Feb – Sept	x	x							x	x	x	x
Blue-winged Parrot presence	All year	x								x	x	x	x
Migratory shorebird presence	Oct – Jan (peak numbers/species)			x	x	x	x	x	x				

Table notes – shaded cells indicate presence within project area. Cells marked with x indicate peak numbers (and species for shorebirds) according to database searches, see section 3.3.3.

4.2.1.5 Conclusion

The use of the drone within the proposed treatment sites for the purpose of the treatment program is expected to result in short-term, temporary disturbance that may affect a small portion of the overall population of MNES within the proposed action area. Collision events and near miss events have not been recorded through previous studies and appear to be highly unlikely. This risk may increase during years where more treatments are required, and/or greater bird numbers are reported, however the overall risk to MNES is not considered substantial across the course of the six-year program.

The City has undertaken helicopter operations for over 10 years within the proposed action area and whilst there have been fluctuations in the number of species for each relevant species MNES reported (see section 3.3.3), all species have persisted within the proposed action area, and there have been year-to-year increases in observed abundances, as well as decreases. It can therefore be inferred that no one species has abandoned or been disturbed to the extent that it no longer finds the habitats of the proposed action area suitable as a result of the mosquito management program using helicopters to this point. Whether there is a cumulative or long-lasting effect of disturbance beyond the life of the proposed action (from drones and other sources of disturbance such as birds of prey, humans etc) on birds at these sites remains unknown. The City intends to investigate the potential disturbance of birds from the drone for this program through the ecological surveys presented Section 5.

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5).

4.2.2 Exposure to larvicide products – Bti and S-methoprene

A literature review was completed to understand the potential direct and indirect impacts on MNES from the use of two larvicide products (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) by the City of Greater Geelong for their proposed 2024 - 2030 Mosquito Management Program (see Appendix F). A full list of references cited in section 4.2.2 is provided in Appendix F. For application of the larvicides Bti and S-methoprene, the literature review component of the impact assessment considered:

– Direct ingestion of or exposure to pesticide products
– Potential direct and indirect impacts over the expected timeframe of use of the larvicides, including cumulative, multigenerational and food chain effects, on MNES, including listed species, migratory species and Ramsar site
– Potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)
– Potential for metabolism and degradation of active ingredients and adjuvants, and subsequent impacts on MNES from metabolites and degradants

4.2.2.1 Potential direct and indirect impacts

A focus of the literature review was on the effects on non-target organisms. Many of the reviewed articles for S-methoprene make no mention of non-target organisms, other than a standard introductory statement based on earlier research, that biological agents are considered safe for the environment, with low impact on non-target organisms (e.g., Bakr and Tanani, 2018). The same was found for *Bacillus thuringiensis* var. *israelensis* (Bti) as it is reported to be environmentally safe because it does not cause adverse effects on humans, livestock or other non-target beneficial species.

Some of the non-target organisms of interest here are vertebrates (fish, frogs, reptiles, birds). Many of the studies that consider vertebrates are concerned with effects of larvicides on human health (e.g., Competent Authority Report, 2016; Simmering et al. 2005). Consequently, there is a focus on mammals, particularly lab-reared mammals such as rats, mice, rabbits, guinea-pigs, cats and dogs, because toxicity research tends to involve those groups in controlled and ethically acceptable ways. There are also studies that investigate the effects on agricultural animals, including pigs, sheep and cattle. Mammals were not identified as a focal group for this literature search (none of the MNES of concern are mammals), but the searches resulted in many articles that included information on mammals, as well as other vertebrate groups of interest (e.g., birds).

4.2.2.1.1 Effects on vertebrates

S-methoprene

Almost all of the literature reviewed concluded that S-methoprene is harmless and non-toxic to vertebrates, particularly when applied at the recommended dose. S-methoprene is one of the two enantiomer forms of Methoprene, R-methoprene being the other, and the form that is active as a growth regulator. The term S-methoprene is used in this report except when cited as ‘methoprene’, in which case the term used by the author is maintained.

The Competent Authority Report (2016) evaluated S-methoprene and reviewed numerous other studies up to 2009 that focused on the effects of the larvicide on mammals (e.g., Kuhn 1999a-e, Leeper 1999, Ford 2009 and 2010, Szakonyi 2002, Hernadi 2002, Beres 2002 and 2003, Torok 2007, Kolep 2009)[2]. A lot of specific information has been redacted in the freely accessible version of the report, but the outcomes and conclusions for most applications of the larvicide are accessible. The studies mostly found no lethal or consistent sub-lethal effects on mammals (Glare and O’Callaghan 1999; USEPA 2000 and ESFWS 1984 in Anon 2017), unless doses are extraordinarily high (Simmering et al. 2005), and far higher than any field application would be able to achieve.

No evidence was found that S-methoprene is mutagenic (Hernadi 2002, Beres 2002, in Competent Authority Report 2016; Simmering et al. 2005), clastogenic (causes chromosomal aberrations) (Beres 2003, in Competent Authority Report 2016), oncogenic (tumour causing), a skin sensitiser, or has effects on vertebrate (mammals and birds) reproduction (Simmering et al. 2005). One study (Kuhn 1999d, in Competent Authority Report 2016) observed minor eye irritation in rabbits, which was quickly reversible.

[2] Unpublished reports, as referred in Competent Authority Report (2016)

Non-lethal effects on birds have been reported at very high doses. Effects included “slowness, reluctance to move, sitting, withdrawal, and poor coordination, potentially decreasing bird survival by making them temporarily more susceptible to predation” (Hudson et al. 1984, in Simmering et al. 2005). Anon (2017) also reported methoprene has slight acute avian toxicity, observing some reproductive impairment in Mallards at a dietary dose of 30 ppm, but no effects at 3 ppm (USEPA 1991) (the dose required to kill common mosquitoes is generally around one part per billion (i.e., 0.001 ppm), which is 3,000 times smaller than 3 ppm; Glare and O’Callaghan 1999).

Anon (2017) calculated that normal environmental concentration after application of Altosid (commercial name, refer Appendix F), calculated as a dose rate of 0.13 lbs a.i/acre, equivalent to 0.15 kg a.i./ha. This rate is similar to the application rates proposed by the City (Table 7 and Table 13. Altosid Pellets, which is a comparable product to the City’s preferred product known as Prolink Pellets, has a higher concentration of S-methoprene at 4.25%; Prolink Pellets report a concentration of 40g/kg, or 4%.

Methoprene may have slightly higher toxicity to fish than other vertebrates (USEPA 2000, ESFWS 1984; in Anon 2017; Glare and O’Callaghan, 1999), but a description of the effects could not be found in the articles reviewed. Glare and O’Callaghan (1999) conclude that acute fish toxicity would not be expected during mosquito management programmes as the methoprene concentration considered by Glare and O’Callaghan (1999) remains well below the levels needed to induce the effect (Anon 1973 and Ross et al. 1994b; in Glare and O’Callaghan 1999). Other studies also acknowledge that S-methoprene can have negative impacts on fish (Kuo et al., 2010, in Staples 2016).

Anon (2017) concludes that, for birds, fish and mammals, the RQ (risk quotient) for methoprene is below the LOC (level of concern) for the USA Environment Protection Authority (EPA). For most risk assessments, EPA uses a deterministic approach or the quotient method to compare toxicity to environmental exposure. Calculation of risk quotients are based upon ecological effects data, pesticide use data, fate and transport data, and estimates of exposure to the pesticide.

The lack of effects observed in vertebrates (mammals, in this case) compared with invertebrates is explained by the way S-methoprene works: “…toxicity to insects is manifest through interference with metamorphosis, a process without parallel in mammals” (Simmering et al. 2005).

S-methoprene may affect amphibians more than other terrestrial vertebrates. Methoprene (not specifically S-methoprene) was implicated in observations of frog deformities in the USA in the mid-1990s. However, extensive subsequent investigations into this association were never able to replicate the effects and, with more likely explanations now forthcoming (e.g., infection with parasitic trematodes), it is now thought to be unsubstantiated (reported in Simmering et al. 2005; Stark 2005).

Pauley et al. (2014) investigated the effects on tadpoles of three forms of mosquito control used in the USA: ‘Mosquito Dunks’, ‘Mosquito Bits’ (both are formulations of Bti) and ‘Mosquito Torpedoes’ (a methoprene formulation). Use of the methoprene formulation resulted in the lowest tadpole survival rates when applied in the presence of tadpole predators (aquatic). Other studies also acknowledge that S-methoprene can have negative impacts on amphibians (Kuo et al., 2010, in Staples 2016).

While the reduced survival of tadpoles with Methoprene is concerning (as concluded by Pauley et al. 2014), context around the observations is required. ‘Mosquito Torpedoes’ are designed for slow release of Methoprene for longer-term mosquito control (up to 60 days), which differs from aerial application of S-methoprene. Also, aquatic predators of tadpoles prey on aquatic invertebrates also. S-methoprene is toxic to many aquatic invertebrates, and it is possible that the methoprene served to remove prey choice from the predators, thereby resulting in more tadpoles being eaten (Pauley et al. 2014). Also, Pauley et al. (2014) noted that the commercial products tested are likely to have contained active or inert ingredients other than methoprene, and that the effects of those ingredients are unknown. Ingredients are not disclosed in the SDS of the products (Vectobac G -Granule, Prolink XR -Briquets and ProLink ProSand) and are labelled as “secret”, protected by patent of the product.

No reference to reptiles was found during the review. The literature review process identified a general lack of literature and studies on the effects of S-methoprene on reptiles.

Bti

Bti is widely considered safe for vertebrate fauna. Laboratory tests, necessary for the registration of Bti as a commercial product, have confirmed the safety of Bti for other vertebrates, including mammals (Saik et al. 1990, Siegel and Shadduck 1990, Sudha Rani 1996, Siegel 2001, Arteaga et al 2014; in Tamilselvan 2015; Recluse et al no date).

In an evaluative review of numerous articles, Anon (2017) reports that Bti has practically no acute or chronic toxicity to mammals, birds, fish or vascular plants, and no acute toxicity to amphibians, fish or crustaceans. Furthermore, environmental exposure to Bti is considered to be negligible for most birds, mammals, bees, and non-target arthropods other than bees (EFSA 2013).

For mammals (laboratory rats, dogs, mice, rats, guinea pigs and rabbits) using oral exposure, inhalation exposure, intravenous exposure, intraperitoneal exposure and dermal exposure, little or no adverse effects were reported, even at very high doses (EFSA 2013; Ahmad et al. 2015). Mild symptoms were seen in albino rabbits (minor skin irritation around eye). For birds (Mallard and Northern Bobwhite), LC50s were very high, which suggests very low toxicity (EFSA 2013). For fish, long exposure times and high LC50s also suggest low toxicity (EFSA 2013). Note that these studies used LC50/LD50 (concentration or dose that kills 50% of the sample population) and NOEC (no observed effects concentration), which do not reflect long-term exposure effects such as cancer, birth defects, or reproductive toxicity.

Nair et al. (2020) provide an explanation for the general absence of effects in vertebrates: "*the insecticidal crystal proteins, called δ-endotoxins, target specifically pathogenic insects with no harmful effect on vertebrates (Lacey, 2007; Merritt et al., 1989; Lee and Scott, 1989*)" (in Nair et al. 2020).

For birds, pesticides such as Bti may have no direct effects on avian populations, but they may impact prey availability, thereby influencing time spent for foraging (Brunk et al 2019). Work by Poulin et al. (2010) (cited in Brunk et al 2019) raised concern for the safety of Bti with birds in France, thereby re-igniting the debate about the environmental safety of Bti (Lagadic et al 2016). For Bti and the House Martin (*Delichon urbanicum*), the intake of Diptera (Nematocera) and predators of Diptera (Arachnida and Odonata) decreased significantly at treatment sites: "*At treated sites, two effects occurred: a significantly higher rate of very small prey was consumed, but total foraging rates were lower. Clutch size and nestling survival were significantly lower at treatment sites*" (Poulin, 2012; Poulin et al., 2010; in Brunk et al 2019).

Similarly for insectivorous bats, indirect effects may include reduced food, which could have knock-on effects of habitat selection and community dynamics, and ingestion of contaminated prey (Brunk et al 2019). For bats, direct exposure is likely to be low, because bats are secreted away during the daytime when application would occur.

For amphibians, tadpoles of three species (*Rhinella arenarum*, *Rhinella fernandezae*, and *Physalaemus albonotatus*) were exposed to commercial formulations of insecticides, including a commercial liquid formulation of Bti (Introban®) (Junges et al. 2017). Acute toxicity was evaluated in terms of median lethal concentration (LC50), no observed effect concentrations (NOEC) and lowest observed effect concentrations (LOEC). The results showed that tadpole species were affected differently depending on the chemical properties of the pesticide and on a dose response effect of the insecticide. The main finding for Bti (Introban®) was that sub-lethal effects were observed – treatment tadpoles were less active in their swimming, which could have implications for predation (Junges et al. 2017).

Lajmanovich et al. (2015) also found that Introban® affected tadpoles. Introban® was found to be relatively toxic for tadpoles of *Leptodactylus latrans* (LC50–48h=22.45mgl−1), and also "*altered enzymes of oxidative stress, induced genotoxicity, and caused intestine damage at sublethal concentrations*" (in Junges et al. 2017).

Allgeier (2019) found that Bti treatment alone did not lead to acute toxic effects on amphibian larvae (European common frog *Rana temporaria*), but found hints of sub-lethal effects, in the form of potentially increased energy demand from "investment in subcellular responses to xenobiotics". Allgeier (2019) wrote: "*exposure to Bti induced significant increases of GST (37 - 550%), GR (5 - 140%) and AChE (38 – 137%) irrespectively of the applied formulation, indicating detoxification, antioxidant responses as well as an alteration of neuronal activity*."

Pauley et al. (2014) investigated the effects on tadpoles of two forms of Bti mosquito control used in the USA: 'Mosquito Dunks', 'Mosquito Bits' (both are formulations of Bti). 'Mosquito Bits' had no survival effect on tadpoles, while 'Mosquito Dunks' reduced tadpole survival slightly, and only in the presence of tadpole predators (aquatic). While the reduced survival of tadpoles with 'Mosquito Dunks' is concerning, context around the observations is required. 'Mosquito Dunks' are designed for slow release of Bti for longer-term mosquito control (>30 days), which differs from aerial application of Bti used by and proposed by the City. Pauley et al. (2014) note that the commercial products tested are likely to have contained active or inert ingredients other than Bti, and that the effects of those ingredients are unknown. Anon (2017) provides a similar cautionary note: while Bti itself may not be toxic, other ingredients in Bti formulations are potentially toxic.

Other than Brunk et al (2019), no reference to reptiles was found during the review. The literature review process identified a general lack of literature and studies on the effects of Bti on reptiles. Therefore, potential impacts are not well understood.

4.2.2.1.2 Non-target invertebrates

S-methoprene

S-methoprene is a synthetic hormone that regulates insect growth, preventing larvae from developing into adults and reproducing (Simmering et al 2016). It is used for mosquito control, but its effects are non-specific to mosquitoes. It is not surprising, therefore, that many of the reviewed articles reported effects in non-target aquatic invertebrates (e.g., Glare and O'Callaghan 1999; Siemering et al. 2005; Kuo et al., 2010, in Staples 2016; Anon 2017).

The New Zealand Government evaluated the use of Methoprene as a pesticide more than 20 years ago (Glare and O'Callaghan 1999). They reported: "Methoprene is toxic to a range of insects from 12 orders, including Diptera, Lepidoptera and Coleoptera. Methoprene also kills some mite species. It is most toxic to Diptera, but has been used in the field against a number of pests such as mosquitoes, biting flies, hornflies, ants, hemipteran pests and termites."

Methoprene (not reported specifically as S-methoprene) was found to have detrimental effects on two aquatic non-target crustaceans, where chronic exposure reduced body length and moulting frequency, and for one species, caused shortened life expectancy, repressed body development, and reduced fecundity (Hu 2019). Padmanabhan et al. (2017) found that sublethal doses impaired ovarian growth and resulted in a reduced proportion of mature oocytes in non-target freshwater crabs.

Tonjes et al. (2018) reported on a localised collapse of a lobster industry, thought to be associated with use of Methoprene: "*The 1999 collapse of the Long Island Sound lobster fishery was linked by litigants and in the press to widespread pesticide use following the initial West Nile virus (WNV) outbreak in the New York City area. It was suspected that the pesticides applied in urban settings and marshes washed into open waters where it would not affect mosquitoes but could impact other organisms, such as lobsters. An investigation of the die-off did not find methoprene or other mosquito pesticides to be important factors (but did not rule out potential contributory effects) (Pearce and Balcom 2005).*"

Tonjes et al. (2018) also reported effects on non-target invertebrate populations in areas where mosquitoes develop in numerous studies since the 1970s. Taxa included: mayflies and dytiscid beetles (Norland and Mulla 1975, in Tonjes et al. 2018), scud, shrimp and prawn populations, flies, midges, chironomidae larvae, and several species of beetles (Breaud et al. 1977, in Tonjes et al. 2018), insects generally, especially predatory insects, and most especially chironomidae (Hershey et al. 1998 in Tonjes et al. 2018; Stark 2005).

However, other studies reported by Tonjes et al. (2018) did not find impacts (Lawler et al. 2000; Pinckney et al, 2000). Breaud et al. (1977, in Tonjes et al. 2018) found that, alongside negative effects on insects, water boatmen nymphs, moth fly larvae, diving beetles, and crawfish populations increased. Butler et al. (2010) undertook field and laboratory trials, and found no evidence of reduced abundance of any invertebrate taxa attributable to methoprene application, and no consistent changes in community-level parameters related to methoprene application.

Many earlier studies were done in laboratories or mesocosms, rather than in the field. Whether the doses that caused effects in experiments match those experienced in the field during mosquito control operations is not certain. Glare and O'Callaghan (1999) suggested that doses used in the field are typically low: "The lethal dose required to kill common mosquitoes is generally around one part per billion. Field application rates used against mosquitoes would be unlikely to be lethal to many other insects".

An assessment of impacts of Methoprene on non-target soil invertebrates and soil function indicated that, at an application rate of 2 kg/ha three times a year, no detectable effects were seen in the measured variables (Fuessel 2013).

Bti

According to Gowelo (2020), "*strains of the bacteria Bacillus thuringiensis var. israelensis (Bti) are widely used as active ingredients in larvicides because they do not cause harm to non-target organisms or the environment* (Kandyata et al. 2012, Aïssaoui and Boudjelida 2014; in Gowelo 2020)." This has been attributed to the specificity of Bti's endotoxins (Gwal et al. 2015, in Gowelo 2020) and its low persistence under field conditions (Davis and Peterson 2008, Tetreau et al. 2012, Fayolle et al. 2016, in Gowelo 2020). Bti did not affect the entire range of organisms that inhabited a saltmarsh community (Russell 2006; Russell *et al.* 2009).

For invertebrates (laboratory and field studies), EFSA (2013) reported that there is little evidence of adverse effects caused by Bti. Studies in lentic and lotic (still versus flowing) habitats have shown little or no effects of Bti on most non-target organisms (Merritt et al. 1989, Lacey and Mulla 1990, Molloy 1992, Boisvert and Boisvert 2000, Jackson et al. 2002, WHO 2007; in Tamilselvan 2015; Caquet et al. 2011, Lagadic et al. 2014, in Junges et al. 2017).

Tamilselvan (2015) tested non-target organisms with a Bti dose at 10 times the concentration of one known to kill 90% of the least susceptible mosquito species (*Anopheles stephensi*), and reported no mortality of organisms during the experimental period.

In a longer-term study (up to four years), Lagadic et al (2016) found no association between the use of Bti for mosquito control and the dynamics of non-target aquatic invertebrates (focussing on Chironomids) in French coastal and continental wetlands, providing the following summary of findings:

> "1) Bti dosages recommended for mosquito control do not affect non-target invertebrates.
>
> 2) The abundance of most-at-risk chironomids varies independently from Bti treatments.
>
> 3) No immediate or long-term effects were shown on invertebrate diversity and abundance.
>
> 4) Invertebrate community dynamics are mainly driven by flooding frequency and duration."

WHO (2009; in Junges et al. 2017) considers Bti safe to be used in waterbodies, containers and even in drinking water. Marina *et al.* (2014) investigated the efficacy and non-target impact of Bti and other larvicides in southern Mexico. Aquatic insect diversities were highest in the control and Bti treatments, and lower in treatments using other larvicides. The results found that Bti had little effect on aquatic insects generally.

Bti is engineered to kill selected invertebrates, so detection of effects is likely to depend on which organisms are sampled. Bti is known to affect non-target chironomids (closely related to mosquitos), potentially changing invertebrate community structure (Anon 2017; Stark 2005). The effects of Bti on chironomids is still debated in the scientific community. Some studies show reduced chironomid abundance in wetlands after Bti application (Hershey et al., 1998; Jakob and Poulin, 2016; in Allgeier 2019) while others found no negative effects (Duchet et al., 2015; Lagadic et al., 2016; Lundström et al., 2010b; Wolfram et al., 2018; in Allgeier 2019).

Allgeier (2019) cautions against sampling one group only, and suggests that the finding of 'no observable effects' on chironomids (or other non-target organisms) needs to be supported by observed and measured reductions in the mosquito abundance. "*Otherwise it could also be possible that the applied concentration was ineffective* [to both mosquitoes and chironomids] *due to environmental conditions*."

Olmo et al. (2016) undertook laboratory experiments, using Bti on zooplankton collected in the wild from wetlands that had been treated with Bti for decades. While responses were variable, the authors found a general pattern of increasing mortality with concentration and time, and conclude that negative effects of Bti, using doses close to those used in field applications, are possible or even probable at the community level (zooplankton).

One study investigated the long-term ecological impacts of Bti under field conditions, with results that contradicted those from many laboratory-based experiments (Hershey et al. 1998, in Russell 2006). In that study, density of freshwater insects was found to be significantly reduced for three years during repeated applications of Bti and S-methoprene. The degree to which Bti contributed to this observation is not known. The decrease in insect populations is thought to be from direct toxicity effects (specifically to Diptera) and secondary effects from a disruption to the invertebrate food chain (South Australia 2006).

4.2.2.1.3 Dose

S-methoprene

The effects of Methoprene are likely to be inextricably linked to application dose. Lawler (2017) concluded that "*realized environmental concentrations of methoprene were usually 2–5 µg/kg (range 2–45 µg/kg) and that its motility is limited. These levels were not toxic to the vast majority of vertebrates and invertebrates tested in laboratories, except for a few species of zooplankton, larval stages of some other crustaceans, and small Diptera. Studies in natural habitats have not documented population reductions except in small Diptera*".

In the early 1990s, concerns expressed by the US EPA resulted in a thorough review of the toxic effects of S-methoprene. The review found that, when used at recommended mosquito-control doses, S-methoprene poses a low risk to non-target species, including estuarine invertebrates (US EPA, 2001; in South Australia 2006).

Effects on non-target organisms generally appear to have been at doses considerably higher than label recommendations (Glare and O'Callaghan 1999). According to Glare and O'Callaghan (1999), the dose of Methoprene required to kill mosquitoes is generally approximately 1 ppb[3], and field application rates used against mosquitoes are unlikely to be lethal to many other insects.

Bti

As for most pesticides, the effects of Bti may be linked to application dose. However, there appears to be less data in the literature to support this than there is for S-methoprene, and the results of some studies suggest that dose may not be important. Tamilselvan (2015) tested non-target organisms with a Bti dose at 10 times the concentration of one known to kill 90% of the least susceptible mosquito species (*Anopheles stephensi*), and reported no mortality of organisms during the experimental period.

For the Pauley et al. (2014) test of slow-release Bti formulations ('Mosquito Dunks' and 'Mosquito Bits') on tadpoles, reduced tadpole survival may have been linked to the duration of the exposure (30 or 60 days).

The biomass, abundance and diversity of microorganisms were shown to be affected only by a high dosage of Bti (VectoBac® G) (approx. twice the maximal application rate recommended for mosquito control) applied in outdoor aquatic microcosms (Duguma et al. 2015, in Lagadic et al 2016).

Junges et al. (2017) commented that Bti (Introban®) had low toxicity to tadpoles, but that recommended doses applied to extensive areas of differing depths may result in Bti being applied in doses that are more toxic to tadpoles and other non-target organisms than reported in this study. However, the literature review has not found data to demonstrate this.

Lagadic et al (2016) concluded that, when following recommended application rates and best mosquito control practices, Bti treatments had "*no detectable influence on the dynamics of non-target aquatic invertebrate communities, including chironomids, in coastal and continental wetlands, where environmental factors are the driving forces of these communities*".

4.2.2.2 Bioaccumulation, degradability, multigeneration, endocrine disruption and long-term effects

S-methoprene

The literature review found limited evidence on bioaccumulation, multigeneration effects, or endocrine disruption as a result of S-methoprene application. The literature indicates that Methoprene breaks down quickly in the environment and appears to have few lasting effects after treatment (review of numerous studies by Glare and O'Callaghan 1999).

Methoprene is reported to have low persistence in soils, with a half-life up to 10 days (US EPA 1982, Glare and O'Callaghan 1999; in Fuessel 2013). Its breakdown is thought to be attributable to microbial degradation, but it also degrades rapidly in sunlight (US EPA 1991, in Fuessel 2013). The solubility of methoprene in water has been reported as 1.4 mg/L (ANZG 2018) which indicates that at environmental concentrations, expected to be much lower than 1.4 mg/L, S-methoprene degrades rapidly in water (Menzie 1980, Hartley and Kidd 1991, in Fuessel 2013).

[3] Parts per billion

Methoprene is not persistent in mammals, and is rapidly and completely broken down and excreted, mostly in the urine and faeces (EXTOXNET 1996, in Siemering et al. 2005), and mostly within 24 to 48 hours of administration (Ford 2009, in Competent Authority Report 2016). Whether this breakdown occurs similarly in other vertebrates was not evident in the articles reviewed. No bioaccumulation was observed in animals that ate mosquito or midge larvae treated with Methoprene (Siemering et al. 2005).

There appears to be some evidence of short-term bioaccumulation of Methoprene in some organisms. Methoprene residues were reported to bioconcentrate in fish and crayfish, but it was noted that up to 95% of the residue in fish was excreted within 14 days (USEPA 1991, in Anon 2017). It must be noted that this was reported from a toxicity test and not a bioaccumulation test, hence standard depuration rates have not been reported.

Many of the early toxicology studies were done in laboratories or mesocosms. One study investigated the long-term ecological impacts of S-methoprene (and Bti) under field conditions, with results that contradicted those from many laboratory-based experiments (Hershey et al. 1998, in Russell 2006). In that study, density of freshwater insects was found to be significantly reduced for three years during repeated applications of Bti and S-methoprene. Another, however, found that Methoprene was close to undetectable within one day in 1-m deep saltmarsh ditches, and present but without accumulation in marsh sediments, despite repeated applications (Tonjes et al. 2018). Tonjes et al. (2018) further noted that Methoprene concentrations observed in the saltmarsh ditches were below those found to be of 'toxicological significance' in other studies.

Given the way S-methoprene tends to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are not expected Stark (2005). Rapid recolonisation of sites by target mosquitos themselves, thereby requiring repeated treatments, attests to this too.

In relation to the potential effect of metabolites of degradant products, it is noted that adverse effects were observed in embryonic development of the amphibian species *Xenopus laevis* after exposures of 1µL/L of several S-methoprene degradants (La Clair et al 1998).

Bti

Little information was found in the Bti literature on bioaccumulation, multigeneration effects, and endocrine disruption. Lagadic et al (2016) investigated the potential endocrine-disrupting effects of several Bti formulations, but detected no sign of endocrine activity.

EFSA (2013) discussed the potential for transfer of genetic material from Bti to other organisms, given that "*bacilli are known to have the capacity to transfer genetic material through exchange of plasmids*". In the absence of data on this, EFSA (2013) calls for assessment to demonstrate that this transfer does not occur or does not lead to unacceptable effects on the environment.

The literature reports fairly consistently that Bti has low persistence under field conditions (Davis and Peterson 2008, Tetreau et al. 2012, Fayolle et al. 2016; in Gowelo 2020).

Alto and Lord (2016) suggested that mosquitoes that survive treatment with Bti may actually gain an advantage: "*survivors will have a fitness advantage (growth, development, enhanced production of eggs) relative to conspecifics that are not under larvicide pressure. However, under most circumstances, these transstadial effects are unlikely to outweigh reductions in the adult population by Bti*."

Given the way Bti tends to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are not expected (Stark 2005).

4.2.2.3 Dietary effects and secondary poisoning

S-methoprene

No evidence of secondary poisoning was found in articles reviewed, but few articles investigated or focussed on this aspect. One study reported that: "no bioaccumulation of methoprene has been seen in animals that have eaten mosquito or midge larvae treated with Methoprene" (Siemering et al. 2005). Niemi et al. 1999 (in Anon 2017) reported that birds are not negatively affected by feeding on foods exposed to Methoprene (or Bti), based on no effects being observed in Red-winged blackbirds breeding in mosquito treatment areas.

No evidence was found of indirect food-chain effects (i.e., effects of reduced insect population on insect predators). In the USA, the US EPA (1996) found no substantial evidence to support the suggestion that waterbirds and waterfowl are affected. Siemering et al. (2005) concluded for aquatic systems: “although methoprene, at label rates for mosquito control, can prevent adult emergence of midges, it does not directly kill mosquito or midge larvae and therefore does not remove them from the food chain”.

In the terrestrial system, Hanowski et al. (1997, in Anon 2017) found no negative effects in 19 different bird species on wetlands two years before treatment and three years after treatment using Methoprene (and Bti).

Bti

No evidence of secondary poisoning was found in articles reviewed, but few articles investigated or focussed on this aspect. Niemi et al. (1999, in Anon 2017) reported that birds are not negatively affected by feeding on foods exposed to Bti – no effects were seen in Red-winged blackbirds breeding in mosquito treatment areas.

One important group of studies provides evidence of direct or indirect food-chain effects (i.e., effects of reduced insect population on insect predators). For birds, pesticides such as Bti may have no direct effects on avian populations, but they may impact prey availability, thereby influencing time spent for foraging (Brunk et al 2019). Work by Poulin et al. (2010) raised concern for the safety of Bti with birds in France, thereby re-igniting the debate about the environmental safety of Bti (Lagadic et al 2016). For Bti and the House Martin (*Delichon urbanicum*), the intake of Diptera (Nematocera) and predators of Diptera (Arachnida and Odonata) decreased significantly at treatment sites: “*At treated sites, two effects occurred: a significantly higher rate of very small prey was consumed, but total foraging rates were lower. Clutch size and nestling survival were significantly lower at treatment sites*“ (Poulin, 2012; Poulin et al., 2010; in Brunk et al 2019).

Similarly for insectivorous bats, indirect effects may include reduced food, which could have knock-on effects of habitat selection and community dynamics, and ingestion of contaminated prey (Brunk et al 2019). For bats, direct exposure is likely to be low, because bats are secreted away during the daytime when application would occur.

In the terrestrial system, Hanowski et al. (1997, in Anon 2017) found no negative effects in 19 different bird species on wetlands two years before treatment and three years after treatment using Bti.

Allgeier (2019) investigated indirect effects of Bti (as used in mosquito control) on aquatic food webs, focussing on chironomids, which are a non-target organism potentially affected by Bti (chironomids are closely related to mosquitoes). Because chironomids make up a large proportion of the invertebrate biomass in many wetland systems, reduced abundance of chironomids may have ecological food-chain effects. Allgeier (2019) showed that growth rates in larval newts (amphibians) reduced, most likely as a result of Bti-induced chironomid prey limitation. Further, Allgeier (2019) showed that Bti increased the vulnerability of newt larvae to predation by the dragonfly *Aeshna cyanea* and decreased survival of newt larvae by 27%. Allgeier (2019) proposed from this that entire amphibian populations have the potential to be threatened by mosquito control activities using Bti, if treatment is applied to sites where amphibians occur.

4.2.2.4 Studies using similar application rates

Nearly all articles reviewed related to the use of Methoprene as a mosquito control agent. However, no study reviewed reported on an application exactly the same as the one used or proposed by the City for the previous application process using a helicopter, or for the new process using a drone. It is noted that the use of a drone will substantially reduce the overall volume of both S-methoprene and Bti deployed within the proposed action area (see section 1.5.2, Table 2) when compared to using a helicopter.

The most similar application found for review is that of the mosquito management actions and investigations by the Shire of Busselton. Since 2009, the Shire of Busselton has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands, in Western Australia. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty. For the Busselton project, mosquito management was implemented by helicopter application for expansive areas requiring control. S-methoprene (sand-based formulation) alone was used from 2009 to 2014, after which it was used in association with Bti.

As part of the Shire of Busselton's investigations into the management of mosquitoes at the Vasse-Wonnerup Wetlands, Paice (2016) undertook monitoring of non-target aquatic invertebrates from 2009 to 2015 in an attempt to determine whether or not food resources for waterbirds are negatively impacted by the use of larvicide. Specifically, Paice investigated pre-and post-treatment sampling in three treatment and three control wetlands associated with 19 applications of S-methoprene and three applications of Bti. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti. The conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. Aquatic invertebrate community composition was similar in treatment and control sites. Composition data was affected more by natural variation over time caused by factors such as environmental conditions, sampling bias and measurement error, than by any measurable effect of larvicide application. Paice concluded that the indirect impact on waterbirds through reduced availability of aquatic invertebrates as a food resource was highly unlikely. Paice (2016) considers the results for S-methoprene to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and Paice suggested that continued sampling was required to achieve more confidence in the conclusion.

The action by the City of Busselton of implementing mosquito management measures in the Vasse Wonnerup Wetlands was referred to the former Department for the Environment, Heritage, Water and the Arts (DEWHA) in keeping with the requirements of the EPBC Act. The decision from DEWHA was that the action was *not a controlled action if undertaken in a particular manner*.

Tonjes et al. (2018) also shows similarity to the City's proposed application with aerial application of S-methoprene (and Bti) in saltmarsh environments in north-eastern USA. Another relevant article focussed on mosquito control, using Bti and Methoprene, to suppress human disease outbreaks at an American wildlife refuge, which had been established to provide habitat for migratory birds, in particular waterfowl (Anon 2017). The larvicidal products were chosen because of their safe environment record and low impacts on non-target organisms.

As part of the Shire of Busselton's investigations into the management of mosquitoes at the Vasse-Wonnerup Wetlands, Paice (2016) undertook monitoring of non-target aquatic invertebrates from 2009 to 2015 to determine whether or not food resources for waterbirds are negatively impacted by the use of larvicide. Specifically, Paice investigated pre-and post-treatment sampling in three treatment and three control wetlands associated with 19 applications of S-methoprene and three applications of Bti. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti. The conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. Community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application. It was also concluded that the indirect impact on waterbirds through reduced availability of aquatic invertebrates as a food resource was highly unlikely. Paice (2016) considers the results for S-methoprene to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and Paice suggested that continued sampling was required to achieve more confidence in the conclusion.

Relationship between application rate and aquatic exposures of Bti

No relevant information has been found in the systematic literature review about the environmental concentrations of Bti after application rates similar to those proposed by The City. Hence, a non-exhaustive literature review was conducted to target studies providing that type of information. This found a study by Weeks and Parris (2020) providing Estimated Environmental Concentration (EEC) for *Bti* based on the USEPA (1996) method. According to that study, an application rate of 2 fl oz/1000 sq. ft (equivalent to 6.1 kg/ha) has a calculated EEC of 0.0042 ml/L in wetlands nearby agricultural application and runoff following rainfall. Refer to section 4.2.2.2 for further discussion on the effects of bio-accumulation and degradation of Bti.

4.2.2.5 Summary of literature review findings

4.2.2.5.1 Key outcomes and conclusion

The systematic search of literature, grey literature and other sources provided limited results directly linking the two larvicides to MNES. Of particular interest was the City of Busselton, Western Australia EPBC Act referral (referral number 2016/7780) for aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, Western Australia.

Since 2009, the Shire of Busselton (Western Australia) has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty, so are considered to be a MNES. Mosquito control was implemented by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control.

For the Shire of Busselton's investigations, the conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. The conclusion for S-methoprene was considered to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and the suggestion was that continued sampling was required to achieve more confidence in the conclusion.

The action by the City of Busselton of implementing mosquito control measures in the Vasse Wonnerup Wetlands (a Ramsar site) was referred to the Minister for the Environment in keeping with the requirements of the EPBC Act. The Minister's decision was that the action was *not a controlled action if undertaken in a particular manner*.

No other articles reporting effects on specific MNES identified for this proposed action were identified in the literature search. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world.

The following conclusions have been reached following the systematic literature review on the potential non-target impacts of S-methoprene and Bti:

– Both Bti and S-methoprene are widely used larvicides globally and have been the subject of comprehensive toxicological evaluations over several decades
– There is limited literature available on the topic of larvicide effects on MNES, vertebrates, and non-target organisms, particularly from recent years and from Australian ecosystems. Much of the literature on this topic globally is older (pre-2010), and more recent studies appear to have produced findings that do not conflict with the findings of older studies.
– No studies identified potential direct or indirect effects from the application of S-methoprene or Bti on species identified as MNES for the proposed action. One study provides information for a monitoring program assessing impacts on aquatic invertebrates due to S-methoprene and Bti on the Western Australian Vasse-Wonnerup Ramsar site (a MNES). After seven years of aquatic invertebrate sampling, that study has found no evidence of adverse impacts on non-target organisms due to Bti or S-methoprene use.
– No articles were identified in the literature search that reported on effects on specific MNES identified for the proposed action. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world
– Almost all the literature reviewed concluded that S-methoprene and Bti are not directly toxic to vertebrates
– The effects of S-methoprene on non-target invertebrates are likely inextricably linked to application dose. Higher application doses are more likely to result in non-target invertebrate effects. However, when used at recommended application rates (e.g., as per those recommended by APVMA), the literature generally concludes that there is a low risk to non-target species, including estuarine invertebrates. Low persistence in the environment (when used at recommended does rates) means that impacts on water quality are low. Given the way larvicides tend to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are considered unlikely.
– The effects of Bti include some non-target effects on Chironomid species (non-biting midges; closely related to mosquitoes), although there is no clear consensus in the literature. There appears to be no bioaccumulation, multigeneration, or endocrine disruption effects, and that Bti has low persistence under field conditions.

– An on-going concern regarding the use of both larvicides is the potential impact that seasonal declines in mosquito numbers could have on the ecological food web. Few studies report on this, and there is on-going conjecture about the repeatability of the findings from the main study that does (Poulin et al. 2010). Of the MNES in question for the proposed action, none are likely to depend on mosquitoes as a food source and all MNES species will have access to other non-treated habitats within the proposal area. Indirect impacts of larvicides on the food chain are partly mitigated by the availability of untreated areas of mosquito habitat as sanctuaries for mosquitoes and natural mosquito predators (e.g. the program proposes to focus treatment along the northern, eastern and parts of the southern shorelines of Lake Connewarre. Large portions of the lake system including the central portion and western shoreline will not be treated).
– According to information found in the literature review, it can be concluded with reasonable confidence that, at the application rates proposed by the City for Bti and S-methoprene, non-target organisms are unlikely to be significantly affected. It is noted that direct supporting evidence for this is currently limited and more studies in other areas and at different applications rates would be needed to firm this conclusion.
– The literature is relatively consistent in the conclusion that, among the products used for mosquito control, Bti and S-methoprene are among the safest for the environment and for non-target organisms, particularly vertebrates

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5).

4.2.2.5.2 Knowledge gaps

The systematic literature review has highlighted a number of knowledge gaps in relation to the effects of S-methoprene and Bti. A number of these knowledge gaps limit the ability to address all issues raised as part of the proposed action. Ultimately, these knowledge gaps should form the basis of on-going monitoring programs done in association with future mosquito management programs. The main gaps identified include:

– There are very few published studies that have investigated the indirect impact on the wider environment of an ongoing significant reduction in adult mosquito populations resulting from a long-term broad-scale mosquito management program
– Without local long-term studies, or quantitative studies identifying the relative importance of mosquitoes (or susceptible non-target taxa such as Chironomids) as specific components of the ecosystem (e.g. as a food source, pollinator, nutrient recycler, or disease vector), it is difficult to accurately assess the indirect long-term environmental impacts beyond the life of the proposed mosquito management program within the proposed action area
– With year-to-year fluctuations across a range of environmental variables, natural changes in the abundance, diversity and behaviour of local wildlife further complicate our understanding of the ecological effects of mosquito management. We have not taken into account these natural factors or anthropogenic variables – e.g. surrounding land use, nutrient run off etc and how that impacts the habitats of the species.
– The potential effects of other ingredients used in S-methoprene and Bti products and formulations remain unknown – some articles suggest that associated ingredients may be more toxic than the larvicide itself
– The potential for endocrine disruption associated with the use in S-methoprene and Bti remains uncertain due to a lack of research
– More research is needed to clarify the potential for S-methoprene to bioaccumulate in the food web
– The potential for intergenerational indirect effects of slow release Bti granules (i.e Vectobac G granules) has been identified as a data gap and there is little information about the rate at which these granules break down and expose the Bti to the environment. It is noted that while slow-release exposures last relatively long periods (e.g., 30 – 150 days), the nature of their composition is to expose only a low concentration of the active ingredient at a given time. However for the purpose of the proposed action, the application of some slow-release products, like the S-methoprene Prolink briquets or VectoPrime FG-Granules, which are designed to remain in the environment for an extended period (e.g. 150 and 120 days respectively), is limited to a few ground-based sites within residential areas to prevent re-emergence of mosquito larvae after treatment, and would not be applied to areas with MNES or tidal or marine habitats, thus reducing the risk to MNES.

4.2.2.6 Direct ingestion of or exposure to larvicide products

MNES of concern can be exposed to the two larvicide products in several ways including direct exposure (e.g. through ingestion whilst foraging in recently treated site) or indirect exposure (e.g. consumption of prey containing the product). Direct exposure can occur as the products are released from the drone and fall onto the MNES species. The larvicide is delivered in two forms – pellets 3-8 mm diameter (Bti and S-methoprene) and granular (sand like) at 0.5-1 mm diameter. Both are delivered toward the ground via an auger/hopper system attached to the agricultural drone. Typical width of area covered by dispersal is between 7-20 m by the time the larvicide contacts the ground/water surface. Although there is a lack of information regarding the consequences of the product striking/coming into direct contact with fauna, there is a low chance of this occurring for the following reasons:

– The majority of birds leave the immediate area as the drone approaches overhead, reducing the likelihood of the product coming into immediate direct contact with birds
– The use of granular sized treatment product at all aerial treatment sites further reduces the risk of adverse contact with fauna
– The small area of dispersal (swath at 5-15 m^2 by the time the larvicide contacts the ground or water surface), coupled with the low chance of a threatened or migratory species being in that area during the dispersal
– The favoured habitats of many species are not typically targeted for treatment (e.g. mosquito habitat is minimal or not present in those areas, or treatments may not be effective in those areas) including Orange-bellied Parrot, Blue-winged Parrot, Growling Grass Frog, Australian Grayling, Yarra Pygmy Perch, Australasian Bittern and Australasian Fairy Tern

Direct ingestion can occur following the application of larvicide, particularly within aerial treatment sites. Aerial sites are typically larger and are located within key areas of fauna habitat (e.g. Lake Connewarre complex and Swan Bay). Migratory shorebirds feed in both tidal (e.g. beach/shoreline, mudflats) and non-tidal habitats (e.g. edges of wetlands, shallow ephemeral waterbodies, saltmarsh habitats). The largest areas of known tidal influenced habitat includes the Lake Connewarre delta, shoreline (to hide tide mark) and mudflat areas and Swan Bay shoreline (to hide tide mark), which do not support mosquito breeding habitat and are therefore not part of the treatment program. Given that the proposed program does not involve applying larvicide to tidal areas, the focus of the potential for exposure is on non-tidal foraging and roosting habitats.

Some species of migratory shorebird bird may unintentionally directly ingest larvicide product because of their foraging strategy (e.g. wading in shallow water probing for invertebrate or molluscs following a treatment) or come into direct contact with larvicide product following application (e.g. collecting the product on legs, bill, feathers whilst bathing). Typically, shorebirds that occur at the treatment sites feed while walking or wading, although some may also do so by swimming (e.g. Red-necked Avocet, Banded Stilt). Other species including the Blue-winged Parrot, Orange-bellied Parrot and wetland birds may also occasionally directly ingest the product whilst foraging. For example, Orange-belied Parrots may forage on saltmarsh plants located on the edge of a recently treated waterbody. However, the Orange-bellied Parrot is a selective feeder on specific parts of its foraging plants, and it is unlikely to directly ingest or be directly exposed to larvicide via other means.

The Australasian Bittern inhabits densely-vegetated wetlands, including areas that support taller reeds and rushes. These are not typically the areas that are subjected to larvicide treatments. Furthermore, bitterns primarily feed on vertebrates (frogs, birds, mammals, fish) and large macro-invertebrates (e.g., crayfish), so is therefore unlikely to directly ingest non-moving larvicide products.

The Growling Grass Frog, Australian Grayling and Yarra Pygmy Perch are unlikely to ingest the product whilst foraging. Application of larvicide is unlikely to occur within habitats occupied by these species as the majority of their habitat is not considered suitable mosquito breeding habitat or the habitats are not targeted due to the presence of open water or dense aquatic/emergent vegetation. All three species are unlikely to directly ingest larvicide product, but may indirectly ingest larvicide product via prey including non-target insects and their larvae.

4.2.2.6.1 Risk of exposure to larvicide product for MNES fauna species

An assessment was undertaken to determine those species/fauna groups that may be at greatest risk of indirect or direct exposure to larvicide products during a season and therefore more exposed to the potential impacts of the two larvicide products over the course of the program.

A likelihood ranking (high to low) for risk of exposure was applied to each species or species group (Table 44). The ranking considers aspects of the species' or fauna group's ecology (e.g. known records, foraging and roosting behaviours) and treatment program (e.g. how many sites treated and how often for a typical treatment program). Table 45 provides an assessment of the risk of exposure for each relevant species identified in section 3.3.3.

A review of each treatment site was undertaken to determine its habitat value for relevant MNES fauna species (see section 3.4). A summary of the review is provided below and has also been considered for the risk exposure assessment:

– Of the nine ground-based sites, all are known for or have potential habitat for MNES (see section 3.4). Of these, six are considered to be of sufficient size, habitat quality, connectivity with adjoining habitats and have historical data to support ongoing and regular use by MNES. The remaining three sites are unlikely to provide a substantial portion of or important habitat for MNES.
– Of the 43 aerial sites, 42 are known for or have potential habitat for MNES (see section 3.4). Of these, 41 are considered to be of sufficient size, habitat quality, connectivity with adjoining habitats and historical data to support ongoing and regular use by MNES. The remaining two sites are unlikely to provide a substantial portion of or important habitat for MNES.

Table 44 Risk of exposure rationale

Risk of exposure	Species rationale
High (3)	Species has many recent (e.g. <10 years) records and a widespread geographic distribution of records across the proposed action area (PAA). Species is common resident OR non-resident, showing ongoing regular usage of treated habitats within the PAA OR annual seasonal non-breeding usage within PAA during the proposed treatment period. Species known from multiple treatment sites within key habitat areas (e.g. Lake Connewarre complex, Swan Bay, Lake Victoria, Breamlea wetlands, etc). Important habitats (foraging, roosting and possibly breeding or combination of all) occur within the treatment sites with little available alternative habitat in broader area (non-treatment areas). Foraging behavior increases risk of exposure (e.g. majority of species' diet consists of mosquito larvae or non-target invertebrates affected by larvicide) and a large portion of foraging habitat across the PAA occurs within treatment sites.
Medium (2)	Species has some recent records and reasonably broad geographic distribution across the PAA. Species known from one or more treatment sites in key habitat areas (Lake Connewarre complex, Swan Bay, Lake Victoria, Breamlea wetlands, Lake Murtnaghurt etc) or other potential habitat within treatment sites. Species is uncommon resident OR non-resident, showing ongoing regular or seasonal usage of treated habitats within the PAA OR annual seasonal non-breeding usage within PAA during the proposed treatment period. Important habitats (foraging, roosting and possibly breeding) occur within some of the treatment sites with other available alternative habitat in broader area (non-treatment areas). Foraging behavior may increase risk of exposure (e.g. part of species' diet consists of mosquito larvae or non-target invertebrates affected by larvicide) and a portion of foraging habitat across the PAA occurs within treatment sites.
Low (1)	Few records of species within the PAA, with few records within treatment sites. Species may be rare/uncommon resident or non-resident, showing occasional use of treated habitats within the PAA and within the treatment period OR annual seasonal non-breeding usage within PAA during the proposed treatment period OR annual seasonal usage within PAA outside the proposed treatment period (Orange-bellied Parrot). Species does not typically forage within habitats of treatment sites, and/or a small portion of the overall foraging habitat for the species is subject to treatment (e.g. species prefers foraging on tidal mudflats, however may also spend time foraging in saltmarsh). Species habitat typically not subjected to treatment (e.g. tidal habitats, or dense emergent vegetation over freshwater lagoon).

Table 45 Risk of exposure assessment for key MNES fauna species

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Orange-bellied Parrot	***Presence and habitat*** Seasonal, non-breeding visitor in small numbers, overwinters in the proposed action area (PAA) between March and September. Known from nine sites (VBA and DELWP). Likely to expand range to include sites with suitable habitat. Aerial sites – 2.17, 3.13, 4.1, 7.1, 7.3, 7.5, 8.14, 8.18, 10.8, 14.3, 15.8 Ground site - 0 Potential habitat also recorded within 14 additional treatment sites associated with Lake Connewarre and Swan Bay. Uses primarily coastal saltmarsh habitats, as well as littoral heathlands and low scrublands for foraging and roosting. Habitat areas at Lake Connewarre and Swan Bay are considered to be extremely important. Also Breamlea Flora and Fauna Reserve and Lake Victoria. ***Type of exposure*** The preferred habitats for this species are not typically mosquito breeding habitat, however small portions may be subject to larvicide application (e.g. along the fringes of waterbodies or small sections of habitat between waterbodies). There is a very low possibility the species may ingest larvicide after contact with preferred food plants e.g. seeds and fruits of sedges and salt-tolerant coastal and saltmarsh plants located around the edges of shallow, ephemeral depressions and waterbodies.	***Frequency*** *(treatments per season (p/s))* – Site: 2.17, 8.14 – 1 or <1 p/s. Sites: 3.13, 4.10, 7.1, 7.3, 7.5, 8.18, 10.8, 14.3,15.8 – 2 or more p/s (treatments at least 7 days apart). ***Timing*** Timing and type (e.g. low-level aerial) of treatments deliberately structured to minimise interactions with this species at key sites. Proposed aerial treatments occur between 16 August - 14 March, except Swan Bay, 16 Nov - 14 March. Proposed ground-based treatment between 16 August – 31 May.	**Low risk** Aerial treatments of key habitats including Lake Connewarre and Swan Bay restricted to period when species is largely absent from the mainland and the PAA. Although key habitats may be treated two or more times per season. The preferred habitats for this species are not typically subject to larvicide application. Species is unlikely to be in regular contact with larvicide as the total area of available habitat in Lake Connewarre and Swan Bay will not be treated during a single treatment period or over the course of one season. The species may expand to include sites with suitable habitat without historical records, although a substantial increase in population is unlikely to occur over the life of the proposed action (6 years).

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Blue-winged Parrot	***Presence and habitat*** Occurs and breeds in Tasmania, Victoria, and south-eastern South Australia. Nesting occurs in a tree hollow or stump, and the breeding season is from October to February. The VBA contains no nesting records on the Bellarine Peninsula. The species is partly migratory between Tasmania and the mainland – some birds migrate to and from Tasmania after breeding each year, leaving Tasmania in March to April and returning in August to October. Aerial sites – 2.7, 3.13, 4.12, 4.6, 7.2, 7.3, 7.5, 8.18, 8.2, 8.4, 9.1, 9.2, 9.5, 10.8, 14.1, 15.8 Ground sites - 3.2 Favours grasslands and grassy woodlands, and inhabits a range of habitats from coastal, sub-coastal and inland areas, right through to semi-arid zones. Often found near wetlands, and in altered environments such as airfields, golf courses and paddocks, where it forages mainly on the ground for grass seeds and seeds of herbaceous plants. Habitat areas at Lake Connewarre, Reedy Lake and Swan Bay are considered to be likely to be important. Also Breamlea Flora and Fauna Reserve. ***Type of exposure*** The preferred habitats for this species are not typically mosquito breeding habitat (e.g. It favours grasslands and grassy woodlands, and is often found near wetlands, and in altered environments such as airfields, golf courses and paddocks, where it forages mainly on the ground for grass seeds and seeds of herbaceous plants), however small portions may be subject to larvicide application (e.g. along the fringes of waterbodies). There is a very low possibility the species may ingest larvicide after contact with preferred food plants (e.g. grass seeds and seeds of herbaceous plants located around the edges of wetlands).	***Frequency*** *(treatments per season (p/s))* – Site: 3.2, 8.14, 8.2, 9.1, 9.2, 9.5 – 1 or <1 p/s. Sites: 2.7, 3.13, 4.12, 4.6, 7.2, 7.3, 7.5, 8.18, 8.4, 10.8, 14.3,15.8 – 2 or more p/s (treatments at least 7 days apart). ***Timing*** Timing and type (e.g. low-level aerial) of treatments will reduce interactions with this species at key sites. Proposed aerial treatments occur between 16 August – 14 March, except Swan Bay, 16 Nov – 14 March. Proposed ground-based treatment between 16 August – 31 May.	**Low risk** The preferred breeding habitats for this species (e.g. tree hollows) are not typically subject to larvicide application. Furthermore, there are no reported nesting records on the Bellarine Peninsula. Species is unlikely to be in regular contact with larvicide as the total area of available habitat in Lake Connewarre, Reedy Lake, Swan Bay and Breamlea Flora and Fauna Reserve where most historical records reside – will not be treated during a single treatment period or over the course of one season. The species may–expand to include sites with suitable habitat without historical records, although a substantial increase in population is unlikely to occur over the life of the proposed action (6 years).

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Growling Grass Frog	***Presence and habitat*** Resident, probably breeding within PAA. Known from 2 sites: Aerial site – 10.8 and Ground site – 5.1. Only known from a few areas on the Bellarine Peninsula. Readily detectable species – records likely to reflect current distribution. Recent and historical records in similar freshwater habitats adjacent sites within Reedy Lake and upstream of the PAA along Barwon River. Large, relatively permanent waterbodies, with a high proportion of emergent vegetation cover are more likely to be occupied by this species. The species is dependent upon permanent freshwater lagoons for breeding (e.g. Reedy Lake/Hospital Swamp and Portarlington Flora and Fauna Reserve). Breeding occurs between November and March. ***Type of exposure*** The application of larvicide will potentially occur within this species' habitat. Although preferred habitats for this species are not targeted for application (e.g. freshwater lagoons with dense areas of emergent vegetation) as treatment it is unlikely to be effective in such habitats, some portions may be subject to larvicide application (e.g. along the fringes of waterbodies). Species unlikely to directly ingest larvicide products – more likely to indirectly ingest product through prey items including various insects and their larvae.	***Frequency*** *(treatments per season)* – Site 5.1 – 1 or <1 p/s. Site 10.8 – 2 or more p/s. Other potential habitats adjacent to site 10.8 ***Timing*** Proposed aerial treatments occur between 16 August – 14 March Proposed ground-based treatment between 16 August – 31 May	**Low risk** Species is resident at a few known habitats within the PAA. Known habitats within the PAA, although few are within treatment sites. Timing of treatments coincides with breeding season of species and there may be a localised reduction in prey availability. However, there are substantial areas of potentially suitable habitat not treated adjacent to treatment areas and in the local area (local area refers to the search area applied to the habitat importance modelling – see section 3.3.3). The Growling Grass Frog, although found within treatment sites is unlikely to breed within the treatment (application) area of the site, given the species' preference for permanent freshwater lagoons with emergent vegetation cover. The Growling Grass Frog feeds on a wide variety of invertebrates, but also small vertebrates including other frogs. The species may indirectly ingest larvicide through prey items however is not reliant on mosquito larvae and chironomids. Relatively long-lived tadpole (>3 months) – may be exposed to larvicide in water. However the habitats for breeding and tadpole development are typically not within the application area of the site therefore unlikely to receive regular direct exposure following treatment or prolonged exposure given short life of treatment products used in these habitats.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Eastern Curlew	***Presence and habitat*** Non-breeding, migratory species occurs in small numbers from August through March within the PAA. Some first-year birds may overwinter. Found across the PAA and known from aerial sites: Aerial – 3.13, 3.8, 4.12, 4.6, 7.5, 8.18, 8.2 and Ground – 4.1, 8.16, 14.1. Within the PAA mainly occurs in estuaries, bays, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass, often near mangroves, on salt flats and in saltmarsh. The species is carnivorous, mainly eating crustaceans (including crabs, shrimps and prawns), small molluscs, as well as some insects. In Victoria, ghost-shrimps are an important part of the diet. Both diurnal and nocturnal, with feeding and roosting cycles determined by the tides. The species finds the burrows of prey by sight during the day or in bright moonlight, but also locate prey by touch. During high-tide periods, the species roosts on sandy spits, sandbars and islets, especially on beach sand near the high-water mark, and among coastal vegetation including low saltmarsh or mangroves. ***Type of exposure*** The application of larvicide will potentially occur within habitat used occasionally by this species, particularly saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour, however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – 4.1, 8.16, 8.2 – 1 or < 1p/s 3.13, 3.8, 4.12, 4.6, 7.5, 8.18, 14.1 – 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most likely to be present within PAA.	**Low risk** Uncommon species that has a widespread distribution across the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets, which are not suitable for mosquito breeding. Some records associated with historical treatment areas. Large areas of suitable habitat located adjacent to treatment sites (e.g. Swan Bay, Barwon River Estuary) and within local area. Species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Habitat for foraging and roosting are typically not within the application area of the site therefore unlikely to receive frequent direct exposure following treatment or prolonged exposure given short life of treatment products used in these habitats.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Curlew Sandpiper	***Presence and habitat*** Non-breeding, migratory species occurs regularly and in moderate numbers from August through March within the PAA. Some first-year birds may overwinter. Found across a range of habitats within the PAA and known from most aerial sites: Aerial – 2.17, 2.7, 3.13, 3.8, 4.1, 4.6, 7.2, 7.5, 8.18, 8.2, 8.4, 9.2, 9.3, 10.8, 11.6, 15.8 and Ground – 1.4 Within the PAA mainly occurs on intertidal mudflats in sheltered coastal areas, such as estuaries, bays, inlets and lagoons, and also around non-tidal swamps, lakes and lagoons near the coast, and ponds in saltworks. The species forages on mudflats and nearby shallow water. In non-tidal wetlands, it usually wades. Birds forage at the edges of shallow pools and drains of intertidal mudflats and sandy shores. At high tide, they forage among low sparse emergent vegetation, such as saltmarsh, and sometimes forage in flooded paddocks or inundated salt flats. Forages mainly on invertebrates, including worms, molluscs, crustaceans, and insects, as well as seeds. Generally roosts on beaches, sandspits and islets in or around coastal or near-coastal lagoons and other wetlands, occasionally roosting in dunes during very high tides and sometimes in saltmarsh. ***Type of exposure*** The application of larvicide will potentially occur within this species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour, however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Most sites treated each season 2.17, 1.4, 4.1, 4.7, 11.6, 2.17, 8.2, 9.2, 9.3, 1.6 – 1 or < 1p/s 2.7, 3.13, 3.8, 4.6, 7.2, 7.5, 8.18, 8.4, 10.8, 15.8 – 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most abundant within the PAA. Proposed aerial treatments occur between 16 August - 14 March, except Swan Bay, 16 Nov - 14 March Proposed ground-based treatment between 16 August – 31 May	**Medium risk** Frequently recorded species with a widespread distribution across the PAA, although most records appear to be associated with tidal habitats (e.g. mudflats), estuary and inlets, which are not suitable for mosquito breeding. However many records associated with historical treatment areas. Species may directly ingest larvicide products because of foraging behaviour (e.g. wading and gleaning in shallow non-tidal waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Habitats for roosting are typically not within the application area of the site. However a portion, albeit probably small area of foraging habitats (e.g. shallow wading habitats) are within the application area of treatment sites. The species is therefore likely to receive infrequent direct exposure following treatment within some of the available habitats within the PAA. However is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the availability of untreated habitats (e.g. species not reliant on or forages entirely within treatment sites).

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Common Greenshank	***Presence and habitat*** Non-breeding, migratory species occurs regularly in relatively small numbers from August through March within PAA. Some first-year birds may overwinter. Common migratory bird species recorded from the PAA and is known from most aerial sites. Found across a range of habitats within the PAA and known from most aerial sites: Aerial – 2.17, 2.7, 3.13, 3.8, 4.12, 4.6, 7.1, 7.3, 7.5, 8.18, 8.2, 8.4, 9.1, 9.5, 10.8, 15.8 and Ground – 1.4 Forages at the edge of wetlands, in soft mud on mudflats and within shallows around the edge of waterbodies often near or among emergent or fringing vegetation such as sedges or saltmarsh. Forages on worms, molluscs, crustaceans, insects and small fish. The species is active day and night. Reported to roost in coastal and inland locations - in estuaries and mudflats, mangrove swamps and lagoons, billabongs, swamps, sewage farms, and flooded crops. Prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation including includes lagoons, swamps, lakes and pools near the coast, and dams. Occur in saltworks and sewage farms. Use intertidal mudflats in sheltered bays, inlets, estuaries and seashores, and also swamps and creeks lined with mangroves. Roosting predominantly occurs at the edges of wetlands, on wet open mud or sand, in shallow water, or in short sparse vegetation, such as grass or saltmarsh. ***Type of exposure*** The application of larvicide will potentially occur within this species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour (i.e. wading through shallow treated pools), however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Most sites treated each season 1.4, 2.17, 4.1, 4.7, 11.6, 2.17, 8.2, 9.1, 9.5, 11.6 – 1 or < 1p/s 2.7, 3.13, 3.8, 4.12, 4.6, 7.1, 7.3, 7.5, 8.18, 8.4, 10.8, 15.8 – 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most abundant within PAA.	**Medium risk** Commonly recorded species with widespread distribution across the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets not suitable for mosquito breeding. Species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Some of the habitats for roosting are within the application area of the site, albeit probably small portion of the overall available roosting habitat within the PAA and local area. A portion of foraging habitats (e.g. shallow wading habitats) are within the application area of treatment sites. The species is therefore likely to receive direct exposure following treatment within some of the available habitats within the PAA. However is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or forages entirely within treatment sites).

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Sharp-tailed Sandpiper	***Presence and habitat*** Non-breeding, migratory species occurs regularly and in relatively large numbers from August through March within PAA. Some first-year birds may overwinter. One of the most common migratory bird species recorded from the PAA and is known from most aerial sites. Found across a range of habitats within the PAA: Aerial – 2.17, 2.7, 3.13, 3.14, 3.8, 4.12, 4.6, 5.1, 7.2, 7.5, 8.18, 8.4, 9.1, 9.2, 9.3, 9.5, 10.8, 11.6, 14.1, 15.8 and Ground – 1.4, 1.7, 4.1, 5.1, 8.16 Prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation including includes lagoons, swamps, lakes and pools near the coast, and dams. Occur in saltworks and sewage farms. Use intertidal mudflats in sheltered bays, inlets, estuaries and seashores, and also swamps and creeks lined with mangroves. Forages on seeds, worms, molluscs, crustaceans and insects. It is recorded to eat selected plant seeds. Roosting predominantly occurs at the edges of wetlands, on wet open mud or sand, in shallow water, or in short sparse vegetation, such as grass or saltmarsh. ***Type of exposure*** The application of larvicide will potentially occur within this species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour (i.e. wading through shallow treated pools), however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Most sites treated each season 1.4, 2.17, 4.1, 4.7, 5.1, 11.6, 2.17, 8.16, 9.1, 9.2, 9.3, 9.5, 11.6 – 1 or < 1p/s 1.7, 2.7, 3.13, 3.14, 3.8, 4.1, 4.6, 7.2, 7.3, 7.5, 8.18, 8.4, 10.8, 14.1, 15.8 – 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most abundant within PAA.	**Medium risk** Commonly recorded species with widespread distribution across the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets not suitable for mosquito breeding. Species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Some of the habitats for roosting are within the application area of the site, albeit probably small portion of the overall available roosting habitat within the PAA and local area. A portion of foraging habitats (e.g. shallow wading habitats) are within the application area of treatment sites. The species is therefore likely to receive direct exposure following treatment within some of the available habitats within the PAA. However is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or forages entirely within treatment sites).
Great Sand Plover, Lesser Sand Plover	***Presence and habitat*** Non-breeding, migratory species occurs in small numbers from August through March within the PAA. Both species considered rare/uncommon and found in few sites within the PAA. Within the PAA mainly occurs in estuaries, bays, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass, often near mangroves, on salt flats and in saltmarsh. ***Type of exposure*** The application of larvicide will potentially occur within habitat used occasionally by this species, particularly saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour, however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Great Sand Plover No historical records with treatment sites Lesser Sand Plover 4.1 – 1 or < 1p/s 4.5, 4.6, 10.8 - 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most likely to be present within PAA.	**Low risk** Both species are rare/uncommon within the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets not suitable for mosquito breeding. Few or no records are associated with historical treatment areas. Substantial areas of un-treated suitable habitat available in the local area. Both species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Great Knot, Red Knot, Bar-tailed Godwit	***Presence and habitat*** All species are non-breeding, migratory and occurs in small numbers from August through March within the PAA. The Bar-tailed Godwit is more common, occurring in greater numbers with a broader distribution across the PAA. Tend to be predominantly coastal, preferring salt-water and estuarine habitats to freshwater habitats. While any of these species may visit some of the treatment sites from time to time, none is expected to be common, except perhaps at Swan Bay. The Swan Bay and Mud Islands area is notable in Victoria as supporting substantial populations of Bar-tailed Godwit and Red Knot. These birds forage in Swan Bay, then return to Mud Islands to roost. ***Type of exposure*** The application of larvicide will potentially occur within habitat used occasionally by this species, particularly the sites around Swan Bay. Species may directly ingest larvicide products because of foraging behaviour, however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Great Knot 0 – 1 or < 1p/s 8.18, 8.4, 10.8 - 2 or more p/s (treatments at least 7 days apart) Red Knot 0 – 1 or < 1p/s 4.12, 4.6, ,8.18, 8.2, 8.4, 10.8 - 2 or more p/s (treatments at least 7 days apart) Bar-tailed Godwit 8.2, 9.1, 9.2, 9.3, 9.5 – 1 or < 1p/s 3.13, 4.6, 7.5, 8.18, 8.4, 10.8, 15.8 - 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most likely to be present within PAA.	**Low risk** The Red Knot and Great Knot are both uncommon within the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets not suitable for mosquito breeding. Few records are associated with historical treatment areas. The Bart-tailed Godwit is more widely distributed across the PAA and has more records associated with treatment sites. Preferred foraging habitats are not treated (e.g. tidal mudflats of Swan Bay), yet it is recognised that all species may directly ingest larvicide products because of foraging behaviour (e.g. occasionally wading through ephemeral shallow waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Red-necked Stint	***Presence and habitat*** Non-breeding, migratory species occurs regularly and in relatively large numbers from August through March within PAA. Some first-year birds may overwinter. One of the most common migratory bird species recorded from the PAA and is known from most aerial sites. Found across a range of habitats within the PAA: Aerial – 2.17, 2,7, 3.13, 3.8, 4.6, 5.2, 7.1, 7.5, 8.18, 8.2, 8.4, 9.1, 9.2, 9.3, 9.5, 10.7, 10.8, 11.6, 14.1, 14.3, 15.8 and Ground – 1.4, 1.7, 4.1 Foraging habitat includes bare wet mud on intertidal mudflats or sandflats or in very shallow water, mostly in areas with a film of surface water and mostly close to edge of water. During high tides, foraging may occur in non-tidal wetlands. May also forage in samphire, generally avoiding beds of seagrass. The species is omnivorous. It jabs and probes with its bill into the soft substrate for small invertebrates. It also gleans from plants in saltmarsh and water, and sometimes eats grit. It forages on plant seeds (e.g Ruppia spp. and Polygonum spp.) and on a range of marine worms, molluscs, snails and slugs, shrimps, spiders, beetles, flies and ants. Roosting predominantly on sheltered beaches, spits, banks or islets, of sand, mud, coral or shingle, sometimes in saltmarsh or other vegetation. ***Type of exposure*** The application of larvicide will potentially occur within this species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Species may directly ingest larvicide products because of foraging behaviour (i.e. wading through shallow treated pools), however unlikely to indirectly ingest product through prey.	***Frequency*** *(treatments per season (p/s))* – Most sites treated each season 1.4, 2.17, 4.1, 4.7, 5.2, 11.6, 2.17, 8.16, 8.2, 9.1, 9.2, 9.3, 9.5, 10.7, 11.6 – 1 or < 1p/s 1.7, 2.7, 3.13, 3.8, 4.1, 4.6, 7.1, 7.5, 8.18, 8.4, 10.8, 14.1, 14.3, 15.8 – 2 or more p/s (treatments at least 7 days apart) ***Timing*** Proposed treatments occur when species is most abundant within PAA.	**Medium risk** Commonly recorded species with widespread distribution across the PAA, with the majority of records associated with tidal habitats (e.g. mudflats), estuary and inlets not suitable for mosquito breeding. However, many records associated with historical treatment areas. Species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). Unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Some of the habitats for roosting are within the application area of the site, albeit probably small portion of the overall available roosting habitat within the PAA and local area. A portion of foraging habitats (e.g. shallow wading habitats) are within the application area of treatment sites. The species is therefore likely to receive direct exposure following treatment within some of the available habitats within the PAA. However is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or forages entirely within treatment sites).

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Resident shorebird/seabird species (Fairy Tern and Eastern Hooded Plover)	***Presence and habitat*** Resident species with records along coastal areas (Swan Bay) and lakes (Lake Victoria, Murtnaghurt) and Barwon River/estuary in the PAA. Neither species is abundant within the PAA. The Fairy Tern does not breed within treatment sites of the PAA. The species nests in small colonies on sandy spits and beaches above the high-water mark in sheltered bays including Sand Island off Swan Bay. Roosts on beaches at night. This species may occasionally forage for small fish in some of the wetlands or coastal areas in the proposed action area, but is unlikely to be a common visitor to the treatment sites. Historical breeding sites for the Eastern Hooded Plover include areas nearby treatment sites including Breamlea Flora and Fauna Reserve. It is unlikely this species would breed within a treatment site. The Eastern Hooded Plover prefers ocean beaches, foraging on the beach and rock platforms, and nesting on the beach above the high-tide mark. Breeding locations for last 10 years restricted to coastal/foreshore habitats. ***Type of exposure*** The habitats of both species are not typically targeted for larvicide treatment. Given the habitat requirements and foraging behavior, neither species is likely to directly or indirectly ingest larvicide product.	***Frequency*** *(treatments per season (p/s))* – The species' habitat is not targeted for treatment however nearby and adjoining areas receive the following treatments p/s: Eastern Hooded Plover 2.17, 8.2, 9.1, 9.2, 9.5 – 1 or < 1p/s 1.7, 2.7, 8.4, 15.8 - 2 or more p/s (treatments at least 7 days apart) Fairy Tern 1.4, 2.17, 8.2 – 1 or < 1p/s 3.13, 3.8, 4.6, 7.2, 7.5, 8.13, 8.18, 10.8, 15.8 - 2 or more p/s (treatments at least 7 days apart)	**Low risk** The Eastern Hooded Plover is a resident shorebird at a few known habitats within the PAA. Breeding is largely restricted to coastal foreshore habitats not within treatments sites. The Fairy Tern may occasionally forage in some of the wetlands or coastal areas in the proposed action area, but is unlikely to be a common visitor to the treatment sites. It does not breed within treatment sites. The habitats of both species are not typically targeted for larvicide treatment. Given the habitat requirements and foraging behavior, neither species is likely to directly or indirectly ingest larvicide product.
Wetland bird species Australasian Bittern, Australian Painted Snipe	***Presence and habitat*** The Australian Painted Snipe is a very rare, nomadic species that prefers larger freshwater wetlands, and occurs singly or in pairs or small groups. This species is mainly crepuscular (active at dawn and dusk), preferring to sit quietly under cover of grass, reeds or other dense cover during day, becoming more active at dawn, dusk and during night. The Australian Painted Snipe eats vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates. This species may turn up at any suitable habitat, but for the most part is unlikely to be present. The Australasian Bittern is a rare, solitary species that eats vertebrates (frogs, birds, mammals, fish) and large macro-invertebrates (e.g., crayfish). It inhabits densely vegetated wetlands, including areas that support taller reeds and rushes. ***Type of exposure*** The application of larvicide will potentially occur within both species habitat. Although preferred habitats for both species are not targeted for application (e.g. freshwater wetlands with dense areas of emergent vegetation) as treatment it is unlikely to be effective in such habitats, some portions may be subject to larvicide application (e.g. along the fringes of waterbodies). Given the habitat requirements and foraging behavior, neither species is likely to directly or indirectly ingest larvicide product.	***Presence and habitat*** 9.1, 9.2 9.5 – 1 or < 1p/s 10.8, 8.18 around site - 2 or more p/s (treatments at least 7 days apart) Note: the Australian Painted Snipe is only known from site 8.18 Only known from a few areas on the Bellarine Peninsula. Readily detectable species - records likely to reflect current distribution. Recent and historical records in similar freshwater habitats adjacent sites within Reedy Lake and upstream of the PAA along Barwon River. Relatively permanent waterbodies, with a high proportion of emergent vegetation cover are more likely to be occupied by both species.	**Low risk** Both species are rare/uncommon within the PAA and are associated with few sites. There are many more records in the local area for both species compared to the PAA. The habitats of both species are not typically targeted for larvicide treatment. The modelled habitat for both species is substantially greater within the local area compared to the PAA. Given the habitat requirements and foraging behavior, the Australasian Bittern is unlikely to directly or indirectly ingest larvicide product. The Painted Snipe is known to occasionally occupy waterlogged grassland or saltmarsh which may be subject to mosquito treatment within the PAA however this does not substantially increase the risk of exposure to larvicide product for this species.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Australian Grayling	***Presence and habitat*** Resident breeding - diadromous, spending part of its lifecycle in freshwater and at least part of the larval and/or juvenile stages in coastal seas. Few records within the PAA limited to Lake Connewarre (although not within treatment area of site 3.13, 10.7) and the Barwon River section between Reedy Lake and Hospital Swamp (although confined to Barwon River section and not within treatment area of site 10.8). Many records upstream of the PAA in the Barwon River. Adults (including pre-spawning and spawning adults) inhabit cool, clear, freshwater streams with gravel substrate and areas alternating between pools and riffle zones**.** During the larval stage, the species is likely to inhabit the Barwon River Estuary and Swan Bay. Omnivorous, feeding on a variety of small aquatic organisms, including crustaceans (such as cladocerans), insects and their larvae and algae. Non-aquatic insects have also been taken from the water surface and small components of plant material, including macrophytes and filamentous algae. ***Type of exposure*** The application of larvicide is unlikely to occur within the species' habitat as it is not considered suitable mosquito breeding habitat. Species highly unlikely to directly ingest larvicide product, however may indirectly ingest larvicide products via prey including non-target insects and their larvae – although this would be a proportion of their diet.	***Frequency*** *(treatments per season (p/s))* – The species' habitat is not targeted for treatment however nearby and adjoining areas receive the following treatments p/s: Aerial sites 10.8 and 3.13 – 2 or more p/s (treatments at least 7 days apart). Noting less than 8% of site 10.8 will be treated each season Most other sites located along the Barwon River/Estuary receive 1 or more treatments per season.	**Low risk** Species is likely to utilise and migrate through a few known habitats within the PAA which are restricted to permanent moving freshwater (adult) or saltwater (larval) waterbodies – not considered suitable habitat for mosquito breeding. Records likely to reflect current distribution of species within the PAA. The species is highly unlikely to occur or breed within treatment sites, given the species' habitat requirements. The species may indirectly ingest larvicide through prey however is not reliant on mosquito larvae and feeds on a wide range of other non-target invertebrates.

MNES species/group	Species presence/habitat/behaviour	How often will sites be treated/timing of treatments – typical season	Risk exposure justification
Yarra Pygmy Perch	***Presence and habitat*** Probably resident breeding - entire lifecycle in freshwater. Few records within the PAA limited to site 10.8 Reedy Lake (not within treatment sites) and 3.7 (Ocean Grove Golf Course Creek). Many records outside of the PAA upstream of Breamlea in Thompson Creek and Waurn Ponds Creek. Occurs in slow-flowing or still waters which possess large amounts of aquatic vegetation (particularly emergent vegetation) such as lakes, ponds and slow-flowing rivers. The diet includes microcrustaceans, molluscs and aquatic insects, including mosquito larvae. ***Type of exposure*** The majority of the habitats occupied by this species within the proposed action area are not typically subject to larvicide treatments as they lack mosquito breeding habitat (e.g. flowing water) or treatment cannot be applied effectively (e.g. areas of dense emergent vegetation). However some areas of Reedy Lake and the Ocean Grove Blue Lake/Golf Course Creek are subject to larvicide treatment. Species highly unlikely to directly ingest larvicide product, however may indirectly ingest larvicide products via prey including mosquito larvae, and other non-target insects and their larvae.	***Frequency*** *(treatments per season (p/s))* – The majority of this species' habitat within the PAA is not targeted for treatment (e.g. all of Reedy Lake) however sites 3.7 is subject to treatment: Site 10.8 – 2 or more p/s (treatments at least 7 days apart). Noting less than 8% of site 10.8 will be treated each season Ground-based site 3.7 – 1 or fewer treatments each season Species may also occur in other parts of the Blue Lakes system.	**Low risk** Species is resident at a few known habitats within the PAA. The majority of habitat within the PAA including Reedy Lake is not treated. Records likely to reflect current distribution of species within the PAA. The species is highly unlikely to breed within treatment sites, given the species' habitat requirements and typical habitats treated (e.g. mostly shallow surface water areas). The species may indirectly ingest larvicide through prey however is not reliant on mosquito larvae and feeds on wide range of other non-target invertebrates.

4.2.2.6.2 Summary of risk assessment

A risk assessment was undertaken to determine those species/fauna groups that may be at greatest risk of indirect or direct exposure to larvicide products during a season and therefore more exposed to the potential impacts of the two larvicide products over the course of the program.

It was determined that the majority of species are at low risk of indirect or direct exposure to larvicide products over the course of each season and the cumulative risk of exposure of the course of the six season program is also low. Key reasons to justify this outcome include:

– The species' habitat is typically not treated (e.g. the Growling Grass Frog, preferred habitats for this species are not targeted for application including freshwater lagoons with dense areas of emergent vegetation) as treatment is unlikely to be effective in such habitats, however it is acknowledged that some portions may be subject to larvicide application (e.g. along the fringes of waterbodies)
– Habitat for foraging and roosting are typically not within the application area of the site (e.g. migratory shorebird species) therefore unlikely to receive frequent direct exposure following treatment or prolonged exposure given short life of treatment products used in these habitats
– There are substantial portions of habitat available within other parts of the proposed action area and local area, often adjacent to the treatment sites (e.g. tidal mudflats of Swan Bay for migratory wader species) that will not be treated each treatment period (on the same day), during the season or over the course of proposed program
– Treatments do not coincide with the breeding season of the species (e.g. Orange-bellied Parrot and migratory shorebirds species) or not targeted at breeding habitat of the species (e.g. hollow-bearing trees for Blue-winged Parrot)
– For species where the timing of treatments coincides with breeding season of species and there may be a localised reduction in prey availability (e.g. Growling Grass Frog), there are substantial areas of potentially suitable habitat not treated adjacent to treatment areas and in the local area.
– Some species may occasionally directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding), but most are unlikely to indirectly ingest larvicide through prey items as most species feed mainly on prey not affected by the larvicide. The species that may indirectly ingest larvicide through prey, however, are not reliant on mosquito larvae and chironomids, and feed on a wide range of other non-target invertebrates
– Most species are not reliant on, or forage entirely within, treatment sites within the proposed action area. Most species are known to use multiple other alternative habitat areas within or nearby the proposed action area

Four species (Sharp-tailed Sandpiper, Curlew Sandpiper, Common Greenshank and Red-necked Stint) were identified as medium risk of indirect or direct exposure to larvicide products over the course of the six season program. Key reasons to justify this outcome include:

– These species occur regularly and in larger numbers across many sites, particularly aerial treatment sites
– These species may directly ingest larvicide products because of foraging behaviour (e.g. wading through ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). However, they are unlikely to indirectly ingest larvicide through prey items as they feed mainly on prey not affected by the larvicide.
– Some of the habitats for roosting are within the application area of the site, albeit a small portion of the overall available roosting habitat within the PAA and local area
– A portion of foraging habitats (e.g. shallow wading habitats) are within the application area of treatment sites. These species may therefore encounter direct exposure following treatment within some of the available habitats within the PAA. However, the species are unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or foraging entirely within treatment sites).

4.2.3 Other impacts

4.2.3.1 Habitat removal or modification

The application of larvicide by drone or hand and monitoring of sites will not require the removal of native vegetation or fauna habitat. It is possible that some maintenance of existing access tracks into ground-based treatment and monitoring sites may be required (e.g. slashing of overgrown tracks and verges), however this will only apply to a few sites each season and be conducted with hand tools (e.g. weed slasher, pruning shears/saw) and kept to a minimum. This activity is highly unlikely to remove or modify any substantial portion of habitat for any MNES or the Ramsar site.

The application of larvicide by drone or hand and monitoring of sites for the purpose of this proposed activity does not require any new structures (e.g. levee or culverts) in waterways or changes to existing structures in waterways. Furthermore, no new artificial waterways or modifications to existing waterways will be required for the application of larvicides. The proposed action does not constitute an activity that will result in a substantial or measurable change to the hydrological regime of the Ramsar wetland or any other wetland (e.g. Breamlea) that supports habitat for MNES within the proposed action area.

Conclusion

The proposed action will not remove or substantially modify any area of habitat for MNES species or any part of the Ramsar site within the proposed action area.

4.2.3.2 Changes to the physico-chemical nature of the proposed action area

The proposed action requires the use of a drone for the application of larvicides. There is potential for the accidental spillage of larvicide during the loading process for both aerial and ground-based treatment processes.

In the case of an accidental larvicide spill, the spill would be contained to a very small area as the hopper used with the drone (container for the larvicide product) is small (e.g. <64 kg). The combined weight of the drone (46 kg), battery and full hopper is up to 110 kg. Furthermore, loading will take place away from waterways. The drone is powered by a series or rechargeable batteries.

All forms of larvicide used for the proposed mosquito management program are delivered in non-liquid form (e.g. granules, sand, pellets or briquets). For aerial application, the product is loaded into the drone hopper at the launch site. For hand delivery at ground-based sites the product is loaded into a backpack and delivered by a duster (granule and/or pellet) or distributed by hand (granule, pellet and/or briquets). Although an accidental spill is highly unlikely, the product is loaded over dry land and therefore quickly recovered. There is some potential for the loading of the product near a waterway at ground-based sites and in the unlikely scenario the product spills into the waterway, it would not need to be recovered given the small spill volume (e.g. 10-15 L backpack) and the short duration over which the larvicide remains active.

Conclusion

Changes to the physico-chemical nature of the proposed action area, including contaminants and pollutants resulting from leaks or spills of larvicide, are highly unlikely. Furthermore, in the unlikely event of a leak or spill, it is unlikely to substantially impact the receiving environment or the MNES within the proposed action area.

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5)

4.2.3.3 Risk of introduction and spread of disease

In response to the 2016 Victorian Auditor-General report on 'Meeting obligations to protect Ramsar wetlands' (Frost, 2016), the recent Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Management Plan was developed and comprised a risk assessment. Priority threats were identified (see 3.3.4) however, one of the key knowledge gaps identified in this risk assessment was 'causes and effects of pathogens and disease on waterbirds (e.g. botulism, avian cholera)' (DELWP, 2018). Consequently, a disease risk analysis (DRA) was undertaken by the IUCN SSC Conservation Planning Specialist Group (Wiethoelter et al 2020). The DRA included a review of available literature on wild bird species, potential pathogens, non-infectious diseases, and other health hazards relevant to the Ramsar site, as well as a stakeholder review process and a 2-day disease risk analysis workshop. A summary of the report and its relevance to the proposed action is provided here.

The DRA provides a systematic, evidence-based process to document and analyse available disease information and develop a risk management plan incorporating the expertise of key stakeholders. The goal of this DRA was to (1) identify and prioritise health hazards for wild birds present at the Ramsar site, (2) identify mitigation strategies and (3) inform further research and/or management needs (Wiethoelter et al 2020). The DRA highlighted the fact that several aspects of diseases in Australian wild birds are poorly understood. There have been very few systematic studies that have proactively screened for potential pathogens and that provide quantifiable data on morbidity and mortality in wild birds. Due to fragmentation of jurisdictions and subsequent sources of data, it was difficult to gain a complete picture of bird mortality and morbidity at this Ramsar site. However many gaps exist due to the incompleteness of databases, difficulties accessing all reported causes of disease and lack of reporting of geographical sources in the literature (Wiethoelter et al 2020).

The DRA focused on 111 infectious and non-infectious health hazards to wild birds through their interactions with the wetlands identified in an extensive review of the literature (Wiethoelter et al 2020) including the Lake Connewarre complex and Swan Bay. To facilitate prioritisation of hazards, wild bird species, which formed the populations of interest, were divided into three groups: shore and water-based, land-based and predatory birds. Hazards that were highest ranked by multiple functional bird groups were assigned a higher weight, resulting in three hazards being selected for a detailed qualitative risk assessment, namely botulism, pasteurellosis, and pollutants and contaminants (Wiethoelter et al 2020). Other high-ranking hazards included Enteric bacteria and Tricomonas (land-based birds) and Myobacteria (shore and water-based bird). Each of the three hazards selected for the qualitative risk assessment is briefly discussed.

Botulism

– The overall risk of botulism to wild birds at the Ramsar site was ranked as high with a high confidence in this DRA risk estimation. Botulism is caused by a toxin produced by *Clostridium botulinum* and causes neurological disease in a range of species. Clostridia are bacteria commonly present in soil and mud that can produce resistant spores, which survive long-term. Avian botulism is present throughout the world and regularly causes bird mortality events (Le Marechal et al., 2016 cited in Wiethoelter et al 2020). While all birds may be affected by it, waterfowl are the most predisposed. In Australia, botulism is seen mainly in Anseriformes and Pelecaniformes during the warmer months (Nov-April) (Grillo et al., 2013, Brandis et al., 2019 cited in Wiethoelter et al 2020).
– *Clostridium botulinum* is probably already in the proposed action area. It was found in sediment samples at Melbourne Water Western Treatment Plant (pers. Comm. W. Steele 28/05/2020 cited in Wiethoelter et al 2020). There was also an outbreak in silver gulls and terns at Mud Island in 2018 (pers. Comm. Parks Victoria and Mark Hawes cited in Wiethoelter et al 2020) and large outbreak was reported at the WTP in 2015-16 with over 3,000 reported mortalities affecting multiple species (e.g. shelduck, silver gull, pelican, white ibis, black swans) and botulism toxin isolated (Whiteley, 2020 cited in Wiethoelter et al 2020).
– Although all birds are susceptible to botulinum toxins, feeding ecology seems to be the main risk factor with omnivorous waterbirds feeding on eutrophic water ponds at highest risk (Rocke and Friend, 1999). Nevertheless, exposure risk also exists for predatory birds and to a lesser extent passerines and psittacines (Rocke, 2006 cited in Wiethoelter et al 2020).
– Dropping water levels leaving edges exposed or other factors may result in decaying vegetation or other organic matter (e.g. dead invertebrates), thereby providing favourable conditions for spore germination, bacterial growth and toxin production. Invertebrates and soil can become contaminated with toxin. Invertebrates may accumulate toxin (Wiethoelter et al 2020).

Pasteurellosis

– The overall risk of pasteurellosis to wild birds at the Ramsar site was ranked as medium with the potential to move to high risk (based on overseas experience) with a low-medium confidence in the DRA risk estimation. Pasteurellosis, also known as avian cholera or fowl cholera, is caused by the bacterium *Pasteurella multocida*. Different strains of *P. multocida* cause disease in many vertebrate species, including humans. Avian pasteurellosis is transmitted via close contact, inhalation or ingestion. The bacteria are shed in all bodily secretions, especially in faeces. Birds that recover are considered to have life-long infections and continue to shed (Botzler, 1991, cited in Wiethoelter et al 2020).

– Endemic disease in poultry (chickens, ducks, turkeys) occurs in Australia (Singh et al., 2013, cited in Wiethoelter et al 2020) and Victoria (Agriculture Victoria, 2020 cited in Wiethoelter et al 2020), but has rarely been diagnosed in waterbirds in Australia, probably due to inadequate surveillance. It has been detected at Melbourne Water Western treatment plant and elsewhere in Victoria in a chestnut teal, a black swan and Eurasian coots.
– An outbreak is most likely triggered via introduction of the pathogen through carrier birds or potentially other animals (Botzler, 1991, Samuel et al., 2007, Singh et al., 2014, cited in Wiethoelter et al 2020). Ongoing transmission is driven by environmental contamination of soil and water caused by contaminated carcasses (Blanchong et al., 2006, cited in Wiethoelter et al 2020). There may also be a significant role for other species (e.g. predators/scavengers like foxes, cats, rodents) in the transmission of *P. multocida* between animals in both directions (Singh et al., 2014 cited in Wiethoelter et al 2020).

Pollutants and contaminants

– The overall risk of pollutants to wild birds at the Ramsar site is ranked as high with a high confidence in the DRA risk estimation. Pollutants encompass a wide variety of chemicals that may contaminate wetland environments from many different sources including water run-off, sewage and direct contamination of waterways and land environments. The broad groups that were considered included heavy metals, pesticides (including insecticides, herbicides, fungicides and persistent organic pollutants such as DDT), fertilisers and other agricultural chemicals, PFAS, pharmaceuticals and anticoagulants (Wiethoelter et al 2020). Note the use of larvicides was not mentioned.
– Many of these chemical compounds are stable in the environment and cause persistent contamination leading to biomagnification and bioaccumulation through food chains
– The Lake Connewarre complex and Swan Bay is surrounded by agricultural land and residential areas and is likely to result in historical and continuing runoff of agricultural chemicals as well as heavy metals and trace elements from soil works and other sources (e.g. quarries)

The DRA considered potential transmission pathways for infectious disease between and amongst the populations of interest. Wild birds at this Ramsar site are highly mobile. Some species migrate across Australia and along international migratory bird flyways, while interacting with other wildlife (mammals, reptiles, amphibians, fish, and insects), domestic animals, and humans. These interactions provide potential transmission pathways for infectious diseases. Infectious and non-infectious diseases therefore not only represent significant health hazards to birds, but also potentially to other wildlife, domestic animals, humans, and the catchment area ecosystems. The possible spectrum of interactions between wild birds and in-contact species at the Ramsar site is diverse, including:

– Some infectious diseases included in the hazard list are zoonotic, which means they are transmissible between animals and humans
– Other diseases (so-called vector-borne diseases) are transmitted by vectors such as mosquitoes, ticks, and fleas
– Anthropogenic activities at or near this Ramsar site include boating, fishing, bait collection, swimming, walking, nature observation, research, birdwatching, (duck) hunting as well as sewerage treatment, agriculture, and salt production

The development and implementation of a comprehensive surveillance program to monitor syndromes, diseases and mortality events for early diagnoses and response as well as providing wildlife health baseline data would not only mitigate the risk of botulism, pasteurellosis, pollutants and contaminants, but also address other causes of mortality and morbidity.

Conclusion

Diseases are known to occur in the project area, but the proposed action is very unlikely to introduce a new disease, or exacerbate an existing disease, that causes an MNES species including wild bird populations known or likely to occur within the proposed action area to decline. The activities associated with the proposed action, including the treatment of sites using drone and by hand or vehicle, are unlikely to introduce a new disease.

The DRA notes that at least two serious diseases (botulism and pasteurellosis) have been detected within the broader Ramsar site, with several others also detected (e.g. low pathogenic avian influenza, poxvirus, psittacine beak and feather). For the purpose of this report, both botulism and pasteurellosis are assumed as present within the treatment sites. The activities of the proposed action, including the application of larvicide by drone or ground-based methods, are unlikely to substantially spread or indirectly contribute (e.g. secondary toxicity) to the prevalence of these diseases which are already within the area. It is possible that, during hand and/or vehicle application, dirt/mud containing the spore of clostridia bacteria could be spread from one site to another (e.g. on shoe or vehicle tyres); however this only appears likely under favourable conditions (e.g. seasonal and environmental factors). Furthermore, the City undertakes hygiene control measures when treating ground-based sites to prevent the spread of weeds and diseases including: use of protective, disposable covers and removal of dirt from other items of clothing with antibacterial solution before treatment of next site. Vehicles are also parked away from the treatment area of the site and City staff actively avoid driving off track onto muddy areas. If dirt/mud does accumulate on tyres, it is removed and the tyre is washed before treating the next site.

As stated in the DRA, hazard exposure is not continuous, it is affected by seasonal, environmental factors, and can follow other causes of mortality resulting in decaying carcases that provide additional sites for clostridial growth and toxin production (Anza et al., 2014, Soos and Wobeser, 2006, Vidal et al., 2013 cited in Wiethoelter et al 2020). The exposure is likely to increase due to climate change, increasing predisposing environmental factors and, at the same time, leading to higher bird densities at the site due to its nature as a drought refuge for birds due to tidal zones and constant water influx from the Western Treatment Plant. However some parts of the Ramsar site, including Point Cook and Swan Bay, are potentially of lower risk due to their intertidal ecology and the high salinity of the water (Wiethoelter et al 2020).

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5).

4.2.3.4 Risk of introduction and spread of environmental weeds

Environmental weed species, including pest weed species, are considered a key threat to the values of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site and habitat for some MNES species.

An assessment of the vegetation condition at the Ramsar site undertaken in 2010 (Sinclair 2010) revealed that much of the vegetation assessed within the Ramsar site is degraded, by a range of factors including weed invasion and losses of native species diversity. There are at least 53 known weed species within the proposed action area (Bellarine Landcare Group, 2018). Some species are widespread, others have a restricted distribution and their impacts, though serious, may be localised. See section 3.3.5 for a list of weeds.

It is unlikely that, during drone or hand and/or vehicle application, dirt/vegetation containing weeds would be spread from one site to another (e.g. on shoe or vehicle tyres). The City undertakes weed hygiene procedures, including regular inspection of drones and vehicles and use of protective, disposable covers for boots. Vehicles are also parked away from the treatment area of the site and City staff actively avoid driving off track onto muddy areas. If dirt/mud does accumulate on the tyres, it is removed and the tyre is washed before treating the next site.

Conclusion

The proposed action is very unlikely to introduce a weeds that cause an MNES species known or likely to occur within the proposed action area to decline. The activities associated with the proposed action, including the treatment of sites using drone and by hand or vehicle, are unlikely to spread existing weeds or introduce a new weed species.

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5)

4.2.3.5 Risk of introduction and spread of pest animals

Six pest animal species (Red Fox, European Rabbit, Feral Cat, European Carp, Goldfish and Eastern Gambusia – section 3.3.5) are known to be present and have established populations within the proposed action area. The activities of the proposed action are unlikely to interact with or create a situation (e.g. modify existing habitats) that would be favourable for further spread of the existing populations of Red Fox, Feral Cat or European Rabbit.

Eastern Gambusia (mosquito fish), are known from the Lake Connewarre Complex and most likely occur in other water bodies of the proposed action area. Of the eight species of exotic fish recorded in the broader Ramsar site, the most concerning are the European Carp, Goldfish and Eastern Gambusia (Dahlhaus and Reeves 2013). Activities that that are known to spread pest fish include transferring fish or eggs via water transfers or transfer of juveniles or eggs attached to aquatic weeds, waders or boots.

Conclusion

It is highly unlikely that any of the activities associated within the proposed action would increase the risk of spread of the Red Fox, European Rabbit or Feral Cat. Furthermore, the activities associated with the proposed action do not include activities that would facilitate transport or spread of pest fish species, such as Gambusia, Goldfish or European Carp.

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5).

4.2.4 Potential cumulative impacts over the expected timeframe of the program

Cumulative impacts are broadly described as the combined impacts of one or more activities, such as mining, agriculture and urbanisation, on the environment, society and the economy (Franks et al. 2010). Cumulative impacts typically result from the collective and interacting effects of multiple stressors, and often arise from multiple sources of multiple activities (Hodgson et al. 2019). For example, collective impacts of stressors such as degradation of waterways and habitat removal from several adjacent activities such as agriculture and urbanisation may combine with the identified potential impacts to cumulatively impact on valued assets (e.g., MNES) within the proposed action area.

For the purposes of this assessment, cumulative impacts are defined as the potential combined impacts within the reasonably foreseeable future, including the proposed action and other activities within the proposed action area over the course of the six-year program that may cumulatively impact on the MNES discussed in this report.

The following process was undertaken to understand the potential extent of cumulative impacts within the proposed action area:

1. Review of other activities within or adjacent to the proposed action area (section 4.2.4.1) including:
    a. Identify controlled actions within the proposed action area, proposed by others, through a desktop review process of the DCCEEW EPBC Act Public Portal All Referrals database (Table 46) (DCCEEW n.d.a) and Australian Governments National Map *EPBC Referrals Web Map Service* Table 47) (Australian Government n.d.) – that have been recently approved (dating back to 2018), in construction or construction complete and now in operation.
    b. Review the identified activities and proposed impacts with regard to relevant MNES
2. Review of the potentially cumulative nature of project specific impacts (section 4.2.4.2)
3. Discuss the potential impacts of the other proposed activities with consideration to the proposed impacts of this action and cumulative impacts.

4.2.4.1 Review of other activities within or adjacent to the proposed action area

DCCEEW's EPBC Act referral database and Australian Government's National Map EPBC Referrals Web Map Service were used to identify other projects with potential to cause impacts within the vicinity of the Mosquito Management Program area. The EPBC Referrals Web Map Service provides locations of referrals submitted to the Department under the EPBC Act. Proponents (i.e., those proposing a development) must supply the maximum extent (location) of any proposed activities that need to be assessed under the EPBC Act through an application process.

It should be noted that not all referrals captured within the Referrals Spatial Database are assessed and approved by the Minister for the Environment; some are withdrawn before assessment takes place.

Table 46 Desktop review of DCCEEW referral database and National Maps to inform cumulative impact assessment 2018-2024

Source	Search	Summary of results	Relevance to proposed action
DCCEEW, EPBC Act referrals list - **https://epbcpublicportal.awe.gov.au/all-referrals/**	A review of referrals from the start of 2018 to date was undertaken for projects within the proposed action area with a focus on impacts to MNES discussed in this report including Ramsar wetlands, listed threatened species and communities and migratory species. Key words using partial and full text search function of the database in the jurisdiction of Victoria included: Geelong, Bellarine, Surf Coast, Lake Connewarre, Reedy Lake, Portarlington, Ocean Grove, Breamlea, Swan Bay, Queenscliff, Barwon, mosquito	Three projects listed: – 2023/09724 – Barwon Heads Road Reserve Road to Lower Duneed Road Upgrade Project. Approval level: referral decision. Status: Referral Published. – 2022/09288 – Geelong Hydrogen Hub. Assessment level: referral decision. Status: Referral Published. – 2020/8835 – DIDR01 Wetlands, Barwon Heads Road, Armstrong Creek. Assessment level: Post approval Status: Not a controlled action if undertaken in a particular manner. – 2020/8737 – Barwon Heads Road Settlement Road to Reserve Road Duplication Project. Assessment level: Post approval Status: Not a controlled action if undertaken in a particular manner. – 2018/8375 – Water Management and Use/1-87 Groves Road, Armstrong Creek/Charlemont, VIC, 3217/Victoria/Sparrovale Wetland stormwater management, Armstrong Creek and Charlemont. Assessment level: Completed Status: Not a controlled action.	None of the listed projects will contribute cumulatively to impacts resulting from the project in the proposed action area

Table 47 EPBC Referrals identified within the vicinity of the Mosquito Control Project using the Australian Government's National Map EPBC Referrals Web Map Service 2018-2024

Reference number	Name	Referral decision – status	Stage	Year	Category
2017/8127	INDIGO Central Submarine Telecommunications Cable	Referral Decision Made – Not Controlled Action	Completed	2018	Telecommunications
2018/8375	Sparrovale Wetland stormwater management, Armstrong Creek and Charlemont, VIC	Referral Decision Made – Not Controlled Action	Completed	2018	Water Management and Use

Referral 2023/09724 – Barwon Heads Road Reserve Road to Lower Duneed Road Upgrade Project

The proposed action is the upgrade of 6 km of Barwon Heads Road between Reserve Road, Charlemont, and Lower Duneed Road, at Armstrong Creek.

The referral identifies relevant MNES to the proposal including the Growling Grass Frog, Yarra Pygmy Perch, Latham's Snipe and White-throated Needletail.

Although the Growling Grass Frog and Yarra Pygmy Perch were identified as relevant MNES, significant impacts to both were considered unlikely with mitigation measures. EPBC Act listed migratory species, Latham's Snipe (now listed as Vulnerable, but not listed at the time of referral) and White-throated Needletail were assessed as potentially occurring within the project area. A significant impact on Latham's Snipe and White-throated Needletail is considered unlikely both with and without mitigation. Furthermore, the proposed action will not impact what is likely to constitute 'important habitat' for Latham's Snipe at Warralily Wetlands, which is located to the west of the project. Latham's Snipe were not detected in the project area during targeted surveys and it is unlikely there will be changes to water quality at Warralily Wetlands during construction and operation of the project.

Significant impact to White-throated Needletail is not expected given the almost exclusively aerial nature of the species and the availability and extent of forest habitat in the region for the species.

No significant direct or indirect impacts to any MNES are anticipated to occur. The Barwon Heads Road Reserve referral does not overlap with the City's Mosquito Management Project, and it is unlikely to contribute to a cumulative impact, as the City's project does not involve direct loss of habitat.

Referral 2022/09288 – Geelong Hydrogen Hub

This referral is for the development of a facility to import bulk liquid green ammonia and produce hydrogen and nitrogen b ammonia decomposition and distribute the green hydrogen to gas market participants for blending with natural gas and to industrial offtake users within the Port of Geelong or its immediate vicinity. The assessment of this referral is expired.

The proposed is located at 138/140 Corio Quay Road, approximately 8 km from the project area. The referral is located in an industrial and port area in Geelong. The area surrounding the port is heavily developed and industrial, with current nearby operations comprising an oil refinery, cement manufacture and clinker grounding, and fertiliser manufacture.

A botanical field assessment was completed, during which no EPBC Act-listed ecological communities were found within the Geelong Hydrogen Hub project area. The assessment did not identify any threatened flora species within the project area, nor were any threatened flora species considered likely to occur there, due to the limited extent of remnant native vegetation and highly modified area of the site.

A total of 54 threatened fauna species listed under the EPBC Act were identified by terrestrial and marine ecology desktop assessments as having the potential to occur in the project area (inclusive of a 10 km and 2 km buffer for terrestrial and marine, respectively). Of the 54 species, one was recorded within 500 m of the project area, the Fairy Tern, which is listed as vulnerable under the EPBC Act. However, the Fairy Tern was considered unlikely to rely on habitat within the project area.

This referral is not in the mosquito management proposed action area, and is not anticipated to impact the City's proposal, as the Fairy Tern is unlikely to rely on habitat within the project area. The referred area is approximately 18 km away from Hospitals Swamp.

Referral 2020/8737 – Barwon Heads Road Settlement Road to Reserve Road Duplication Project

This proposal is for the duplication of approximately 4 km of Barwon Heads Road between Settlement Road, Belmont and Reserve Road, Charlemont, Victoria and is located approximately 5 km north of Hospitals Swamp.

The referral identifies MNES relevant to the proposal including the Growling Grass Frog, Yarra Pygmy Perch, Eastern Dwarf Galaxias and Latham's Snipe and migratory bird species associated with Waurn Ponds Creek and Jerringot Wetlands. DAWE (now DCCEEW) assessed and approved the proposal, concluding that the proposed action was not a controlled action, provided it was undertaken in the manner set out in the decision notice.

The proposal will result in clearing of approximately 0.04 ha of wetland habitat in the south-western corner of Jerringot Wetlands. The Proponent will apply construction programming constraints, such that works directly adjacent to the wetlands will not occur during the months when EPBC listed migratory birds are utilising the wetlands. The referral also identifies impact avoidance and reduction measures to minimise footprint disturbance.

Despite the proposal being located outside and beyond the City's proposed action area, there are two common habitat areas potentially impacted by this proposal and the City's proposed action. These include Waurn Ponds Creek, which is traversed by the existing road, and Belmont Common/Jerringot Wetlands which is located adjacent to the northern end of the City's proposed action area.

This proposal will include the direct loss of 0.04 ha of wetland habitat for a few EPBC Act listed species, while the City's proposed action does not involve direct loss of any habitat. The cumulative contribution of the City's proposed action to this proposal of the Barwon Heads Road Settlement Road to Reserve Road Duplication Project is expected to be negligible.

2018/8375 – Water Management and Use/1-87 Groves Road, Armstrong Creek/Charlemont, VIC, 3217/Victoria/Sparrovale Wetland stormwater management, Armstrong Creek and Charlemont.

The assessment of this referral is complete and the Department has determined that the project is not a controlled action.

The site area, although not in the proposed action area, shares a boundary with Hospitals Swamp, Lake Connewarre and the Barwon River. The site is to be used as part of a drainage solution for urban growth areas within Mount Duneed, Armstrong Creek and Charlemont, Victoria. Specifically, an existing wetland known as 'Sparrovale Wetland' (which occurs within 1-87 Groves Road and 109-215 Sparrovale Road), is proposed to receive drainage services from these growth precincts as part of the water sensitive urban design of the Armstrong Creek and Horseshoe Bend growth areas. Water within Sparrovale Wetland can then be directed, as required, into Hospitals Swamp and Lake Connewarre, or retained within Sparrovale Wetland, via a re-instated channel.

The site is partly contained within, and is directly upstream of, the Port Phillip Bay Western Shoreline and Bellarine Peninsula Ramsar wetland. This Ramsar site comprises a number of interconnected wetlands within the vicinity of the proposed action, referred to hereafter as the 'Ramsar Complex', which includes Lake Connewarre (directly downstream of the proposed action) and Hospitals Swamp (directly downstream of a related action), in addition to a number of other wetlands less connected to the site (including, but not limited to, Reedy Lake, Salt Swamp and Murtnaghurt Lagoon). The primary aim of the action is to mitigate impacts to the Ramsar Complex through the management of inflows.

The referral considered the removal of 1.1 ha of the Ramsar site in order to re-instate a drainage channel, changes to the hydrological regime of the wetland, water quality of the wetland, impacts to habitat for various threatened flora and threatened and migratory fauna species including the Orange-bellied Parrot, Growling Grass Frog and Australian Grayling.

The referral concluded that action is not considered likely to have a significant impact on any Matters of National Environmental Significance following a review of MNES that are known from or likely to occur within the site, including the Orange-bellied Parrot, Australasian Bittern, Australian Painted Snipe, Yarra Pygmy Perch, Australian Grayling and Growling Grass Frog and the Ramsar site.

The project will include the loss of 1.1 ha of wetland and habitat for a few EPBC Act listed species, while the City's proposed action does not involve direct loss of any habitat. The project will also result in changes, albeit not significant, to the hydrological regime of the Ramsar wetland, noting it is the intention of the project to mitigate impacts to the Ramsar Complex through the management of inflows.

Given the above understanding of this project, cumulative impacts on MNES of this action in combination with the City's proposed action are highly unlikely.

4.2.4.2 Project specific cumulative impacts

This section assesses the potential for cumulative impacts to occur over the six-year duration of the City's proposed action. Consideration has been given to the following over the course of the six season (year) program when assessing the potential for significant cumulative impacts:

– Application rates – how much product is applied
– Timing between treatments within a season and between seasons
– Life of product used in key habitat areas
– Ability of mosquito population to recover, useful surrogates for other non-target invertebrates
– Local recruitment of non-target organisms within larger sites
– Number of sites with MNES values and number of sites with little or no value for MNES
– Availability of suitable habitat within larger sites and local area
– Risk of exposure for each MNES species

S-methoprene is widely accepted to be non-toxic to higher vertebrates, including birds and mammals (and humans), following "repeated, comprehensive toxicological evaluations of 241ethoprene and S-methoprene over several decades" (Siemering et al. 2005). The most often reported concern regarding 241ethoprene is its non-specificity in the aquatic environment. S-methoprene can negatively impact non-target insect larvae, crustaceans, and potentially amphibians and fish (Kuo et al., 2010, in Staples 2016). However, Methoprene's low persistence in the environment reduces the potential for impacts on non-target organisms and evolution of resistance (Wolterink et al. 2001, in Fuessel 2013), and Glare and O'Callaghan (1999) noted that, while negative impacts on some organisms were observed, recovery after application was rapid.

Bti has been used as a larvicide for decades. Exhaustive laboratory tests, necessary for the registration of Bti as a commercial product, have widely confirmed Bti as being relatively safe for vertebrate fauna, most non-target invertebrates, and the environment. The insecticidal crystal proteins target specific parts of specific larval insects with no harmful effect on vertebrates. However, there are non-target effects in some chironomid species – chironomids are closely related to mosquitoes. Perhaps the greatest concerns for Bti are:

– The potential for indirect food-chain effects reported for birds (House Martins)
– Potential sub-lethal behavioural responses by tadpoles and chironomids
– Potential decline of chironomid populations after Bti treatment, as shown in some studies

However, for all areas of concern, there are other studies that show contrasting results, and no area of concern has been conclusively demonstrated or reinforced by additional studies from other systems, so conjecture remains. Furthermore, there appear to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.

The most closely aligned application of S-methoprene and Bti was by the Shire of Busselton for larvicide treatment in the Ramsar-listed Vasse-Wonnerup Wetlands in Western Australia. Reports from a seven-year investigation relating to that application have consistently concluded that there was no evidence of adverse impacts of larvicide use on non-target aquatic invertebrates – community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application (Paice 2016). However, Paice (2016) suggested that continued sampling was required to achieve more confidence in the conclusion for Bti.

Almost all the literature reviewed concluded that S-methoprene and Bti are not directly toxic to vertebrates when applied at the recommended application rates. The effects of S-methoprene on non-target invertebrates are likely inextricably linked to application dose. Higher application doses are more likely to result in non-target invertebrate effects. However, when used at recommended application rates (e.g., as per those recommended by APVMA), the literature generally concludes that there is a low risk to non-target species, including estuarine invertebrates. Low persistence in the environment (when used at recommended does rates) means that impacts on water quality are low.

The City intend to apply 1.701 kg of S-methoprene and 117.755 kg of Bti to 690.87 ha of treatment area (aerial and ground-based treatment sites combined) per season, of which 670.52 ha is within or adjacent to the Ramsar site. Using the actual ingredient calculation presented in Table 18 and Table 20, the maximum intended application (cumulative total for the six season program) for S-methoprene and Bti is 2551.041 kg and 24829.549 kg respectively over 3279.72 ha, of which 3208.91 ha occurs within or adjacent to the Ramsar site. The doses used historically, and proposed for continued use, by the City are invariably low, compared with lethal doses identified from the review of literature (see 4.2.2). Furthermore, it is important to note that none of the aerial sites were treated during the 2021-2023 season meaning at least 41 months will pass between the last treatment (March 2021) and the next treatment opportunity (August 2024).

Table 17 and Table 19 provide a summary of the aerial and ground-based treatment sites with MNES values and number of treatments proposed for each site during a typical season. Table 39 and Table 40 provide additional detail regarding the MNES values at each site. Assuming a typical treatment season occurs, the City propose to complete 924 treatments across the six year program, of which up to 612 treatments or 66% will be within sites with MNES values for the six season program. During a typical treatment season, 28 of the 52 sites will receive one or fewer treatments per season (for example, some sites treated once every two to three years) (Table 16). This would result in a gap of at least six months between treatments for the majority of sites, allowing for a period of recovery and recruitment by targeted and non-targeted organisms. Of these 28 sites, 18 have documented MNES value Table 40. Of the 24 remaining sites that will or may receive two or more treatments per season, 23 have documented MNES values (Table 40). This scenario of multiple treatments per season is more likely to occur every two to three years. Although the time between each treatment within a season is reduced (e.g. at least seven days between treatments for Bti and 14 days for S-methoprene), there is at least a five-month period between seasons for aerial sites and at least three months between seasons for ground-based sites with no treatments.

Not all available mosquito habitat within the proposed action area is treated each season and therefore large areas of untreated habitat remain for mosquitos, natural mosquito predators and threatened and migratory species, as discussed in this report. For example, the total area of sites including Ramsar wetland within the proposed action area is 3279.72 ha. The seasonal treatment area of all sites (including sites within and outside the Ramsar site) is 690.87 ha and the seasonal treatment area of all sites within the Ramsar site is 670.52 ha (approximately 20% of the reported Ramsar site area within the proposed action area). The area of untreated habitat is much larger than the area being treated, for any one treatment per season and over the six-year course of the proposed action. Also, it is highly unlikely that the exact same area within each site will be treated each time. The following site-specific examples include some of the largest areas of Ramsar site and habitats known for regularly supporting larger numbers of multiple threatened and migratory species:

– Site 10.8 Reedy Lake margins is 817.5 ha in area and within the Ramsar site. The seasonal treatment area is 65.64 ha or 8% of the site and the cumulative program treatment area is 393.81 ha. A very small portion of this site will be treated each season with extensive portions of habitat suitable for MNES, including mosquito breeding habitat, not treated over the course of the program.
– Site 8.18 Salt Swamp within the Ramsar site occurring at the back of Lake Connewarre Swamp is 452.5 ha. The typical seasonal treatment area is 12.60 ha or 2.8% of the site. The cumulative program treatment area is 50.41 ha. A very small portion of this site will be treated each season with extensive portions of habitat suitable for MNES, including mosquito breeding habitat, not treated over the course of the program.
– Site 3.13 Lake Connewarre East is 341.9 ha in area. This site is part of the larger Lake Connewarre area at c. 880 ha and within the Ramsar site. The typical seasonal treatment area is 35.08 ha or 10.26% of the site. The cumulative program treatment area is 210.45 ha. Although not all of Lake Connewarre is considered suitable mosquito breeding habitat due to it being tidal and deep in parts, extensive portions of habitat suitable for MNES, including the western shoreline, will not be treated as part of the proposed action.
– Site 7.5 Swan Bay North Jetty North and South side is 161.40 ha in area. This site is part of the larger Swan Bay area at c. 3000 ha and within the Ramsar site. The typical seasonal treatment area is 93.33 ha or 57.80% of the site. The cumulative program treatment area is 559.99 ha (noting that other treatment sites occur within the Swan Bay area). Although not all of Swan Bay is considered suitable mosquito breeding habitat due to it being tidal and deep in parts, extensive portions of habitat suitable for MNES, including tidal areas/mudflats, will not be treated as part of the proposed action.
– Site 15.8 Breamlea Tidal Wetland Lakes is 176.1 ha in area and is part of the larger Breamlea Flora and Fauna Reserve and foreshore reserve, but not within the Ramsar site. The seasonal treatment area is 16.45 ha or 9.34% of the site and the cumulative program treatment area is 98.73 ha. A small portion of this site will be treated each season with large portions of habitat, including mosquito breeding habitat, not treated over the course of the program.

The examples cited above combine to form 32% of the seasonal and cumulative program treatment areas. With consideration of the larvicide application, including the frequency of treatments and area treated within the proposed action area, the recolonisation by affected non-target organisms is likely from surrounding untreated areas. Consequently, long-term negative effects to ecosystem function from short-term loss of a portion of the local invertebrate fauna are not expected within the proposed action area or within the local area. Furthermore, recolonisation of sites by targeted mosquitos themselves, thereby requiring repeated treatments, demonstrates that successful recolonisation does and will continue to occur at sites.

A risk assessment was undertaken to determine those species/fauna groups that may be at greatest risk of indirect or direct exposure to larvicide products during a season and therefore more exposed to the potential impacts of the two larvicide products over the course of the program. It was determined that the majority of species, with the exception of four (Sharp-tailed Sandpiper, Curlew Sandpiper, Common Greenshank and Red-necked Stint), are at low risk of indirect or direct exposure to larvicide products over the course of each season, and the cumulative risk of exposure of the course of the six season program is also low. The four species were identified as medium risk of indirect or direct exposure to larvicide products over the course of the six season program, although over the course of a typical season the risk is considered to be low. Key reasons to justify these conclusions are provided in section 4.2.2.6.

4.2.4.3 Conclusions

The potential for intrinsic or extrinsic cumulative impacts (direct and indirect) over the six year mosquito management program is expected to be negligible for the following key reasons:

– No other project identified from the review resulted in significant impacts or controlled actions. Other projects proposed direct and indirect impacts in areas outside the mosquito program's proposed action area.

– Other projects proposed minor impacts on a few of the same MNES potentially impacted by the City's proposed action. The potential for cumulative impacts on MNES by these projects, in combination with the proposed action, is expected to be low or negligible.

– No habitat will be directly removed or modified by the proposed action over the course of the six-year program

– The intended seasonal application of at 1.7 kg of S-methoprene and 117.7 kg of Bti to 690.87 ha of treatment area (all sites combined) and the maximum intended application (cumulative total for the six season program) of 2551.041 kg of S-methoprene and 24829.549 kg of Bti over 3279.72 ha proposed by the City are relatively low, compared with harmful or lethal doses identified from the review of literature

– Although there are knowledge gaps regarding the use of the larvicide products as identified by the literature review (e.g. potential for long-term endocrine disruption from the use of S-methoprene, potential for larvicides to accumulate in the food web), the potential direct impacts on MNES as a result of the proposed action are in part mitigated by the following key factors:

  - There are substantial time periods where no treatment will occur at 28 of the 52 sites, of which 18 have documented MNES value. This would result in a gap of at least six months between treatments for the majority of sites allowing for a period of recovery and recruitment by targeted and non-targeted organisms.
  - Not all available mosquito habitat is treated each season within the proposed action area – large areas of untreated habitat will remain for mosquitos, natural mosquito predators and threatened and migratory species. The area of untreated habitat is much larger than the area being treated, for any one treatment season or over the six-year course of the proposed action.
  - Affected non-target organisms are likely to recolonise from surrounding untreated areas, and long-term negative effects to ecosystem function from short-term loss of a portion of the local invertebrate fauna are not expected within the proposed action area or within the local area
  - The majority of species are considered to be at low risk of indirect or direct exposure to larvicide products over the course of each season, and the cumulative risk of exposure of the course of the six season program is also low

- Four species were identified to be at medium risk of indirect or direct exposure to larvicide products over the course of the six season program, but it was determined that each species is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species are neither reliant on, nor forage entirely within, treatment sites)

Therefore, the impact to criteria 2, 3, 4, 5, 6 and 8 are considered to be low to negligible, with avoidance and mitigation measures in place (details of avoidance and mitigation discussed in section 5).

4.2.4.3.1 Potential facilitated impacts

A potential facilitated impact is defined as "consequences of actions taken by third parties (also known as secondary persons), where the third-party action is facilitated to a major extent by the primary action, and the impacts of the third-party action could be reasonably foreseen. For example, when constructing a dam to facilitate the use of water by irrigators, the associated impact of the irrigators' water consumption on water quality or the aquatic environment could be called a facilitated impact." (DCCEEW n.d.b).

Facilitated impacts as a result of the City's proposed action are not expected. No other associated or ancillary activities would occur connected to the proposed action.

4.3 Summary of potential impacts and conclusions

Table 48 presents a summary of potential impacts from the proposed action on relevant listed threatened species, migratory species and/or the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site. For each of the potential impacts, there is a summary of MNES considered most at risk, likelihood of the impact occurring, and the predicted consequence (low, medium, high) with regard to MNES.

Table 48 Summary of potential impacts on MNES from the proposed action

Potential impact	MNES most at risk	Likelihood of impact and justification	Consequence
Drone operations			
Drone disturbance – disturbance to fauna as a result of noise or vibration caused by the drone whilst deploying product	Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Blue-winged Parrot. (Orange-bellied Parrot at very low risk because drone will operate outside the birds' Victorian season).	Likely - Aerial application of larvicide by drone within the proposed treatment sites is likely to result in very localised and short-term disturbance. The temporary disturbance is expected to affect a very small portion of the overall population of any MNES within the proposed action area. Some (e.g., Orange-bellied Parrot) will not be affected at all due to the seasonal timing of treatments. A review of similar operations within Australia has revealed similar findings.	Low – significant impact on MNES unlikely
Collision risk – drone may collide with fauna species whilst deploying product	Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Blue-winged Parrot. (Orange-bellied Parrot at very low risk because drone will operate outside the birds' Victorian season).	Unlikely – No bird strike reported to date for the City's historical helicopter operations or during drone trials. No collision events or near misses reported during local surveys. A review of similar operations in Australia did not report any collision events using drones.	Low – significant impact on MNES unlikely

Potential impact	MNES most at risk	Likelihood of impact and justification	Consequence
Application of larvicides			
Direct ingestion of or exposure to larvicide product	Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot and Growling Grass Frog. (Orange-bellied Parrot at very low risk. The program will operate outside the birds' Victorian season).	Likely/possible - A risk assessment determined that the majority of species, with the exception of four, are at low risk of indirect or direct exposure to larvicide products over the course of each season and the cumulative risk of exposure of the course of the six season program is also low. Four species were identified as medium risk of indirect or direct exposure to larvicide products over the course of the 6-season program. However, each species is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area. Both products are reported to be non-toxic and relatively safe to vertebrates if applied using the recommended doses.	Low – significant impact on MNES unlikely
Cumulative impacts of larvicide products	Resident shorebirds/seabirds, Wetland birds, Fish, and Growling Grass Frog.	Unlikely – Although there are knowledge gaps with regards to use of the larvicide products as identified by the literature review (e.g. potential for long term endocrine disruption from the use of S-methoprene, potential for S-methoprene to accumulate in the food web) the potential direct and indirect impacts on MNES as a result of the proposed action are not expected to accumulate, and are in part mitigated because of the substantial time periods between treatments for the majority of sites, the availability of equivalent untreated habitat within the proposed action area each season and the local area, the potential for non-target organisms to recolonise treated areas during and following each season from nearby untreated areas and the low risk of exposure for the majority of MNES species reviewed in this report.	Low - significant impact on MNES unlikely
Other impacts			
Removal or modification of habitat resulting in habitat loss Edge effects, habitat fragmentation, loss of connectivity for MNES Changes to water quality	Ramsar site Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot, Orange-bellied Parrot and Growling Grass Frog.	Highly unlikely – Proposed action does not involve the removal or modification of any habitat or area of the Ramsar site. The action will not change the hydrology of the water bodies within the proposed action area.	Nil - significant impact on MNES unlikely

Potential impact	MNES most at risk	Likelihood of impact and justification	Consequence
Changes to the physico-chemical nature of the proposed action area (i.e. contaminants and pollutants including leaks or spills arising from improper handling of mosquito control agents) Changes to water quality (i.e. on water dependent ecosystems)	Ramsar site Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot, Orange-bellied Parrot and Growling Grass Frog.	Unlikely – The chance for an accidental spill arising from improper use of larvicides is unlikely. In the case of an accidental spill, the larvicide would be contained to a very small area, away from waterways and immediately remediated. The proposed action is unlikely to change water quality within the Ramsar Site or habitats of MNES in the proposed action area. Low persistence of the larvicides in the environment (when used at recommended does rates) means that impacts on water quality are low.	Low – significant impact on MNES unlikely
Human disturbance – ground-based application of product	Ramsar site Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot Orange-bellied Parrot and Growling Grass Frog.	Possible – The application of larvicide by the City at ground-based sites may result in interactions and ultimately disturbance to some species of MNES. The type of disturbance is expected to be of short duration, highly localised, temporary, and infrequent. Furthermore it would only occur within a very small portion of the proposed action area (ground sites).	Low – significant impact on MNES unlikely
Risk of introduction and spread of disease/ pathogens during the proposed action, including amongst wild bird populations	Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot, Orange-bellied Parrot and Growling Grass Frog.	Unlikely - The proposed action is very unlikely to introduce a new disease that causes an MNES species known or likely to occur within the proposed action area to decline. Aerial application avoids direct physical contact of equipment and MNES, thereby significantly reducing any pathway of introducing or spreading disease. The City adopts hygiene protocols including use of protective disposable boot covers that are changed between sites to reduce the chance of disease introduction or spread.	Low – significant impact on MNES unlikely
Risk of introduction and spread of environmental weeds	Ramsar wetland Habitats for MNES	Unlikely - The proposed action is very unlikely to introduce a new weed that causes an MNES species known or likely to occur within the proposed action area to decline. Aerial application avoids direct physical contact with sites and MNES, thereby significantly reducing any pathway of introducing or spreading weeds. The City adopts hygiene protocols including use of protective disposable boot covers that are changed between sites to reduce the chance of weed introduction or spread.	Low – significant impact on MNES unlikely
Risk of introduction and spread of pest animals, spread of existing pest animals (e.g. gambusia)	Ramsar wetland Resident shorebirds/seabirds, Migratory shorebirds, Wetland birds, Fish, Blue-winged Parrot Orange-bellied Parrot and Growling Grass Frog	Unlikely - The activities associated with the proposed action do not include activities that would facilitate transport or spread of pest fish species, such as Gambusia, Goldfish or European Carp. It is very unlikely that the proposed action would increase the risk of spread of other pest species, including the Red Fox, European Rabbit and Feral Cat.	Low – significant impact on MNES unlikely

4.4 Assessment of significance of impacts on MNES

This purpose of this section is to address the relevant EPBC Act criteria for assessing significant impacts on listed threatened and migratory species and the Ramsar site known from or deemed likely to occur within the proposed action area. Where section 4.3 provided an impact-focused approach, this section provides an MNES-focused approach.

4.4.1 Threatened species

The Department identifies five threatened species in the preliminary documentation request that may be significantly impacted by the proposed action:

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine

A further three species that are newly listed as threatened under the EPBC Act could also be impacted by the proposed action:

– Blue-winged Parrot (*Neophema chrysostoma*) – Vulnerable, terrestrial bird species
– Common Greenshank (*Tringa nebularia*) – Endangered, migratory shorebird
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Vulnerable, migratory shorebird

The criteria for assessing significant impacts for listed threatened species are described in EPBC Act Policy Statement Significant Impact Guidelines 1.1 - Matters of National Environmental Significance (Department of the Environment (DotE) 2013). Those criteria are applied for this assessment, with the exception of the Growling Grass Frog, for which the following are applied - Significant Impact guidelines for the vulnerable Growling Grass Frog *Litoria raniformis* Nationally threatened species and ecological communities EPBC Act policy statement 3.14, (DEWA 2009).

An individual assessment for each of the eight threatened species that may be significantly impacted is provided in Table 49 to Table 56.

In addition to the above species, 15 fauna species listed as threatened under the EPBC Act (14 birds and one fish) are also known to occur within the proposed action area, at least occasionally. These were considered for potential impacts (see section 4.2) and included:

– **Wetland birds**
  - Australasian Bittern, *Botaurus poiciloptilus* – Endangered
  - Australian Painted Snipe, *Rostratula australis* – Endangered
– **Shorebirds/seabirds**
  - Eastern Hooded Plover, *Thinornis cucullatus cucullatus* – Vulnerable
  - Australian Fairy Tern, *Sternula nereis nereis* – Vulnerable
– **Migratory shorebirds**
  - Bar-tailed Godwit (Western Alaskan), *Limosa lapponica baueri* – Vulnerable
  - Black-tailed Godwit, *Limosa limosa* – Endangered
  - Greater Sand Plover, *Charadrius leschenaultia* – Vulnerable
  - Great Knot, *Calidris tenuirostris* – Critically Endangered
  - Grey Plover, *Pluvialis squatarola* – Vulnerable
  - Lesser Sand Plover, *Charadrius mongolus* – Endangered
  - Red Knot, *Calidris canutus* – Endangered
  - Ruddy Turnstone, *Arenaria interpres* – Vulnerable

- Terek Sandpiper, *Xenus cinereus* – Vulnerable
- Latham's Snipe, *Gallinago hardwickii* – Vulnerable, Migratory

– **Fish**
  - Yarra Pygmy Perch, *Nannoperca obscura* – Vulnerable

For a range of reasons, mostly to do with the low likelihood of the species being present in affected habitat during treatment, these species are less likely to be of concern than the eight species discussed above.

For these 15 species, assessments based on the information presented in section 4.2 and the criteria for assessing significant impacts for listed threatened species (section 1.1 Guidelines, DotE 2013) were completed. During the assessment of the relevant impacts, it was determined that none of the 15 species was likely to be significantly impacted by the proposed action. To avoid significant repetition, a summary of that assessment process is provided below.

4.4.1.1 Wetland birds

The Australasian Bittern is a rare, solitary, species that eats vertebrates (frogs, birds, mammals, fish) and large macro-invertebrates (e.g., crayfish). It inhabits densely vegetated wetlands, including areas that support taller reeds and rushes. These habitats are not typically the areas that are subjected to larvicide treatments as the vegetation prevents the pilot and assessing officer from seeing and evaluating the water with respect to mosquitos; therefore, product would not be applied to these areas.

The Australian Painted Snipe is a very rare, nomadic species that prefers larger freshwater wetlands, and occurs singly or in pairs or small groups. This species is mainly crepuscular (active at dawn and dusk), preferring to sit quietly under cover of grass, reeds or other dense cover during day, becoming more active at dawn, dusk and during night. They generally remain in dense cover when feeding, although may forage over nearby mudflats and other open areas such as ploughed land or grassland. The Australian Painted Snipe eats vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates. This species may turn up at any suitable habitat, but for the most part is very rare and unlikely to be present.

It is for the following reasons that the proposed action is unlikely to significantly impact either species:

– Both species are rare/uncommon within the PAA and are associated with few sites according to the historical record. The habitats of both species are not typically targeted for larvicide treatment.
– The proposed action will not remove or modify any habitats within the PAA for either species
– Aerial application of larvicide by drone within the proposed treatment sites may cause disturbance, but this would be localised, short term, temporary disturbance
– No collision events or near miss events were recorded from the studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. Overall, this risk may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to these species is not considered substantial across the course of the six-year program.
– The Australian Painted Snipe is known to occasionally occupy waterlogged grassland or saltmarsh. Habitats of that type may be subject to mosquito treatment within the PAA (e.g. the periphery of Lake Connewarre) however the risk of exposure to larvicide product for this rare species is expected to remain very low.
– Given its habitat requirements and foraging behavior, the Australasian Bittern is unlikely to regularly directly or indirectly ingest larvicide product
– Both species have substantial areas of modelled untreated habitats adjacent to treatment sites and within the local area (10 km buffer of PAA Table 30) in comparison to the area of modelled habitat within the treatment sites

4.4.1.2 Resident shorebirds/seabirds

Both the Eastern Hooded Plover and the Australian Fairy Tern are resident species with records in coastal areas (Swan Bay), lakes (Lake Victoria, Murtnaghurt) and the Barwon River/estuary in the PAA. Neither species is abundant within the PAA.

The Fairy Tern does not breed within treatment sites of the PAA. The species nests in small colonies on sandy spits and beaches above the high-water mark in sheltered bays, including Sand Island off Swan Bay. It roosts on beaches at night. This species may occasionally forage for small fish in some of the wetlands or coastal areas in the proposed action area, but is unlikely to be a common visitor to the treatment sites.

Historical breeding sites for the Eastern Hooded Plover area near to treatment sites including Breamlea Flora and Fauna Reserve. It is unlikely this species would breed within a treatment site. The Eastern Hooded Plover prefers ocean beaches, foraging on the beach and rock platforms, and nesting on the beach above the high-tide mark. Breeding locations for the last 10 years have all been in coastal/foreshore habitats.

It is for the following reasons that the proposed action is unlikely to significantly impact either species:

– Both species are rare/uncommon within the PAA and are associated with few sites according to the historical record. The habitats of both species are not typically targeted for larvicide treatment.
– The proposed action will not remove or modify any habitats within the PAA for either species
– Aerial application of larvicide by drone within the proposed treatment sites may cause disturbance, but this would be localised, short term, temporary disturbance
– No collision events or near miss events were recorded from the studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. Overall, this risk may increase during years where more treatments are required and/or greater bird numbers are reported. However, the overall risk to these species is not considered substantial across the course of the six year program.
– Both species have substantial areas of modelled untreated habitats adjacent to treatment sites and within the local area (10 km buffer of PAA Table 30) in comparison to the area of modelled habitat within the treatment sites
– Given their habitat requirements and foraging behaviour, neither species is likely to regularly directly or indirectly ingest larvicide product

4.4.1.3 Migratory shorebirds

All ten migratory shorebird species listed above are non-breeding, migratory birds that occur in small numbers in south-eastern Australia from August through March, and that may visit the PAA. All ten species are considered rare/uncommon within the PAA.

Greater Sand Plovers usually feed from the surface of wet sand or mud on open intertidal flats of sheltered embayments, lagoons or estuaries, more often on firm sandy flats. During the non-breeding season, they mostly eat molluscs, worms, crustaceans (especially small crabs and sometimes shrimps) and insects (including adults and larvae of termites, beetles, weevils, earwigs and ants). They usually roost on sand-spits and banks on beaches or in tidal lagoons, and occasionally on rocky points, or in adjacent areas of saltmarsh. They tend to roost further up the beach than other shorebirds, sometimes well above high-tide mark.

Lesser Sand Plovers feed mostly on extensive, freshly-exposed areas of intertidal sandflats and mudflats in estuaries or beaches, or in shallow ponds in saltworks. They also occasionally forage on coral reefs and on sandy or muddy river margins. They mainly roost near foraging areas, on beaches, banks, spits and banks of sand or shells.

The Bar-tailed Godwit usually forages near the edge of water or in shallow water, mainly in tidal estuaries and harbours. They appear not to forage at high tide and prefer exposed sandy substrates on intertidal flats, banks and beaches. The also prefer soft mud; often with beds of eelgrass Zostera or other seagrasses. They rarely forage in grassy or vegetated areas. The species usually roosts on sandy beaches, sandbars, spits and also in near-coastal saltmarsh.

The Black-tailed Godwit has a primarily coastal distribution in Australia. It may also be found in shallow and sparsely vegetated, near-coastal, wetlands; such as saltmarsh, salt flats, river pools, swamps, lagoons and floodplains. It is generally found in small numbers in southern regions of Australia, and is uncommon on the Bellarine Peninsula.

The Great Knot typically prefers sheltered coastal habitats, with large intertidal mudflats or sandflats. This includes inlets, bays, harbours, estuaries and lagoons. They are occasionally found on ponds in saltworks, at swamps near the coast, salt lakes and non-tidal lagoons. The Great Knot rarely occurs on inland lakes and swamps.

The Red Knot mainly inhabits intertidal mudflats, sandflats and sandy beaches of sheltered coasts, in estuaries, bays, inlets, lagoons and harbours, and sometimes on sandy ocean beaches or shallow pools on exposed wave-cut rock platforms or coral reefs. They are occasionally seen on terrestrial saline wetlands near the coast, such as lakes, lagoons, pools and pans, and recorded on sewage ponds and saltworks, but rarely seen at freshwater swamps or inland lakes or swamps. The species usually forages in soft substrate near the edge of water on intertidal mudflats or sandflats exposed by low tide. At high tide, it may feed at nearby lakes, sewage ponds and floodwaters. Roosting occurs on sandy beaches, spits and islets, and mudflats; also in shallow saline ponds of saltworks. Red Knots like to roost in open areas far away from potential cover for predators, but close to feeding grounds.

The Grey Plover occurs almost entirely in coastal areas while in Australia, where they usually inhabit sheltered bays, estuaries and lagoons with mudflats and sandflats, and occasionally rocky coasts with wave-cut platforms or reef-flats, or reefs within muddy lagoons (Department of the Environment 2024c). They also occur around terrestrial wetlands such as near-coastal lakes and swamps, or salt-lakes (Department of the Environment 2024c). The species tends to occur in small groups. Twenty important sites have been identified in Australia; two of those are in Victoria: i) Corner and Shallow Inlets (which is also recognised as one of three internationally important sites within Australia), and ii) Swan Bay - Mud Islands, which is within the proposed treatment area (Department of the Environment 2024b). Other than at Swan Bay, there are few records of this species on the Bellarine Peninsula.

The Ruddy Turnstone is found mostly in coastal regions, and strongly prefers rocky shores or beaches (Department of the Environment 2024d). In Australia, 11 important sites have been identified for this species in the non-breeding season, with a further four identified as important staging areas – none of these sites is within Victoria. This species is regularly reported in small numbers along the coast of the Bellarine Peninsula, as it is along much of the Victorian coastline.

The Terek Sandpiper is generally uncommon in Victoria, and there are few records on the Bellarine Peninsula. The species is generally more common in northern coastal Australia. In Victoria, the species has been recorded from Corner Inlet, Anderson Inlet, Westernport Bay and west Port Phillip Bay (Department of the Environment 2024e). Twelve important sites for this species have been identified in Australia; none of these occurs in Victoria (Department of the Environment 2024e).

Latham's Snipe usually occurs singly or in small, loose groups (<12 birds) (Driscoll 1993; Higgins & Davies 1996; Naarding 1983), occasionally occurring in larger groups (Higgins & Davies 1996; Naarding 1983; in Department of the Environment 2024a). In Australia, Latham's Snipe occurs in and around permanent and ephemeral wetlands. The species favours open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands, around bogs and other water bodies) (Frith et. al. 1977; Naarding 1983; Weston 2006, pers. comm.; in Department of the Environment 2024a). There are numerous records of this species on the Bellarine Peninsula, including within the proposed treatment area.

For the following reasons, the proposed action is unlikely to significantly impact these migratory shorebird species:

– The species tend to be rare/uncommon within the PAA and are associated with few sites according to the historical record. The habitats used most by these species (inter-tidal and coastal areas) are not typically targeted for larvicide treatment.
– The proposed action will not remove or modify any habitats within the PAA for any species
– Aerial application of larvicide by drone within the proposed treatment sites may cause disturbance, but the disturbance is expected to be localised, temporary and occasional
– No collision events or near miss events were recorded from the studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. Overall, this risk may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to these species is not considered substantial across the course of the six-year program.
– All species have substantial areas of modelled untreated habitats adjacent to treatment sites and within the local area (10 km buffer of PAA Table 30) in comparison to the area of modelled habitat within the treatment sites
– Given the habitat requirements and foraging behaviour of these species, none are likely to regularly directly or indirectly ingest larvicide product

4.4.1.4 Fish

There are few records within the PAA for the Yarra Pygmy Perch which is limited to site 10.8 Reedy Lake (not within treatment sites) and site 3.7 Ocean Grove Golf Course Creek. The Yarra Pygmy Perch is also found within the Barwon River system and there are many records outside the PAA, upstream of Breamlea in Thompson Creek and Waurn Ponds Creek. The species occurs in slow-flowing or still waters which support large amounts of aquatic vegetation (particularly emergent vegetation) such as lakes, ponds and slow-flowing rivers. Its diet includes microcrustaceans, molluscs and aquatic insects, including mosquito larvae.

For the following reasons, the proposed action is unlikely to significantly impact on this species:

– The majority of the habitats occupied by this species within the proposed action area are not typically subject to larvicide treatments, as they lack mosquito breeding habitat (e.g. flowing water) or treatment cannot be applied effectively (e.g. areas of dense emergent vegetation). Some areas of Reedy Lake and Golf Course Creek (site 3.7) are subject to larvicide treatment. However, treatment within these areas is confined to small areas (e.g. the periphery of Reedy Lake, amounting to approximately 8% of the Reedy Lake area treatment site each treatment).
– The species is highly unlikely to breed within treatment sites, given the species' habitat requirements and typical habitats treated (e.g. mostly shallow surface water areas)
– The species is unlikely to directly ingest larvicide product, although may indirectly ingest larvicide products via prey including mosquito larvae. However, it is not reliant on mosquito larvae and feeds on wide range of other non-target invertebrates.
– The species has substantial areas of modelled untreated habitats adjacent to treatment sites and within the local area (10 km buffer of PAA Table 30) in comparison to the area of modelled habitat within the treatment sites

4.4.1.5 Critically endangered species

This section provides an analysis of the proposed action against the significant impact criteria for critically endangered species, as follows:

– Orange-bellied Parrot (Table 49)
– Eastern Curlew (Table 50)
– Curlew Sandpiper (Table 51)

Table 49 Orange-bellied Parrot - review of the proposed action against the significant impact criteria for critically endangered species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of a population.	The proposed action will not remove or modify any habitats within the proposed action area (PAA) for the Orange-bellied Parrot. However the disturbance to Orange-bellied Parrots by aircraft (drone) noise, particularly young birds at mainland release sites (aerial or ground-based) has been identified by DELWP as a potential impact. Young birds are reportedly highly susceptible to noise disturbance during the release period. Disturbance caused by the drone is expected to be far less than disturbance caused by a helicopter. Aerial treatments of key habitats including Lake Connewarre and Swan Bay restricted to period when species is largely absent from the mainland and the PAA. Aerial application of larvicide within the proposed treatment sites is considered to be short term, temporary disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to this species is not considered substantial across the course of the six-year program. Furthermore, despite the program operating for over	The flying season will be restricted to limit the disturbance created by the aerial treatment to the Orange-bellied Parrot - aerial treatments will not be undertaken between the 16 March and 14 August at any site. Low-level aerial treatments may only occur between 16 August and 14 March in Lake Connewarre sites, and between 16 November and 14 March in Swan Bay sites. The proposed action is unlikely to lead to a long-term decrease in the size of the population of this species. Unlikely significant impact.

Impact criteria	Review of impacts	Assessment outcomes
	10 years already, all species including the Orange-bellied Parrot have persisted within the PAA. The PAA has been found to be a favoured area by the Orange-bellied Parrot over the past 10 years or more, leading to the area being selected as a release site for captive birds. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the previous helicopter activity or mosquito management. The preferred habitats for this species are not typically subject to larvicide application. The species is unlikely to be in regular contact with larvicide as i) treatments will mostly occur during the period when most birds are absent from the PAA, and ii) the total area of available habitat in Lake Connewarre and Swan Bay will not be treated during a single treatment period or over the course of one season.	
Reduce the area of occupancy of the species.	The published area of occupancy for the species is 30 km^2 (3000 ha) (National Environmental Science Program Threatened Species Research Hub (NESPTSRH) 2019). The modelled habitat area available for the Orange-bellied Parrot within the PAA is approximately 2,478 ha; approximately 4,520 ha of equivalent habitat occurs in the local area (10 km buffer of PAA) outside the treatment sites. Up to 690.87 ha in the local area may be treated each season for all sites and all species. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb this species for a short period of time, however it is unlikely that the aerial treatment or other activities of the proposed action would create a long term disturbance for Orange-bellied Parrot to the extent that the species may not return to a treatment site. Treatments will mostly occur during the period when most Orange-bellied Parrots are absent from the PAA,	The proposed action is unlikely to reduce the area of occupancy for the Orange-bellied Parrot. Unlikely significant impact.
Fragment an existing population into two or more populations.	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement the Orange-bellied Parrot through the PAA.	The proposed action is unlikely to fragment a population of the Orange-bellied Parrot into two or more populations or provide a barrier that prevents the seasonal migration of the species from Tasmania to mainland sites. Unlikely significant impact.
Adversely affect habitat critical to the survival of a species.	The proposed action will not remove or modify any habitats for the Orange-bellied Parrot within the PAA. The Ramsar wetland has been identified as important habitat for the survival of all endangered and critically endangered migratory/shorebird species. The proposed action will not remove or modify any habitats within the Ramsar site.	The proposed action will not adversely affect habitat critical to the survival of this species. No significant impact.
Disrupt the breeding cycle of a population.	The Orange-bellied Parrot migrates each year between summer breeding areas in Tasmania and winter foraging areas in coastal Victoria and South Australia. Historically, parts of the Bellarine Peninsula have been favoured locations for non-breeding Orange-bellied Parrots. Treatments of key habitats including Lake Connewarre and Swan Bay are restricted to a period when the species is largely absent from the mainland and the PAA. The proposed action is very unlikely to occur over the entire area of non-breeding habitat the species occupies within the PAA or broader local area.	The proposed action is unlikely to disrupt the breeding cycle of this species. Unlikely significant impact.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The area of available habitat for the Orange-bellied Parrot within the PAA and the general locality is described above. The proposed action will not remove, destroy, isolate or modify any habitats within the PAA. The proposed action will not decrease the availability or quality of Orange-bellied Parrot habitat within the PAA.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that this species is likely to decline. Unlikely significant impact.

Impact criteria	Review of impacts	Assessment outcomes
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Orange-bellied Parrot.	Unlikely significant impact.
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes this species to decline.	Unlikely significant impact.
Interfere with the recovery of the species.	There is a Recovery Plan for this species (DELWP 2016). The City has designed its program based on the advice of DELWP/DEECA to avoid and minimise opportunities for the interference with the recovery of this species. Specific actions considered include (see section 4.2 and section 5): – Restricted flight season (no flying permitted during the Orange-bellied Parrot release period) – Regular communication with DELWP/DEECA prior to treatment, to inform the treatment program for each season with the specific aim of avoiding sites that the species may be occupying With these measures, the proposed action is unlikely to interfere in the recovery of this species within the PAA.	Unlikely significant impact.

Table 50 Eastern Curlew - review of the proposed action against the significant impact criteria for critically endangered species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of a population.	The proposed action will not remove or modify any habitats within the PAA for the Eastern Curlew. Aerial application of larvicide within the proposed treatment sites may cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to this species is not considered substantial across the course of the six-year program. Furthermore, despite the program operating for over 10 years already, the Eastern Curlew has persisted within the PAA. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the previous helicopter activity or mosquito management. The species mainly forages in tidal habitats (e.g. mudflats), estuaries and inlets not suitable for mosquito breeding. However the species may directly ingest larvicide products because a portion of its foraging habitat (e.g. wading through ephemeral shallow saltmarsh waterbodies) is within the area targeted for mosquito treatment. However, it is unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not affected by the larvicide. Given habitats for foraging and roosting are typically not within the treatment application area of the site, the Eastern Curlew is unlikely to receive frequent direct exposure following treatment, or prolonged exposure given short life of treatment products used in these habitats and the availability of untreated habitats (e.g. species not reliant on or forages entirely within treatment sites).	The proposed action is unlikely to lead to a long-term decrease in the size of any population the Eastern Curlew. Unlikely significant impact.

Impact criteria	Review of impacts	Assessment outcomes
Reduce the area of occupancy of the species.	The published area of occupancy for this species within Australia is 8500 km^2 (850000 ha) (NESPTSRH 2019). The modelled area of available habitat for the Eastern Curlew is approximately 2714 ha within the PAA, and 4820 ha in the local area outside the treatment sites. 690.87 ha of habitat may be treated each season for all sites. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long-term disturbance for the Eastern Curlew to the extent that the species may not return to a treatment site.	The proposed action is unlikely to reduce the area of occupancy for the Eastern Curlew. Unlikely significant impact.
Fragment an existing population into two or more populations.	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of the Eastern Curlew through the proposed action area or to its summer breeding grounds.	The proposed action is unlikely to fragment a population of the Eastern Curlew into two or more populations. Unlikely significant impact.
Adversely affect habitat critical to the survival of a species.	The Ramsar wetland has been identified as important habitat for the survival of all endangered and critically endangered migratory/shorebird species, including this species. The proposed action will not remove or modify any habitats within the Ramsar site or other habitats outside the Ramsar site used by this species.	The proposed action will not adversely affect habitat critical to the survival of the Eastern Curlew. No significant impact.
Disrupt the breeding cycle of a population.	The Eastern Curlew does not breed in Australia. Breeding occurs in the Northern Hemisphere, from early May to late June. The Eastern Curlew takes an annual migratory flight to Russia and north-eastern China to breed, arriving back in Australia in August to feed on intertidal mudflats. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the activities including the aerial treatment would create a long-term disturbance to the extent that the species may not return to a treatment site.	The proposed action is unlikely to disrupt the breeding cycle of this species. Unlikely significant impact.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The area of available habitat for the Eastern Curlew is approximately 2714 ha within the PAA and 4820 ha in the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb these species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long-term disturbance for the Eastern Curlew to the extent that the species may not return to a treatment site.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that Eastern Curlew is likely to decline. Unlikely significant impact.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to this species within the PAA.	Unlikely significant impact.
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes this species to decline.	Unlikely significant impact.
Interfere with the recovery of the species.	There is no Recovery Plan for this species. The proposed action is very unlikely to interfere in the recovery of this critically endangered species.	Unlikely significant impact.

Table 51 Curlew Sandpiper - review of the proposed action against the significant impact criteria for critically endangered species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of a population.	The proposed action will not remove or modify any habitats for the Curlew Sandpiper within the PAA. Aerial application of larvicide within the proposed treatment sites may cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to this species is not considered substantial across the course of the six-year program. Furthermore, despite the program operating for over 10 years already, this species has persisted within the PAA. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the previous treatment activity. Habitats for roosting are typically not within the treatment application area of the sites. However a portion, albeit likely a small area, of foraging habitat (e.g. shallow wading habitats) is within the application area of treatment sites. The species may, therefore, receive infrequent direct exposure following treatment within some of the available habitats within the PAA. However, the species is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the availability of untreated habitats (e.g. species not reliant on or forages entirely within treatment sites).	The proposed action is unlikely to lead to a long-term decrease in the size of any population the Curlew Sandpiper. Unlikely significant impact.
Reduce the area of occupancy of the species.	The published area of occupancy for the species within Australia is 6800 km^2 (680000 ha) (Garnett et al 2011). The area of available modelled habitat for the Curlew Sandpiper (HIM moderate to high quality adjusted) within the PAA is approximately 2507 ha. There is 4314 ha of equivalent habitat within the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to reduce the area of occupancy for the Curlew Sandpiper. Unlikely significant impact.
Fragment an existing population into two or more populations.	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of the Curlew Sandpiper through the PAA or to its breeding grounds.	The proposed action is unlikely to fragment a population of this species into two or more populations. Unlikely significant impact.
Adversely affect habitat critical to the survival of a species.	The Ramsar wetland has been identified as important habitat for the survival of all endangered and critically endangered migratory/shorebird species, including this species. The proposed action will not remove or modify any habitats within the Ramsar site.	The proposed action will not adversely affect habitat critical to the survival of this species. No significant impact.

Impact criteria	Review of impacts	Assessment outcomes
Disrupt the breeding cycle of a population.	The Curlew Sandpiper does not breed in Australia. Breeding occurs in the Northern Hemisphere, from early May to late June. The Curlew Sandpiper takes an annual migratory flight to Russia and north-eastern China to breed, arriving back in Australia in August to feed on intertidal mudflats and other wetlands. The proposed action includes activities that may occasionally disturb this species for a short period of time, however it is unlikely that the activities including the aerial treatment would create a long-term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to disrupt the breeding cycle of this species. Unlikely significant impact.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The area of available habitat for the Curlew Sandpiper within and outside the PAA is substantial. Approximately 2507 ha of habitat occurs within the treatment sites, and 4314 ha occurs in the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long term disturbance for the Curlew Sandpiper to the extent that the species may not return to a treatment site.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that Curlew Sandpiper is likely to decline. Unlikely significant impact.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Curlew Sandpiper within the PAA.	Unlikely significant impact.
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes the Curlew Sandpiper to decline.	Unlikely significant impact.
Interfere with the recovery of the species.	There is no Recovery Plan for this species. The proposed action is very unlikely to interfere in the recovery of this species.	Unlikely significant impact.

4.4.1.6 Endangered species

This section provides an analysis of the proposed action against the significant impact criteria for endangered species, as follows:

– Common Greenshank (*Tringa nebularia*) - (Table 52)

Table 52 Common Greenshank - review of the proposed action against the significant impact criteria for endangered species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of a population.	There are currently estimated to be 23,700 (range 16,300–33,400) mature individuals of Common Greenshank in the wild, with an existing and continuing declining trend (Clemens et al. 2021; in DCCEEW 2024a). Aerial application of larvicide within the proposed treatment sites may cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported; however, the overall risk to this species is not considered substantial across the course of the six-year program.	The proposed action is unlikely to lead to a long-term decrease in the size of any population the Common Greenshank. Unlikely significant impact.

Impact criteria	Review of impacts	Assessment outcomes
	Furthermore, despite the program operating for over 10 years already, this species has persisted within the PAA. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the treatment activity. Habitats for roosting are typically not within the treatment application area of the sites. However, a portion, albeit probably a small area, of foraging habitats (e.g. shallow wading habitats) is within the application area of treatment sites. The species may, therefore, receive infrequent direct exposure following treatment within some of the available habitats within the PAA, but is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the availability of untreated habitats (e.g. species not reliant on or forage entirely within treatment sites). The proposed action will not remove or modify any habitats for the Common Greenshank within the PAA.	
Reduce the area of occupancy of the species.	The published area of occupancy for the Common Greenshank within Australia is estimated at 13,000 km^2 (13,000 –20,000 km^2) and is considered stable (Clemens et al. 2021, in DCCEEW 2024a). The modelled area of available habitat for the Common Greenshank is approximately 2857 ha within the PAA and 5232 ha within the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to reduce the area of occupancy for the Common Greenshank. Unlikely significant impact.
Fragment an existing population into two or more populations.	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of the Common Greenshank through the PAA or to its breeding grounds.	The proposed action is unlikely to fragment a population of this species into two or more populations. Unlikely significant impact.
Adversely affect habitat critical to the survival of a species.	The Ramsar wetland has been identified as important habitat for the survival of all endangered and critically endangered migratory/shorebird species, including this species. The proposed action will not remove or modify any habitats within the Ramsar site.	The proposed action will not adversely affect habitat critical to the survival of this species. No significant impact.
Disrupt the breeding cycle of a population.	The Common Greenshank does not breed in Australia. Breeding grounds extend from the northern British Isles, Scandinavia, east Estonia and north-east Belarus, through Russia and east to the Kamchatka Peninsula and the lower Amur River (DCCEEW 2024a). The species migrates annually to the northern hemisphere to breed, arriving back in Australia in August to feed on intertidal mudflats. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the activities including the aerial treatment would create a long-term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to disrupt the breeding cycle of this species. Unlikely significant impact.

Impact criteria	Review of impacts	Assessment outcomes
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.	The area of available habitat for the Common Greenshank within the PAA and local area is substantial Approximately 2857 ha of habitat occurs within the treatment sites and 5232 ha occurs in the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA. The proposed action includes activities that may occasionally disturb small numbers of this species for a short period of time. However, it is unlikely that the aerial treatment or other activities of the proposed action would create a long term disturbance for the Common Greenshank to the extent that the species may not return to a treatment site.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that Common Greenshank is likely to decline. Unlikely significant impact.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Common Greenshank.	Unlikely significant impact.
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes the Common Greenshank to decline.	Unlikely significant impact.
Interfere with the recovery of the species.	There is no Recovery Plan for this species. The proposed action is very unlikely to interfere in the recovery of this species.	Unlikely significant impact.

4.4.1.7 Vulnerable species

This section provides an analysis of the proposed action against the significant impact criteria for vulnerable species, as follows:

– Growling Grass Frog (Table 53)
– Australian Grayling (Table 54)
– Blue-winged Parrot (Table 55)
– Sharp-tailed Sandpiper (Table 56)

Table 53 Growling Grass Frog - review of the proposed action against the significant impact criteria for vulnerable species or their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of an important population of a species	For the purpose of this project, the population of the Growling Grass Frog within the Bellarine Peninsula including the PAA is considered a viable population as described under the DAWE 2009 guidelines. Therefore, it is considered an important population for the purpose of this assessment. The proposed action will not remove or modify any habitats within the PAA for the Growling Grass Frog. The proposed treatment of sites using aerial and ground methods are highly unlikely to disturb the species. The Growling Grass Frog, although found historically within two treatment sites, is unlikely to breed within the treatment (application) area of the site, given the species' preference for permanent freshwater lagoons with emergent vegetation cover (e.g. treatment at Reedy Lake is confined to the periphery of Reedy Lake and the depressions that have naturally formed). The timing of treatments coincides with the breeding season of this species (November – March) including the development period for tadpoles, and there may be a localised reduction in prey availability for frogs due to the use of larvicides. However, there are substantial areas of potentially suitable habitat not treated within Reedy Lake adjacent to known records of the species in treatment areas and in the local area (local area refers to the search area applied to the habitat importance modelling – see section 3.3.3).	The proposed action is unlikely to lead to a long-term decrease in the size of any important population of the Growling Grass Frog within the PAA or local area. Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
	The Growling Grass Frog feeds on a wide variety of invertebrates, but also small vertebrates including other frogs. The species in both frog and tadpole form may indirectly ingest larvicide through prey items however this is unlikely to occur at lethal doses given the frequency of treatments at known sites (e.g. up to 1 treatment per season at site 5.1, and 2 or more treatments per season at site 10.8 – Reedy Lake, noting that back to back treatments will not occur (next day treatments), and multiple treatment over consecutive seasons is unlikely to occur. Furthermore, the species is not reliant on mosquito larvae and chironomids and feeds on a variety of prey not directly affected by the larvicide treatment products. The frog and its relatively long-lived tadpole (>3 months) may be exposed to larvicide in water. However, habitats used for breeding and tadpole development are typically not within the application area of the site and therefore unlikely to receive frequent direct exposure following treatment or prolonged exposure given short life of treatment products used in these habitats.	
Reduce the area of occupancy of an important population	To date there is no known area of occupancy published for this species. In Victoria, it persists in isolated populations in the greater Melbourne area, in the south-west of Victoria and a few sites in central Victoria, north-west Victoria and Gippsland. The area of available modelled habitat (HIM moderate to high quality adjusted) for the Growling Grass Frog is approximately 2342 ha within the PAA, and 6485 ha within the local area outside the treatment sites. 690.87 ha of habitat may be treated each season. The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to reduce the area of occupancy for the Growling Grass Frog. Unlikely significant impact
Fragment an existing population into two or more populations	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of this species through the PAA.	The proposed action is unlikely to fragment a population of Growling Grass Frog within the PAA into two or more populations. Unlikely significant impact
Adversely affect habitat critical to the survival of a species	Although not listed as critical habitat, the areas currently or historically occupied by this species within the PAA including Reedy Lake (site 10.8) and the Port Arlington Flora and Fauna Reserve (site 5.1) are considered important habitats for the survival of the species within the Bellarine Peninsula. The proposed action will not remove or modify any habitats within the PAA.	The proposed action will not adversely affect habitat critical to the survival of the Growling Grass Frog. No significant impact
Disrupt the breeding cycle of an important population	Historical Growling Grass Frog records suggest that the species occurred only in habitats towards the eastern edge of the Reedy Lake. The GHD 2017 assessment identified a more widespread distribution in the Reedy Lake system, and documented that its habitat also includes the western edge and the lake itself, at least during the wetter conditions encountered at the time of the survey. The Growling Grass Frog is dependent upon permanent freshwater lagoons for successful breeding. The ideal breeding habitat is the shallow part of lagoons (up to approximately 1.5 m) where there is generally a complex vegetation structure. The species, although potentially found within treatment sites is considered unlikely to breed within the treatment (application) area of the site, given the species' preference for permanent freshwater lagoons with emergent vegetation cover. The timing of treatments coincides with the breeding season of the species, including the development period for tadpoles, and there may be a localised reduction in prey availability for frogs due to use of larvicides. However, there are substantial areas of potentially suitable habitat not treated adjacent to treatment areas and in the local area. The species in both frog and tadpole form may indirectly ingest larvicide through prey items. However, this is unlikely to occur at lethal doses given the frequency of treatments at known sites. Furthermore, the species is not reliant on mosquito larvae and chironomids and feeds on a variety of prey not subject to treatment.	The proposed action is unlikely to disrupt the breeding cycle of an important population of the Growling Grass Frog. Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
	The frog and its relatively long-lived tadpole (>3 months) may be exposed to larvicide in water. However, the habitats for breeding and tadpole development are typically not within the application area of the site and therefore unlikely to receive frequent direct exposure following treatment or prolonged exposure given short life of treatment products used in these habitats. Furthermore, the proposed action is very unlikely to occur over the entire area of potential breeding habitat for the species with the PAA.	
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that this species within the PAA is likely to decline. Unlikely significant impact
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable habitat	The Eastern Gambusia (mosquito fish) is known from the Lake Connewarre Complex and most likely occurs in other water bodies of the proposed action area including Reedy Lake. The activities associated with the proposed action do not include activities that would facilitate transport or spread of pest fish species, such as Gambusia. Nor would the activities modify the habitats within the PAA occupied by the Growling Grass Frog for the Eastern Gambusia of other invasive species becoming established.	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Growling Grass Frog within the PAA. Unlikely significant impact
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes the Growling Grass Frog to decline.	Unlikely significant impact
Interfere with the recovery of the species	There is a Recovery Plan for the Growling Grass Frog (Clemann and Gillespie 2012). The proposed action is very unlikely to interfere in the recovery of the Growling Grass Frog.	Unlikely significant impact

Table 54 ***Australian Grayling - review of the proposed action against the significant impact criteria for vulnerable species or their habitats***

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of an important population of a species	The Australian Grayling is diadromous, spending part of its lifecycle in freshwater and at least part of the larval and/or juvenile stages in coastal seas. While there are no reliable population estimates for the Australian Grayling, the species is reported to be relatively uncommon. All rivers and streams where this species occurs are considered important to the species' survival as it is unknown which populations are the most effective in terms of reproductive success. The National Recovery Plan notes that important populations necessary for the long term survival and recovery of this species occur in 36 rivers in Victoria, including the Barwon River. For the purpose of this project, the population of the Australian Grayling that occurs within the Barwon River including the estuary environment is considered an important population for the purpose of this assessment. The species is likely to utilise and migrate through a few known habitats within the PAA which are restricted to permanent moving freshwater (adult) or saltwater (larval) waterbodies – these areas are not considered suitable habitat for mosquito breeding so would not be treated. The species is highly unlikely to breed or occupy the treatment (application) area of the sites, given the species' habitat requirements. Consequently, the species is unlikely to be directly exposed to larvicide treatment given its habitat requirements. The species may indirectly ingest larvicide through prey; however, it is not reliant on mosquito larvae and feeds on a wide range of other non-target invertebrates.	The proposed action is unlikely to lead to a long-term decrease in the size of any important population of the Australian Grayling. Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
Reduce the area of occupancy of an important population	To date there is no known area of occupancy published for this species. In Victoria, important populations persist in 36 river systems, including the Barwon River. The area of available modelled habitat for the species is approximately: – 221 ha within the PAA, primarily from Reedy Lake, parts of Hospitals Swamp and the Barwon River estuary – 625 ha in the local area outside the treatment sites, primarily within the upper reaches of the Barwon River above Reedy Lake The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to reduce the area of occupancy for this species within the PAA. Unlikely significant impact
Fragment an existing population into two or more populations	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of the Australian Grayling through the PAA or into the ocean via the Barwon River estuary system.	The proposed action is unlikely to fragment a population of this species within the PAA into two or more populations. Unlikely significant impact
Adversely affect habitat critical to the survival of a species	Although not listed as critical habitat, the areas occupied by this species within the PAA, including Reedy Lake (site 10.8) and the Barwon River and estuary environment, are considered important habitats for the survival of the species. The proposed action will not remove or modify any habitats within the PAA.	The proposed action will not adversely affect habitat critical to the survival of the Australian Grayling. No significant impact
Disrupt the breeding cycle of an important population	The Australian Grayling is diadromous, spending part of its lifecycle in freshwater and at least part of the larval and/or juvenile stages in coastal seas including Swan Bay. Adults (including pre-spawning and spawning adults) inhabit cool, clear, freshwater streams with gravel substrate and areas alternating between pools and riffle zones. Larvae and juveniles inhabit estuaries and coastal seas, although their precise habitat requirements are not known. The species most likely completes part of its breeding cycle in the PAA including Reedy Lake, Barwon River and estuary and Swan Bay. The species is known from several treatment sites, but is unlikely to occupy and breed within the treatment (application) area of the site, given the species' habitat preferences. Furthermore, the proposed action is very unlikely to occur over the entire area of potential breeding habitat for the species with the PAA.	The proposed action is unlikely to disrupt the breeding cycle of an important population of the Australian Grayling. Unlikely significant impact
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the Australian Grayling is likely to decline. Unlikely significant impact
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Australian Grayling within the PAA.	Unlikely significant impact
Introduce disease that may cause the species to decline, or	The proposed action is very unlikely to introduce a disease that causes this species to decline.	Unlikely significant impact
Interfere with the recovery of the species	There is a Recovery Plan for the Australian Grayling (Backhouse et al., 2008). The proposed action is very unlikely to interfere in the recovery of the Australian Grayling.	Unlikely significant impact

Table 55 Blue-winged Parrot - review of the proposed action against the significant impact criteria for vulnerable species or their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of an important population of a species	The Conservation Advice for this species (DCCEEW 2023) provides no definition of 'important population'. Therefore, for the purpose of this project, the population of the Blue-winged Parrot that uses or visits the Bellarine Peninsula including the PAA is conservatively considered an important population. There are currently an estimated 10,000 (range 7,500–15,000) mature Blue-winged Parrots in the wild with an existing declining trend (Holdsworth et al. 2021; in DCCEEW 2023). The proposed action will not remove or modify any habitats within the PAA for the Blue-winged Parrot. The proposed action will not remove or modify any habitats within the proposed action area (PAA) for the Blue-winged Parrot. Aerial application of larvicide within the proposed treatment sites may cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to the species is not considered substantial across the course of the six-year program. Furthermore, despite the program operating for over 10 years already, all species including the Blue-winged Parrot have persisted within the PAA. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the previous helicopter activity or mosquito management. The preferred habitats for this species are not typically subject to larvicide application. The species is unlikely to be in regular contact with larvicide as the total area of available habitat (e.g., across Lake Connewarre and Swan Bay) will not be treated during a single treatment period or over the course of one season.	The proposed action is unlikely to lead to a long-term decrease in the size of any important population the Blue-winged Parrot within the PAA or local area. Unlikely significant impact
Reduce the area of occupancy of an important population	The area of occupancy (AOO) for this species is reported to be contracting and is estimated to be 11,000 km^2 (range 9,000–19,000 km^2) (Holdsworth et al. 2021; in DCCEEW 2023). Significant declines in reporting rates in the core range in Tasmania and Victoria are considered indicative of a population wide decline. This is likely due to changes in habitat quality (Holdsworth et al. 2021; in DCCEEW 2023) The area of available modelled (HIM moderate to high quality adjusted) habitat for the Blue-winged Parrot is approximately: – 3,262 ha within the PAA – 73,807 ha in the local area outside the treatment sites 690.87 ha of habitat may be treated each season for all sites. The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to reduce the area of occupancy for this vulnerable species within the PAA. Unlikely significant impact
Fragment an existing population into two or more populations	The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of this species through the PAA.	The proposed action is unlikely to fragment a population of Blue-winged Parrot within the PAA into two or more populations. Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
Adversely affect habitat critical to the survival of a species	No habitats within the Bellarine Peninsula are known to be critical to the survival of the Blue-winged Parrot. The VBA contains no nesting records on the Bellarine Peninsula. The proposed action will not remove or modify any habitats within the PAA.	The proposed action will not adversely affect habitat critical to the survival of this vulnerable species within the PAA. No significant impact
Disrupt the breeding cycle of an important population	The VBA contains no nesting records for the Blue-winged Parrot on the Bellarine Peninsula. This suggests that most birds that visit the Bellarine Peninsula are there to forage rather than breed.	The proposed action is unlikely to disrupt the breeding cycle of an important population of this vulnerable species within the PAA. Unlikely significant impact
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that this species within the PAA is likely to decline. Unlikely significant impact
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Blue-winged Parrot.	Unlikely significant impact
Introduce disease that may cause the species to decline, or	No known bird diseases are known to be spread or introduced by mosquito larvicide treatments. The proposed action is very unlikely to introduce a disease that causes this species to decline.	Unlikely significant impact
Interfere with the recovery of the species	There is no Recovery Plan for this species. The proposed action is very unlikely to interfere in the recovery of the Blue-winged Parrot.	Unlikely significant impact

Table 56 Sharp-tailed Sandpiper - review of the proposed action against the significant impact criteria for vulnerable species or their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:		
Lead to a long-term decrease in the size of an important population of a species	There are currently estimated to be 71,000 (range 9,500–268,900) mature individual Sharp-tailed Sandpipers in the wild with an existing and continuing declining trend (Clemens et al. 2021; in DCCEEW 2024b). The Sharp-tailed Sandpiper is one of the most common migratory shorebird species recorded from the PAA and is known from many treatment sites. The majority of records for this species are associated with tidal habitats (e.g. mudflats), estuaries and inlets not suitable for mosquito breeding. There are also numerous records from areas adjacent to treatments sites (e.g. within Swan Bay and Lake Connewarre). DoE (2021c) does not define 'important population', but does report on 'important sites' – an important site is determined using the 1% criterion (i.e., a site is considered 'important' if it is occupied by more than 1% of the bird's total population). Thirty-nine 'important sites' have been identified in Australia, and include Ocean Grove to Barwon Heads, which is estimated to attract and support a population of 1684 birds (Bamford et al. 2008; in DoE 2021c). Some, but not all, of the treatment sites provide habitat for this species. The proposed action includes activities that may disturb this species for a short period of time. However, observations of this species before, during and after helicopter and drone trials (GHD 2019, 2020, 2023) suggest that it is unlikely that the aerial treatment would create a long-term disturbance for the species to the extent that the species may not return to a treatment site. The proposed action will not remove or modify any habitats for the Sharp-tailed Sandpiper within the PAA. Aerial application of larvicide within the proposed treatment sites may cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the	The proposed action is unlikely to lead to a long-term decrease in the size of any important population the Sharp-tailed Sandpiper. Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
	helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported; however, the overall risk to this species is not considered substantial across the course of the six-year program. Furthermore, despite the program operating for over 10 years already, this species has persisted within the PAA. It can therefore be assumed that the species has not abandoned the area or been disturbed to the extent that it no longer finds the habitats of the PAA suitable as a result of the treatment activity. Habitats for roosting are typically not within the treatment application area of the sites. However, a portion, albeit probably a small area, of foraging habitat (e.g. shallow wading habitats) is within the application area of treatment sites. The species may, therefore, receive infrequent direct exposure following treatment within some of the available habitats within the PAA, but is unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the availability of untreated habitats (e.g. species not reliant on or forage entirely within treatment sites). The species may directly ingest larvicide products because of its foraging behaviour (e.g. foraging in ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). However, the species is unlikely to indirectly ingest larvicide through prey items as it feeds mainly on prey not within the application area of treatment sites or affected by the larvicide.	
Reduce the area of occupancy of an important population	The area of occupancy for the Sharp-tailed Sandpiper is estimated to be stable at 13,000 km^2 (13,000–20,000 km^2) (Clemens et al. 2021; in DCCEEW 2024b). Modelled habitat data in the form of HIM is not available for this species. However, after a review of historical records and habitat modelling of species that occur in the same treatments sites and similar habitats as the Sharp-tailed Sandpiper, it can be reasonably estimated that the area of habitat within the local area outside the treatment sites is substantial (Refer to section 3.3.3, Table 29). The proposed action will not remove or modify any habitats for the Sharp-tailed Sandpiper within the PAA. The proposed action includes activities that may disturb this species for a short period of time, however it is unlikely that the aerial treatment or other activities of the proposed action would create a long-term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to reduce the area of occupancy for this species within the PAA. Unlikely significant impact
Fragment an existing population into two or more populations	The existing population of Sharp-tailed Sandpipers that visits south-eastern Australia disperses widely across numerous disconnected sites across a large area. The proposed action will not remove or modify any habitats within the PAA or create barriers that may affect the movement of the Sharp-tailed Sandpiper through the PAA. The proposed action includes activities that may disturb this species for short periods of time, which in turn may temporarily displace individuals from the treatment site(s) (e.g. aerial treatments may frighten and flush birds from a site). However, the overall risk to the species is not considered substantial across the course of the six-year program.	The proposed action is unlikely to fragment a population of Sharp-tailed Sandpipers within the PAA into two or more populations. Unlikely significant impact
Adversely affect habitat critical to the survival of a species	The Ramsar wetland has been identified as important habitat for the survival of all threatened migratory/shorebird species. The Ramsar site incorporating the Swan Bay and Lake Connewarre complex regularly supports 1% of the Sharp-tailed Sandpiper when it occurs within Australia, and is an internationally important site for the species. There are also other habitat areas within the PAA outside the Ramsar site that support this species (e.g. Breamlea Flora and Fauna Reserve, and Lake Victoria). The proposed action will not remove or modify any habitats within or outside the Ramsar site.	The proposed action will not adversely affect habitat critical to the survival of this species. No significant impact

Impact criteria	Review of impacts	Assessment outcomes
Disrupt the breeding cycle of an important population	The Sharp-tailed Sandpiper does not breed in Australia – it breeds in northern Siberia from the Lena River delta, east to the Chaun Gulf and the Kolyma River delta (DCCEEW 2024a). The species migrates annually to the northern hemisphere to breed, arriving back in Australia in August to feed on intertidal mudflats and other wetland habitats. The proposed action includes activities that may occasionally disturb this species for a short period of time. However, it is unlikely that the activities including the aerial treatment would create a long-term disturbance for the species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to disrupt the breeding cycle of this species within the PAA. Unlikely significant impact.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The area of habitat available to the Sharp-tailed Sandpiper in the local area is substantial. Following a review of historical records and habitat modelling of species that occur in the same treatments sites and similar habitats as the Sharp-tailed Sandpiper, it can be reasonably estimated that substantial areas of habitat occur within the PAA and within the local area outside the treatment sites (refer to section 3.3.3, Table 29). The proposed action will not remove or modify any habitats within the PAA.	The proposed action is unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that this species within the PAA is likely to decline. Unlikely significant impact
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable habitat	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Sharp-tailed Sandpiper within the PAA.	Unlikely significant impact
Introduce disease that may cause the species to decline, or	No known bird diseases are known to be spread or introduced by mosquito larvicide treatments. The proposed action is very unlikely to introduce a disease that causes this species to decline.	Unlikely significant impact
Interfere with the recovery of the species	There is no Recovery Plan for this species. The proposed action is very unlikely to interfere in the recovery of the Sharp-tailed Sandpiper.	Unlikely significant impact

4.4.2 Migratory species

The Department identifies three migratory species (all are migratory shorebirds) in the preliminary documentation request that may be significantly impacted by the proposed action. The three species are:

– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Vulnerable, migratory shorebird

All three species are also listed as threatened and impact assessments are addressed under threatened species criteria in section 4.4.1.

This section provides an assessment under the specific EPBC Act criteria applied to migratory species. Including the above three species, 64 migratory bird species may occur within the proposed action area. These include terrestrial birds (fantails and flycatchers), aerial birds (swifts and needletails), gulls and terns (noddies, jaegers, terns), marine or oceanic birds (e.g., albatrosses, petrels, shearwaters), and 36 species of migratory shorebird (e.g., plovers, sandpipers, etc). Many of these species do not use or visit the treatment areas. Of the 64 migratory species, 31 species are considered for this assessment.

The migratory shorebirds (and aligned species such as snipe) are the group most likely to use or visit habitats within proposed treatment areas, so were also considered for the potential for impacts by the proposed project. This assessment is focussed on the Red-necked Stint and Sharp-tailed Sandpiper, as the most numerous and ubiquitous (and therefore representative) migratory shorebirds to visit suitable sites within the treatment area, noting that the Curlew Sandpiper, Eastern Curlew and Sharp-tailed Sandpiper are also assessed as threatened species in section 4.4.1. Table 57 presents a review of significant impact criteria for the Red-necked Stint, and Table 58 presents a review of significant impact criteria for the Sharp-tailed Sandpiper.

The criteria used for assessing significant impacts for migratory species are described in EPBC Act Policy Statement Significant Impact Guidelines 1.1 - Matters of National Environmental Significance (DotE 2013). In addition, the EPBC Act Policy Statement 3.21 - Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species (DotE 2017) are also applied.

Table 57 Review of significant impact criteria for Red-necked Stint - migratory species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:		
Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species	The Red-necked Stint is one of the most common migratory bird species recorded from the PAA and is known from many sites. There are also numerous records from areas adjacent to treatments sites (e.g. within Swan Bay and Lake Connewarre). The *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site incorporating the Swan Bay and Lake Connewarre complex regularly supports 1% of this species when it occurs within Australia and is an internationally important site for the species. There are also other habitat areas within the PAA outside the Ramsar site that support this species (e.g. Breamlea Flora and Fauna Reserve and Lake Victoria). Modelled habitat data in the form of HIM is not available for this species. However, after a review of historical records and habitat modelling of species that occur in the same treatment sites and similar habitats as the Red-necked Stint, it can be reasonably estimated that the area of habitat available to the Red-necked Stint and other migratory shorebirds within the PAA and within the local area outside the treatment sites is substantial (refer to section 3.3.3, Table 29). The proposed action will not remove or modify any habitats or create barriers that may affect the movement of this species through the PAA. The proposed action includes activities that may disturb this or other migratory shorebird species for a short period of time, however it is unlikely that the aerial treatment would create a long-term disturbance for any migratory species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to substantially modify, destroy or isolate an area of important habitat for the Red-necked Stint or any other migratory species within the PAA. Unlikely significant impact.
Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Red-necked Stint or any other migratory species within the PAA.	Unlikely significant impact
Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	The proposed action includes activities that may occasionally disturb the Red-necked Stint and other migratory shorebirds for short periods of time, which in turn may temporarily displace individuals from the treatment site(s) (e.g. the aerial treatment may frighten and flush birds from a site). Aerial application of larvicide within the proposed treatment sites is most likely to cause short-term, temporary, localised disturbance. No collision events or near miss events were recorded from the helicopter and drone studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to the Red-necked Stint and other migratory shorebirds is not considered substantial across the course of the six-year program. It is therefore considered unlikely that the aerial treatment would create a long-term or serious disturbance or disruption for any species to the extent that the species may not return to a treatment site. The application of larvicide will potentially occur within this and other shorebird species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Some of the habitats for roosting are within the	Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
	application area of the site, albeit probably small proportions of the overall available roosting habitat within the PAA and local area. This and other species may directly ingest larvicide products because of their foraging behaviour (e.g. foraging in ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). However, the species are unlikely to indirectly ingest larvicide through prey items as they feed mainly on prey not within the application area of treatment sites or not affected by the larvicide. This and other species are therefore likely to receive infrequent direct exposure following treatment within some of the available habitats within the PAA. However, they are unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or forages entirely within treatment sites). The disturbance is unlikely to extend to an ecologically significant proportion of the population of this species, or any other migratory species, that occupies the PAA.	

Table 58 Review of significant impact criteria for Sharp-tailed Sandpiper - migratory species and their habitats

Impact criteria	Review of impacts	Assessment outcomes
An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:		
Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species	The Sharp-tailed Sandpiper is one of the most common migratory bird species recorded from the PAA and is known from many treatment sites. The majority of records for this species are associated with tidal habitats (e.g. mudflats), estuary and inlets that are not suitable for mosquito breeding. There are also numerous records from areas adjacent to treatments sites (e.g. within Swan Bay and Lake Connewarre). The Ramsar site incorporating the Swan Bay and Lake Connewarre complex regularly supports 1% of this species when it occurs within Australia and is an internationally important site for the species. There are also other habitat areas within the PAA outside the Ramsar site that support this species (e.g. Breamlea Flora and Fauna Reserve, and Lake Victoria) Modelled habitat data in the form of HIM is not available for this species. However, after a review of historical records and habitat modelling of species that occur in the same treatment sites and similar habitats as the Sharp-tailed Sandpiper, it can be reasonably estimated that the area of available habitat within the PAA and within the local area outside the treatment sites is substantial (Refer to Section 3.3.3, Table 29). The proposed action will not remove or modify any habitats or create barriers that may affect the movement of this species through the PAA. The proposed action includes activities that may occasionally disturb this and other similar species for a short period of time. However, it is unlikely that the drone treatment would create a long-term disturbance for any migratory species to the extent that the species may not return to a treatment site.	The proposed action is unlikely to substantially modify, destroy or isolate an area of important habitat for a the Sharp-tailed Sandpiper or any other migratory species within the PAA. Unlikely significant impact.
Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of existing invasive species that are harmful to the Sharp-tailed Sandpiper or other migratory shorebird within the PAA.	Unlikely significant impact

Impact criteria	Review of impacts	Assessment outcomes
Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	The proposed action includes activities that may occasionally disturb this and similar species for short periods of time, which in turn may temporarily displace individuals from the treatment site(s) (e.g. the drone may frighten and flush birds from a site). Aerial application of larvicide by drone within the proposed treatment sites is expected to cause short-term, temporary, localised disturbance. No collision events or near miss events were recorded from the studies undertaken by GHD and no collision or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to this and other species is not considered substantial across the course of the six-year program. It is therefore considered unlikely that the drone treatment would create a long-term or serious disturbance or disruption for any species to the extent that the species may not return to a treatment site. The application of larvicide will potentially occur within this species' habitat, particularly shallow non-tidal foraging habitats and saltmarsh foraging habitats. Some of the habitats for roosting are within the application area of the site, albeit probably small proportions of the overall available roosting habitat within the PAA and local area. This or other species may directly ingest larvicide products because of foraging behaviour (e.g. foraging in ephemeral shallow saltmarsh waterbodies, suitable for mosquito breeding). However, the species are unlikely to indirectly ingest larvicide through prey items as they feed mainly on prey not within the application area of treatment sites or not affected by the larvicide. This and other species are therefore most likely to receive infrequent direct exposure following treatment within some of the available habitats within the PAA. However, they are unlikely to be subject to prolonged exposure given the short life of treatment products used in these habitats and the small area of habitat within the treatment sites compared to the availability of untreated habitats within the local area (e.g. species not reliant on or forages entirely within treatment sites). The disturbance is unlikely to extend to an ecologically significant portion of the population of this species or other migratory shorebird species that occupies the PAA.	Unlikely significant impact

4.4.3 Ramsar site

4.4.3.1 Assessment of significance

Approval is required for an action occurring within or outside a declared Ramsar wetland if the action has, will have, or is likely to have a significant impact on the ecological character of the Ramsar wetland.

The 'ecological character' is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time. The phrase 'at a given point in time' refers to the time of designation for the Ramsar List.

The *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site occurs in and around the PAA. No physical harm to the Ramsar site, its habitats or its hydrology is proposed. The main source of potential impact would be through occasional and localised short-term disturbance as a result of a drone passing overhead at a relatively low altitude (between 10 m to 15 m in altitude) and the application of the larvicide products for the purpose of mosquito management. These potential impacts are discussed in earlier sections.

In summary:

– The proposed action will not destroy or substantially modify any area of the Ramsar site or result in a substantial and measurable change to the hydrological regime of the wetland
– The proposed action is very unlikely to result in a substantial change to the habitat or lifecycle of a native species dependent upon a wetland
– The proposed action is very unlikely to result in a substantial and measurable change to the water quality of a wetland
– The proposed action is very unlikely to result in the establishment of an invasive species or the spread of an existing invasive species in the wetland

The proposed program is not likely to affect the values that contribute to the importance of the Ramsar site, therefore it is highly unlikely to change the ecological character of the site.

The criteria for assessing significant impact for Wetlands of International Importance are described in EPBC Act Policy Statement Significant Impact Guidelines 1.1 - Matters of National Environmental Significance (Department of the Environment (DotE) 2013). A review of potential impacts of the proposed action against the significant impact criteria for the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site is provided in Table 59.

Table 59 Review of the proposed action against the significant impact criteria for a Ramsar wetland

Impact criteria	Review of impacts	Assessment outcome
An action is likely to have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in:		
Areas of the wetland being destroyed or substantially modified.	The *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site occupies approximately 22,897 ha (RSIS 2021) of which only the Swan Bay and Lake Connewarre complex components occur within or intercept the PAA. Appendix A shows each of the ground-based and aerial treatment sites within the Ramsar site. Forty-one (3 ground-based and 38 aerial) treatment sites comprising approximately 3,208.91 ha are located within or adjacent to the Ramsar site. Approximately 690.87 ha (21%) of the Ramsar site within the PAA or <5% of the overall Ramsar site is proposed to be treated seasonally. The proposed action does not include modification or destruction of the habitat of the 52 treatment sites. The proposed action includes activities that may occasionally disturb EPBC Act listed migratory and threatened fauna species for short periods of time, which in turn may temporarily displace individuals from the treatment site(s) (e.g. the drone may frighten and temporarily disturb birds from a site). Aerial application of larvicide by drone within the proposed treatment sites is expected to cause short term, temporary, localised disturbance. No collision events or near miss events were recorded from the studies undertaken by GHD and no collision	The proposed action will not destroy or substantially modify any area of the Ramsar site. No significant impact

Impact criteria	Review of impacts	Assessment outcome
	or near miss events have been reported to date to the City since 2010. The risk of collision and disturbance may increase during years where more treatments are required, and/or greater bird numbers are reported. However, the overall risk to species within the Ramsar site is not considered substantial across the course of the six-year program. It is considered unlikely that the drone treatment would create a long-term or serious disturbance or disruption to any site to the extent that a species may not return to a treatment site within the Ramsar site.	
A substantial and measurable change in the hydrological regime of the wetland, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland.	The proposed action does not include any activities that will change the hydrological regime of the Ramsar wetland.	The proposed action will not result in a substantial and measurable change to the hydrological regime of the wetland. No significant impact
The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected.	The proposed action does not include activities that seriously affect any part of the habitat of the Ramsar site. The City uses two products for larval mosquito management, *Bacillus thuringiensis israelensis* (Bti) and S-methoprene that are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Both products are used widely in Australia and internationally to manage mosquito larvae because of their limited impact on non-target species and the general environment. The use of these products will impact the lifecycle of the mosquito species (native species) – however, it is unlikely to substantially impact the lifecycle of any other native species over the course of the six-year program.	The proposed action is very unlikely to result in a substantial change to the habitat or lifecycle of a native species dependent upon the wetland being seriously affected. Unlikely significant impact.
A substantial and measurable change in the water quality of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, or	The proposed action does not include any activities that will substantially change the water quality of the Ramsar wetland. Both products are used widely in Australia and internationally to manage mosquito larvae because of their limited impact on non-target species and the general environment.	The proposed action is very unlikely to result in a substantial and measurable change to the water quality of the wetland. No significant impact.
An invasive species that is harmful to the ecological character of the wetland being established (or an existing invasive species being spread) in the wetland.	The proposed action is very unlikely to result in the establishment of an invasive species or the spread of an existing invasive species in the wetland.	No significant impact

4.4.4 Conclusions

In undertaking this impact assessment, considerations were made to the following aspects:

– The potential impacts described in the previous referral (2005/2132)
– Measures outlined in the conditions of approval for the previous referral
– The nature of the proposed action, including treatment types, frequency and areas, and that it will not remove or modify any habitats for any species
– Field survey outcomes for the previous mosquito management program in relation to aerial treatment and potential impacts to MNES, particularly migratory shorebird species
– Outcomes of the literature review that was conducted to understand the potential direct and indirect impacts on MNES from the use of the two larvicide products Bti and S-methoprene and the use of drones to deploy the two larvicide products

- Occurrence of the species within the proposed action area, habitat requirements and foraging behavior
- EPBC Act Policy Statement Significant Impact Guidelines 1.1 - Matters of National Environmental Significance
- Recovery plans for species, where relevant
- Potential cumulative impacts on MNES from surrounding projects or activities that are planned, approved or currently in construction

The impact assessment of the proposed action against ‘impact criteria’ of the Significant Impact Guidelines 1.1 concludes that significant impacts on MNES and the criteria of the site are unlikely.

5. Proposed avoidance and mitigation measures

5.1 Purpose

In relation to the impacts of the proposed action on MNES, the preliminary documentation must include:

- *A detailed description of the avoidance and mitigation measures proposed for the MNES, including any identified impacts to MNES in adjoining areas. This should include for each measure:*
  - *A statement of the objectives, ongoing management and monitoring, and locations and timing*
  - *The party responsible*
  - *The policy basis, such as relevant conservation advices and recovery plans*
- *Details of proposed ongoing research and monitoring programs to support an adaptive management approach and determine the effectiveness of the proposed mitigation measures. This could include details for non-target organism monitoring, covering invertebrates and vertebrates (in particular, amphibians and fish).*
- *An assessment of the effectiveness of helicopter (now drone) heights proposed (for Orange-bellied Parrot and listed Migratory birds)*
- *Details of surveys to determine if species is present in areas proposed for treatment (for Orange-bellied Parrot and listed Migratory birds)*
- *Details of any measures to minimise disease and noxious aquatic species (including increases in Mosquito Fish (Gambusia holbrooki) populations)*
- *Assessment of the expected or predicted effectiveness of the avoidance and mitigation measures*
  - *This includes the scale and intensity of impacts of the proposed action and the on-ground benefits to be gained through each of these measures*
  - *Where impacts to MNES are avoided, this should be stated clearly*
- *If no measures are proposed, a detailed description of the assessment of why the expected or predicted effectiveness, and affordability or achievability of avoidance and mitigation options makes the measures unfeasible*

5.2 Introduction

The impact assessment process has identified that there will be some impacts as a result of the proposed action. These impacts are deemed ‘not significant’ however the City will implement mitigation measures for the duration of the six year program. This will include the implementation of non-target aquatic invertebrate monitoring and bird monitoring, including ongoing monitoring for potential impacts. The ongoing monitoring will enable the mitigation measures and the mosquito management program to be adaptable and provide mechanisms to avoid and further minimise impacts to MNES within the proposed action area.

The measures aim to continue and build upon the avoidance and minimisation strategy implemented by the City as part of its former program under permit EPBC 2005/2132. The measures also provide a mechanism for the City to regularly monitor and report the progress of the proposed action and determine the effectiveness of the monitoring following independent review. The adaptive management approach will accommodate new information regarding MNES species, including the Orange-bellied Parrot and additional information arising from the proposed bird surveys and aquatic invertebrate monitoring program.

5.3 Aims and objectives of the avoidance and mitigation measures

The City has developed a list of aims and objectives to address each of the key impacts identified in section 4 0 (see Table 60). The objectives enable the City to define aims, guide the development of the proposed measures, monitor the program and ensure accountability.

Table 61 details the measures, implementation timelines, tasks and responsibilities of the measures against each objective. In addition to the measures identified from the previous referral, new measures are also introduced to further reduce the risk of adverse impacts to the Orange-bellied Parrot following consultation with Rachel Pritchard from DELWP in 2021, migratory shorebirds and monitoring for potential impacts to non-target aquatic invertebrates.

Key aims include:

– Aim 1 – Avoid and minimise operational impacts on the Ramsar site, listed threatened species and migratory birds
– Aim 2 – Avoid and minimise operational impacts on the critically endangered Orange-bellied Parrot
– Aim 3 – Monitor potential impacts of larvicides to non-target aquatic invertebrates
– Aim 4 – Prepare operational plan to document objectives and measures and guide the proposed action
– Aim 5 – Provide an annual report for the life of the project to document the outcomes and effectiveness of measures

Table 60 Aims and objectives

Aim and objectives	MNES of concern	Relevant Impact (see section 4)
Aim Avoid and minimise operational impacts to the Ramsar site, listed threatened species and migratory birds Objectives 1A - Use approved products 1B – Conduct pre-treatment monitoring of migratory and wetland birds 1C – Restrict aerial treatment program – treatment area, duration, timing and period 1D – Conduct pre-, during and post treatment surveys to monitor the impact of drone operations on migratory shorebird populations and their behaviour at the sites	Some threatened and migratory shorebird species	**Drone disturbance and collision risk** Drone disturbance - considered to be short term, temporary disturbance that may affect a small portion of the overall population of some threatened and migratory bird species each season within the proposed action area. The possibility of bird-drone collision is considered low for the proposed program. Disturbance and collision risk may increase during years where more treatments are required, and/or greater bird numbers are reported however the overall impact to MNES is not considered significant across the course of the six-year program. Indirect impacts to MNES from the use of larvicide products beyond the life of the proposed program.
Aim Avoid and minimise operational impacts to Orange-bellied Parrot Objectives 2A - Use approved products 2B – Restrict aerial treatment program duration, timing and period 2C – Consult with DEECA to understand Orange-bellied Parrot movements within the PAA prior to commencement of program each season	Orange-bellied Parrot	**Drone disturbance and collision risk** Disturbance to Orange-bellied Parrots by drone noise, particularly young birds at mainland release sites (aerial or ground-based) from April onwards each year.

Aim and objectives	MNES of concern	Relevant Impact (see section 4)
Aim Monitoring non-target invertebrate aquatic fauna and respond to unacceptable changes Objectives 3A – Develop and implement non-target aquatic invertebrate monitoring program for the proposed action 3B - Commence monitoring program before the 2024 – 2025 mosquito treatment program of aerial treatment sites 3C – Undertake seasonal monitoring for three seasons 3D – Apply adaptive mitigation measures pending results of 3 consecutive seasons of monitoring	All MNES listed in section 3 including Growling Grass Frog, Orange-bellied Parrot, some migratory shorebird species	**Indirect impacts to MNES from exposure to larvicide products** Although not considered significant impact for the proposed program the ongoing use of the two larvicide products may have indirect impacts to non-target invertebrate fauna beyond the life of the proposed program. The City proposes to undertake a program to monitor the non-target aquatic invertebrate populations within the proposed action area to understand the impacts of the use of the two larvicide products beyond the life of the proposed program.
Aim Develop operational plan - including documentation of the measures outlined for the above aims and objectives Objectives 4A – Prepare operational plan for DCCEEW submission before 2024 – 2025 mosquito treatment program	All MNES documented in this report	The operational plan incorporates avoidance and mitigation measures designed to address the above-mentioned impacts
Aim Provide annual report Objectives 5A – Annual report structure and content to be agreed upon between the City and DCCEEW 5B - Submit annual report documenting outcomes of the operational plan 1st July each year for the duration of the proposed program	All MNES documented in this report	N/A

Table 61 Avoidance and minimisation measures

Objective and measure	Tasks and Responsibility	Outcome
1A and 2A - Use approved products to minimise indirect impacts to MNES *Use of approved products at documented application rate* The City must only use *Bacillus thuringiensis israelensis* (Bti) and S-methoprene products within the approved application rates to control mosquito breeding at the 52 treatment sites as described in section 2 of this report. Application rates are detailed in Table 7, Table 13,Table 18 and Table 20. The larvicide products as described in Table 7 of the report must only be applied to the treatment sites as detailed in Table 18 and Table 20.	The City must document application rates in the operational plan. The City must report treatment area, product use and application rate for each site treated in an annual report.	Use of approved products will reduce the potential for harm/death to non-target invertebrates, some of which may be a food source for listed threatened species and migratory species. Use of approved products at the documented application rates over the life of the program will avoid a significant impact to MNES.

Objective and measure	Tasks and Responsibility	Outcome
The following S-methoprene products must only be used for ground-based treatment sites of low value for MNES (see section 3.4) - Prolink XR – Briquets and VectoPrime FG-Granules. The application rates for the proposed program must not exceed the maximum program intended application rate for S-methoprene or Bti as documented in Table 18 and Table 20. Annually, the City will review the approved products to ensure there have been no label changes or alterations to directions for use.		Annually, the City will review the approved products to ensure there have been no label changes or alterations to directions for use
1B - Conduct pre-treatment bird monitoring *Undertake pre-treatment migratory and other waterbird surveys of aerial treatment sites to identify aggregations of birds.* Aim – provide information to the drone pilot and the City to avoid large aggregations of feeding or roosting birds during take-off and landing and on approach and departure paths. Note: objective 1B must be incorporated into objective 1D.	The City has engaged ecologists from GHD to undertake surveys to determine the presence and relative abundance of bird species at sites before drone operation occurs. This will provide information for the City to alter their program based on the location of these birds if required. Surveys will ideally be timed to take place during the migratory bird period, November through to February. The report will also include spatial files with take-off and landing points for drones to minimise the disturbance to aggregations of birds based on the survey results. Refer to Appendix I for survey method and reporting requirements.	The survey will identify locations for the City to reduce the risk of collision with birds and reduce the risk of major disturbance. The data collected will be used to inform future aerial treatment flights.
1C and 2B - Restricted aerial treatment program duration, timing and period *Documentation of treatment area for each treatment period.* Ensure sites to be treated are marked by visual markers and/or GPS tools. Drone must not fly beyond treatment area boundaries at low altitude. Record flight path over treatment sites. Drones must take off and land away from aggregations of birds. Aim - refine volume of larvicide applied to each site, minimise bird disturbance and reduce potential for negative interactions with MNES.	The City to provide on-ground visual markers or marked maps and/or spatial files to drone pilot for upload to on-board navigation system. This should include take off and landing points to minimise disturbance to aggregations of birds. Ideally take off and landing points should be located out of sight from bird aggregations (where possible) Alternatively a City Mosquito Management Officer may accompany the drone pilot during aerial treatments to direct the application of larvicide. As not all sites will be subject to a pre-treatment bird survey the City must identify take off and landing locations for the drone in the absence of bird survey data. Pilot to provide flight path logs (e.g. GPS track log) to the City following the completion of each treatment. The City must include copies of maps showing flight paths over each treatment site for each treatment period for annual reporting.	This measure reduces the opportunity for accidental deployment of larvicide into non-target areas within a treatment site and reduces the flight time within a particular treatment area which in turn reduces the potential for interactions with MNES. Furthermore, drone take off location, flight height and flight speed have been shown to influence bird disturbance. Adoption of the recommended take-off and landing location provided from the pre-treatment bird monitoring will also reduce bird disturbance.
1C and 2B - Restricted aerial treatment program duration, timing and period *Timing of aerial treatment program period and flights.*	Aerial treatments timing must be document in the annual report. Drone flights must occur in line with CASA regulations. City to inform drone pilot of best flight times and conduct audits of drone flight times.	This measure reduces risk of major disturbance and collision with birds, particularly listed threatened birds and migratory birds.

Objective and measure	Tasks and Responsibility	Outcome
Aerial treatments will not be undertaken between 16 March and 14 August at any site. Low-level aerial treatments (below 40 m) may only occur between 16 August and 14 March in Lake Connewarre (sites 3.13, 8.13, 8.14, 8.18 and 10.7) and between 16 November and 14 March in Swan Bay (sites 4.6, 7.1, 7.2, 7.3, 7.5, 14.3, and 14.4) to limit the disturbance to the Orange-bellied Parrot created by aerial treatments. As far as practicable, undertake treatments at times of the tidal cycle when birds, if present, are located furthest from the treatment sites (e.g. during low tide). Avoid undertaking treatments during early morning and late afternoon to improve pilot visibility and reduce risk of collision. Flight times must be informed by data collected from the pre-treatment bird surveys outlined in objective 1B. Aim – minimise flight time over treatment sites and larger proposal area to reduce potential for negative interactions.	The City must document any changes to proposed flight plans as a result of the pre-treatment bird surveys undertaken (Objective 1B) as part of the annual reporting. The City to publish aerial and ground-based treatment periods on website.	
1C and 2B - Restricted aerial treatment program duration, timing and period *Duration of drone flights* As far as practicable the pilot must minimise the number of passes and total time spent at each treatment site. Aim – minimise flight time over treatment sites to reduce potential for negative interactions including bird disturbance.	City to inform drone pilot of maximum number of treatment passes and/or maximum flight time over each treatment site and conduct audits of drone flight times. The City must document the duration of each treatment period and sites treated within each treatment period in the annual report.	This measure reduces risk of major disturbance and collision with birds, particularly listed threatened birds and migratory birds.
1C and 2B - Restricted aerial treatment program duration, timing and period *Height at which drone operates.* Low-level flying must comply with the conditions listed above. Aim – fly at height to minimise collision risk and reduce disturbance to birds.	Drone pilot to maintain set heights when flying over sites and between sites. The City must conduct annual audits of drone flight paths and heights. Findings must be documented in the annual report.	This measure reduces the risk of collision with birds and reduces the risk of disturbance within the proposed action area and adjoining areas.
1C and 2B - Restricted aerial treatment program duration, timing and period *Take off, landing and reloading of product.* All take-off and landing, and reloading of larvicide product must only be completed from the launch sites located next to the treatment areas. The drone must not land at any of the treatment sites, or hover for any extended period (e.g. more than two seconds) except in case of emergency.	The drone operator must review these restrictions prior to commencing any aerial treatment.	This measure will reduce the risk and consequence of accidental leaks or spills of larvicide on MNES.

Objective and measure	Tasks and Responsibility	Outcome
If the location of the launch site changes, then it must be placed at a suitable distance similar to the existing launch site away from any bird aggregations, other MNES and waterways.		
1D - Conduct pre-, during and post treatment diurnal bird surveys of migratory shorebird populations *Monitoring of threatened and migratory shorebirds within proposed action area.* Aim – provide information regarding the behaviour of migratory shorebirds to drone disturbance and to inform an adaptive management approach. The data collected will also provide a baseline to determine the effectiveness of the mitigation measures. Note: where possible surveys should incorporate pre-treatment monitoring surveys outlined in objective 1B.	The City has engaged ecologists from GHD to undertake surveys to gather information about the nature and magnitude of disturbance to birds resulting from the drone operations during the treatment program. At a minimum, the following information will be documented for the 'during treatment' surveys: – Approximate number of each species disturbed and first bird species disturbed – Approximate height of the drone and distance between drone and birds at the point of disturbance – The number of passes until disturbance (e.g. 2 of 4) and the period of time between the initial disturbance and when the birds resettle at the original or nearby location – Approximate time between response to other disturbances (e.g. people, other wildlife) and birds returning to the treatment site – Species list including observations of all threatened and migratory species recorded including approximate numbers for each species at each site – Spatial data that indicates the location of large aggregations of birds and colonial breeding sites at each survey site Refer to Appendix I for additional survey method and reporting requirements.	The data collected from surveys during the first season (2024-2025) will be used to inform future aerial treatment flights for the 2025-2026 season onwards. An adaptive management approach and determine the effectiveness of the proposed mitigation measures.
2C –In the absence of DEECA or other information to understand key OBP locations and movements within PPA *Pre-treatment surveys (August, September, October)* Aerial treatments during August September and October must the apply following procedure: Step 1 - Determine if any Orange-bellied Parrots are present or have recently passed through the proposed action area, particularly the Swan Bay or Lake Connewarre sites via correspondence with DEECA. Step 2 - If Orange-bellied Parrots are present or recently (< 2 days) known to be in the area, engage a suitably qualified organisation to undertake site surveys to determine presence of the species at proposed treatment sites. Step 3 - If absent, treatment can commence within 24 hours of survey. If present, treatment at that site must be abandoned or postponed until species is no longer present at the site. Aim – minimise negative interactions with Orange-bellied Parrot.	City to engage suitably qualified ecologist for consultation with DEECA / recovery team and assessment of relevant databases (e.g. VBA) to understand the species locations and movements with regard to the seasonal treatment schedule. This information will be reported in January each year. The information will be used to inform the City's forthcoming control program.	This measure reduces the likelihood of disturbance to the species, if it is present at a treatment site.

Objective and measure	Tasks and Responsibility	Outcome
3A - Develop and implement non-target aquatic invertebrate monitoring program The monitoring program will aim to gather data for the purpose of: – Identifying unexpected impacts to non-target aquatic invertebrates including food sources of MNES – Adaptive management including the implementation of measures to allow these values to recover – Gather data to inform future mosquito management programs The program must include: – Sampling for non-target aquatic invertebrates in treatment and non-treatment sites. – Adaptive management actions. – Program evaluation. **3B - Commence baseline monitoring program before the 2024 – 2025 mosquito treatment program of aerial sites** **3C – Undertake seasonal monitoring for three seasons then evaluate program**	The City has engaged GHD to undertake a non-target aquatic invertebrate monitoring program within the PAA. The monitoring program follows a BACI (Before-After; Control-Impact) study design using multiple lines of evidence to assess the level of risk to non-target invertebrate communities. The following aspects are included in the program design: – Desktop assessment to determine appropriate sampling and analysis methods and sites – Site selection – 'impact sites' (i.e. locations which will be directly treated) and 'control' sites will be selected – Sampling for non-target aquatic invertebrates in treatment and non-treatment sites – Establishment of baseline data – Lines of evidence to support thresholds and decision making – e.g. using EPA guidelines for benchmark 'healthy species' for a category of wetland or other approved indicators – Review after 3 seasons of monitoring to determine if significant decrease in non-target aquatic invertebrates – Adaptive management actions including ceasing of treatment at monitoring sites if significant declines are recorded for the approved indicators caused by larvicide and at most frequently treated sites to allow system time to recover – Annual reporting of results Refer to Appendix I for survey method.	The monitoring program provides a opportunity for the City to: – Identify unexpected impacts to food sources of MNES – Implement measures to allow these values to recover – Gather data to inform future mosquito management programs and understand cumulative impacts beyond the life of the proposed action for future monitoring programs.
4. Preparation of operational plan 4A – Prepare operational plan for DCCEEW submission before 2024 – 2025 mosquito treatment program Aim - City to consistently document process for the purpose of informing future management actions and changes if required.	The City must document measures, timelines, task, key milestones, report timelines and responsibilities outlined for aims and objectives detailed above. In addition to including the above objectives operation plan must be reviewed and updated annually as required.	One document detailing the City's plan to implement aims, objectives and mitigation measures for the proposed mosquito management program.
5. Annual report 5A - Submit annual report documenting outcomes of the operational plan 1st July each year for the duration of the proposed program.	On 1 July of each year the City will submit an annual monitoring report following structure and content of current reports to DCCEEW. City to undertake annual reporting and include all information from objectives and measures 1 – 4.	Public reporting of results with regard to avoidance and mitigation measures designed to minimise impacts to MNES.

5.4 Proposed environmental outcomes to be achieved

With mitigation measures applied where required, the proposed action is expected to successfully minimise the following risks as far as practicable:

– Risk of harming birds and other MNES during release of larvicide
– The likelihood and severity of disturbance of birds
– Risk of birds abandoning any site in the short or long term
– Risk of collision between birds and drone

The City has also incorporated an adaptive management approach to accommodate new information regarding MNES species, particularly the Orange-bellied Parrot and additional information arising from the proposed aquatic invertebrate monitoring program.

These risks are considered to represent the main sources of threat to MNES in the proposed action area. With the implementation of mitigation measures, the proposed environmental outcome is that no significant impacts (direct or indirect) on MNES would occur from the proposed action.

6. Residual impacts and proposed offsets

6.1 Purpose

Describe the residual impacts on MNES that are likely to occur as a result of the proposed action in its entirety, after proposed avoidance and/or mitigation measures are considered. If applicable, this should include the reasons why avoidance or mitigation of impacts cannot be reasonably achieved.

If residual impacts are likely to be significant please provide an offset package to compensate for residual impacts to the MNES. This should consist of an offset proposal (Offset Strategy) and key commitments and management actions for delivering and implementing a proposed offset (i.e. an Offset Management Plan).

Offsets must directly contribute to the ongoing viability of the species and deliver an overall conservation outcome that improves or maintains the viability of the protected matter, as compared to what is likely to have occurred if neither the action nor the offset had taken place. The offset proposal should demonstrate how the conservation outcome will be delivered for the protected matter.

The proposed offset must meet the requirements of the Department's EPBC Act Environmental Offsets Policy (October 2012) available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.

The Department's Offset Assessment Guide may be used as a guide to estimate the area of offset required to adequately compensate for the residual impacts of the project, it is available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.

A project officer within the Department will assess the proposed offset based on the information provided in the offset's proposal using the offsets assessment guide. Please note that proposals with unacceptable impacts will not necessarily be approved because offsets are provided.

6.2 Residual impacts

The impact analysis of the proposed action identified that significant impacts (direct and indirect) to MNES are unlikely. Despite this conclusion, the City has identified several mitigation measures, as outlined in section 5, to minimise potential impacts as far as practicable.

These measures will be adaptive to provide continuing improvement in the minimisation of impacts. Adaptive management will enable measures to be optimised, building upon information collected from long-term monitoring throughout the proposed six-year mosquito management program. Particular focus will be given to measures for the Orange-bellied Parrot and aquatic invertebrates.

With the implementation of the mitigation measures and mechanisms for adaptive management, the residual impacts to MNES are expected to be negligible. These are summarised below.

6.2.1 Impacts from drone operations

Aerial treatment by drone use has the potential to disturb or collide with threatened and migratory shorebirds and the Orange-bellied Parrot. This potential impact is considered to be short-term, with temporary disturbance affecting a small portion of the overall MNES-listed bird species within the PAA. No bird strikes, collision events or near misses have been reported to date for the City's historical helicopter operations or reported during local surveys. With drones being considerably smaller in size and more mobile than helicopters, significant impacts are considered unlikely. Despite this, the City will implement several measures to further avoid and minimise the potential for impacts. The measures will be guided by meeting the prescribed objectives stated in Table 60Table 60 (1A to 1D, 2A to 2C and 4A).

With the implementation of several measures that would meet the prescribed aims and objectives, significant residual impacts on threatened and migratory shorebirds and the Orange-bellied Parrot are expected to be negligible and unlikely.

6.2.2 Impacts from the application of larvicides

Potential impacts to MNES from the application of larvicides could occur through direct ingestion of, or exposure to larvicides and the cumulative effects of larvicides. MNES identified as being most at risk include resident shorebirds/seabirds, migratory shorebirds, wetland birds, fish, the Orange-bellied Parrot, Blue-winged Parrot and the Growling Grass Frog.

Bti and S-methoprene are reported to be non-toxic and safe when applied using recommended doses to vertebrates. Risk assessments indicate that the majority of species, except four, are at low risk of indirect or direct exposure to larvicide products. The cumulative risk of exposure over the six-year program is also considered low. The four species are considered at medium risk but are unlikely to experience prolonged exposure given the short life of the larvicide products and the small area of habitat affected by treatment, compared to surrounding available untreated habitats in the local area.

It is also evident that there are knowledge gaps with regards to use of the larvicide products.

Consideration of application frequencies, seasons and areas indicate there are substantial time periods between treatments for most sites and there is availability of untreated habitat within the PAA each season and the local area. This enables non-target organisms to potentially recolonise treated areas during and following each season from nearby untreated areas. Overall, the risk of exposure for the majority of MNES species is considered low and the potential for significant impacts on MNES is considered unlikely.

Although significant impacts for the proposed program are unlikely the ongoing use of the two larvicide products may have indirect impacts to non-target invertebrate fauna beyond the life of the proposed program. To further reduce risk and minimise the potential for impacts, the City will implement several measures. The measures will be guided by meeting the prescribed objectives stated in Table 60 (3A to 3D and 4A) and will include a program to monitor the non-target aquatic invertebrate populations within the proposed action area to understand the impacts of Bti and S-methoprene beyond the life of the proposed program.

With the implementation of these several measures that would meet the prescribed aims and objectives, significant residual impacts on shorebirds/seabirds, migratory shorebirds, wetland birds, fish, the Orange-bellied Parrot, Blue-winged Parrot and the Growling Grass Frog are expected to be negligible and unlikely.

6.2.3 Other impacts

Other impacts may occur from the six-year mosquito management program with the potential to impact on the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site, shorebirds/seabirds, migratory shorebirds, wetland birds, fish, the Orange-bellied Parrot, Blue-winged Parrot and the Growling Grass Frog.

The method for applying larvicide via aerial and ground treatments will not involve the removal or modification of any habitat or area of a Ramsar site. The methods will also not interact with or change the hydrology of receiving water bodies in treatment areas. The larvicides have a short life and will have low persistence in the environment when recommended dose rates are followed. As a result, the potential to impact on water quality is considered low.

Human disturbance during ground-based application may result in some interactions with MNES, however this will be of short duration, temporary and infrequent and unlikely to result in significant impacts.

The potential to introduce and spread disease/ pathogens, environmental weeds and pest animals is considered unlikely. Aerial application avoids direct physical contact of equipment and MNES, thereby significantly reducing any pathway of introducing or spreading disease. The City adopts hygiene protocols between sites to reduce the chance of disease introduction or spread.

These potential impacts are considered unlikely to result in significant impacts to MNES. The City will implement several measures to further reduce risk and minimise the potential for impacts as stated in Table 60. With regular reporting and review of monitoring results, measures will be adapted to further minimise any observed impacts on MNES.

With the implementation of these measures, residual impacts on the *Port Phillip Bay (Western Shoreline) and Bellarine Peninsula* Ramsar site, shorebirds/seabirds, migratory shorebirds, wetland birds, fish, the Orange-bellied Parrot, Blue-winged Parrot and the Growling Grass Frog are expected to be negligible and significant residual impacts are unlikely.

6.3 Offsets

On the basis that residual impacts are not considered to be significant, an offset package is therefore not required for the proposed action.

7. Other approvals and conditions

7.1 Purpose

The preliminary documentation must include information on any other requirements for approval or conditions that apply, or that you reasonably believe are likely to apply, to the proposed action. This must include:

– *A description of any approval obtained or required to be obtained from a State or Commonwealth agency or authority (other than an approval under the EPBC Act), including any conditions that apply to the proposed action. If this does not need to be sought, or if approval is sought immediately prior or concurrent with the proposed action,please provide justification*

– *Details of any other relevant legislation, policies, guidelines and standards, and assess their specific requirements or implications for the project*

– *A description of the monitoring, enforcement and review procedures that apply, or areproposed to apply, to the action*

7.2 Description of approvals obtained or required to be obtained from a State or Commonwealth agency

A summary of the approvals or conditions that apply, or are likely to apply, to the proposed action (in addition to an approval under the EPBC Act) are outlined in Table 62. Details of any conditions applying to the required approvals are detailed below.

Table 62 Summary of approvals and responsible authorities

Legislation	Responsible authority	Approval trigger	Approval required?	Approval status
Victorian *National Parks Act 1975*	Parks Victoria	Conduct treatments on land managed by Parks Victoria	Yes	Granted when EPBC Act permit approved
Commonwealth *Agricultural and Veterinary Chemicals Code Act 1994*	Australian Pesticides and Veterinary Medicines Authority (APVMA)	Use and application of specific chemicals	No	APVMA register and approve products for use.
Victorian *Civil Aviation Act 1988*	Civil Aviation Safety Authority (CASA)	Conducting drone operations	Yes	Currently in training, to be completed before start of next season and conditionally on approval of EPBC permit.
Agricultural and Veterinary Chemicals (Control of Use) Act 1992	Agriculture Victoria	Conducting aerial treatments using a drone and agricultural chemicals	Yes	Currently in training, to be completed before start of next season and conditionally on approval of EPBC permit.

Parks Victoria

The City has formed consent agreements with Parks Victoria since 2010 for access to their sites, and for permission to conduct aerial treatment of mosquito controlling agents. One of the many conditions in the consent agreement is the compliance with the conditions within the EPBC permit obtained by the City. As the existing permit has ceased, there is currently no agreement with Parks Victoria. Once the decision has been made on the current EPBC application, discussions will commence with Parks Victoria to obtain a permit for the remaining season.

This agreement details that the City can access the Bellarine Peninsula Park between the days of Monday and Friday (excluding public holidays) between the hours of 8:00 a.m. and 4:30 p.m. for the purpose of conducting aerial treatments using Bti and S-methoprene. This agreement is renewed annually, and the City will continue to obtain consent from Parks Victoria on an annual basis throughout the six-year permit.

The City proposes that within the agreement:

– Any aerial treatments are conducted with City staff present
– The City will comply with all laws and industry standards in the operation of the drone, and obtain all necessary approvals associated with the operation of the drone, copies of which must be provided to Parks Victoria prior to the Commencement Date
– The City's staff are appropriately licensed to carry out the treatments
– The City will conduct treatments which protect the interests of Parks Victoria
– The City will prepare a Remotely Piloted Aircraft Operators manual and Management Plan
– The City will at all times take all necessary precautions for the protection and safety of Parks Victoria employees and agents, the public and the environment
– The City will at all times commit to the occupational health and safety of employees, and shall have an effective workplace safety program
– Aerial treatments conducted on the property will be carried out with all due care and skill
– The City shall provide further information in relation to aerial treatments on the property on request by Parks Victoria

The City is required to keep records detailing all the areas that have been treated with either Bti or S-methoprene and the times that the City accessed the property. These records are to be maintained for no less than seven years after the completion date of the consent agreement.

If requested by Parks Victoria, the City will arrange a briefing between the drone operator, representatives from Parks Victoria and the City of Greater Geelong. The briefing would include details such as:

– Purpose, control methods and tasks of Mosquito Treatment Operations
– Locations and defined boundaries of treatment zones marked up on maps
– Locations of all known hazards marked up on maps
– Operational limitations, including weather, visibility, bird activity and sensitive sites
– Plans to manage inadvertent visitors
– Safety procedures and site protection
– Site access arrangements

This agreement is undertaken by:

– The City contacting Parks Victoria requesting access to lands maintained by the state of Victoria
– Dates updated in the agreement to reflect new agreement start and end dates
– The City provides any insurance information to Parks Victoria
– The agreement is signed by both parties and takes effect

The agreement and any of its provisions may be updated in the future by Parks Victoria or the City; the City will continue to work with Parks Victoria to ensure all safety and environmental concerns are addressed in the presented agreement and its revisions.

Department of Energy, Environment and Climate Action

The City intends to form consent agreements with DEECA relating to access of the City onto lands managed by DEECA. No consent agreements have been formed in the past, but the City is looking to enter an agreement that may detail the following:

– Any aerial treatments are conducted with City staff present
– The City will comply with all laws and industry standards in the operation of the drone, and obtain all necessary approvals associated with the operation of the drone, copies of which must be provided to DEECA prior to the Commencement Date
– The City's staff are appropriately licensed to carry out the treatments
– The City will conduct treatments which protect the interests of DEECA

– The City will prepare a Remotely Piloted Aircraft Operators manual and Management Plan
– The City will at all times take all necessary precautions for the protection and safety of DEECA employees and agents, the public and the environment
– The City will at all times commit to the occupational health and safety of employees, and shall have an effective workplace safety program
– Aerial treatments conducted on the property will be carried out with all due care and skill
– The City shall provide further information in relation to aerial treatments on the property on request by DEECA

The City is required to keep records detailing all the areas that have been treated with either Bti or S-methoprene and the times that the City accessed the property. These records are to be maintained for no less than seven years after the completion date of the consent agreement.

If requested by DEECA, the City will arrange a briefing between the drone operator, representatives from DEECA and the City of Greater Geelong. The briefing would include details such as:

– Purpose, control methods and tasks of Mosquito Treatment Operations
– Locations and defined boundaries of treatment zones marked up on maps
– Locations of all known hazards marked up on maps
– Operational limitations, including weather, visibility, bird activity and sensitive sites
– Plans to manage inadvertent visitors
– Safety procedures and site protection
– Site access arrangements

Civil Aviation Safety Authority

The requirement for operating any drone is for the staff members using agricultural drones and the City to have the following qualifications/certifications:

– Remote Pilots Licence (RePL)
– Type specific training (XAG P100 Pro Agricultural Drone)
– Remotely Piloted Aircraft Operator's Certificate (ReOC)
– Aeronautical Radio Operator Certificate (AROC)

These qualifications and certifications are acquired through a CASA approved training organisation and the manufacturer of the drone.

Agriculture Victoria

There are two other requirements for the City to operate drones as a potential service for other government agencies in the event of outbreaks and secure funding for services provided. The licences required are:

– Agricultural Aircraft Operator Licence (AAOL), and
– Pilot (Chemical Rating) Licence (PCRL)

Chemical approvals

The chemicals used in the City's mosquito management program have been approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA). The following table (Table 63) outlines the product names as found in the APVMA PubCRIS database, with general information about the current registration status of each product. Product expiry dates are updated annually in line with the renewal period which occurs in July each year.

Table 63 Details of chemicals used in the mosquito management program

Product Name	Product Number	Status	Category	Poison Schedule	Registrant	Registration date	Expiry date
Vectobac G Biological Larvicide Granule	52834	Registered 2023-07-01	A – Agricultural	0	Valent Biosciences a div of Sumitomo Chemical Australia	2000-05-12	2024-06-30
Prolink Pro Sand Mosquito Growth Regulator	59598	Registered 2022-07-01	A – Agricultural	0	Wellmark International (Australia) Pty Ltd	2005-07-21	2027-06-30
Prolink XR Briquets Mosquito Growth Regulator	58061	Registered 2022-07-01	A - Agricultural	0	Wellmark International (Australia) Pty Ltd	2003-10-08	2027-06-30
Prolink Pellets Mosquito Growth Regulator	58064	Registered 2022-07-01	A – Agricultural	0	Wellmark International (Australia) Pty Ltd	2003-10-07	2027-06-30
VectoPrime FG Biological Larvicide Fine Granule	82315	Registered 2023-07-01	A – Agricultural	0	Valent Biosciences a div of Sumitomo Chemical Australia	2018-06-05	2024-06-30

7.3 Other relevant legislation, policies, guidelines and standards

Framework for mosquito management in Victoria – DSE 2004

The City has used the Framework for Mosquito Management in Victoria developed by former Victorian Government Department of Sustainability and Environment in 2004 to provide an initial structure for the mosquito management program. The framework established a state-wide integrated management approach to mosquito control. It provides information and policy guidance to assist Councils and State government agencies to implement local mosquito management programs in an effective and environmentally appropriate manner.

This framework document provides the City with legislative frameworks and agreements which need to be taken into consideration, tools to assess the risk present to the community and environment, and potential training to maximise an integrated mosquito management program at a local level.

Victorian *Public Health and Wellbeing Act 2008*

The Victorian *Public Health and Wellbeing Act 2008* received Royal Assent in September 2008 and took effect on 1 January 2010.

The Act replaces the previous Victorian *Health Act 1958*. It is a key piece of legislation designed to protect the health of Victoria's population, with implications for:

– Authorised officers within local councils and the Department of Health & Human Services
– Pest control operators
– Cooling tower operators
– The governance and management of a range of consultative councils established under the Act
– The management of infectious diseases, micro-organisms and medical conditions by medical and health practitioners, Victoria's Chief Health Officer and affected individuals
– The development of public health policy through providing for municipal public health and wellbeing plans, a State public health and wellbeing plan and in some circumstances, health impact assessments

Section 24 of the Victorian *Public Health and Wellbeing Act 2008* defines the function of Council to seek to protect, improve and promote public health and wellbeing in the municipal district by –

> *(a) creating an environment which supports the health of members of the local community and strengthens the capacity of the community and individuals to achieve better health;*
>
> *(b) initiating, supporting and managing public health planning processes at the local government level;*
>
> *(c) developing and implementing public health policies and programs within the municipal district;*
>
> *(d) developing and enforcing up-to-date public health standards and intervening if the health of people within the municipal district is affected;*
>
> *(e) facilitating and supporting local agencies whose work has an impact on public health and wellbeing to improve public health and wellbeing in the local community;*
>
> *(f) co-ordinating and providing immunisation services to children living or being educated within the municipal district;*
>
> *(g) ensuring that the municipal district is maintained in a clean and sanitary condition.*

The mosquito management program promotes public health and wellbeing for the municipality by creating an environment which supports the health of members of the local community and strengthens the capacity of the community and individuals to achieve better health by preventing occurrences of vector borne diseases. This is achieved by the monitoring and treatment program and providing education to community. The education program utilises the City's website, social media, phone/email correspondence and media releases to provide community members with information on how they can best prevent breeding sites on their properties and protect themselves from mosquito bites.

The City's Mosquito Management Officers are a part of the Environmental Health Unit. The Officers in this unit are authorised under the *Public Health and Wellbeing Act* and as such are authorised with the powers, duties and functions on the Act.

Under Section 101 of the Act, a person may apply to the Secretary (defined as the Department Head within the meaning of the *Public Administration Act 2004*) via the approved process for the issue or renewal of a pest control licence which enables them to use a pesticide or class of pesticide during business as a pest control operator. The City is exempt from this requirement as the City is not a pest control operator, however the City requires the Mosquito Management Officers to obtain a pest control licence regardless.

Victorian Public Health and Wellbeing Regulations 2019

On 14 December 2019, the Victorian Public Health and Wellbeing Regulations 2019 came into effect and replaced the Public Health and Wellbeing Regulations 2009. The Victorian Public Health and Wellbeing Regulations 2019 cover the following actions within the mosquito management program:

– Replacing 'arbovirus infection control' with 'vector-borne infectious disease control' and broadening the scope of infectious disease control regulation to include other disease vectors, not just mosquitoes
– Defining 'disease vector' so that an animal, including a bird or insect, can be the subject of infectious disease control
– Establishing obligations on owners and occupiers of premises to take reasonable steps to control mosquito breeding grounds and abate conditions conducive to their establishment
– Allowing an authorised officer to direct an owner or occupier of a premises to take steps to control any mosquito breeding ground and control the adult mosquito population on the premises
– Introducing a Chief Health Officer authority to issue a disease vector control notice to address a material public health risk caused by a disease vector
– Allowing an authorised officer to direct an owner or occupier of a premises to control a disease vector (as specified in a disease vector control notice)

The changes also include obligations for owners and occupiers of premises to control potential mosquito breeding sites by taking reasonable steps to reduce risk and allows authorised officers to direct owners and occupiers to control a disease vector.

7.4 Description of the monitoring, enforcement and review procedures

Parks Victoria

As stated in response to question 7(a) of this Preliminary Documentation, one of the many conditions in the consent agreement with Parks Victoria is the compliance with the conditions within the EPBC permit obtained by the City. The City is also required to maintain records for a minimum of seven years detailing the areas that have been treated using with either Bti or S-methoprene and the times that the City accessed land under the management of Parks Victoria. Parks Victoria can, at any time, request a briefing with the City prior to any proposed treatment to discuss the details of the proposed treatments. This permit is renewed annually upon review by Parks Victoria.

Parks Victoria provided an annual report from the City which outlines the actions taken during the season, such as the ones provided in this documentation.

Inventory check

The City has performed an annual audit of the premises where mosquito products and equipment are stored to ensure that any damaged equipment is removed from use until fixed and product is stored according to manufacturer's specifications. The name, size and number of buckets/bags/containers of the products used are recorded in a table along with pictures of product labels to assist with identification. Equipment that is that is disposed of is listed as such but kept in the records for posterity. This auditing of inventory will continue in the new permit in line with the Mosquito Management Operational Plan.

Chemical register

A chemical register is generated annually and includes the date of creation and person compiling the register. The register includes the location and use of each product and whether they are classified as a hazardous or dangerous good. Additionally, the register includes current safety data sheets (SDS), risk assessments conducted for product use and any PPE required to be worn when using the products. This register is kept at the premises as well as in the City's document management system. This auditing of chemicals will continue in the new permit in line with the Mosquito Management Operational Plan.

SDS

Every chemical used within the program has its respective SDS printed, laminated and bound, and kept on the chemical storage site. The SDS are checked every year for any updates from manufacturers or suppliers; any changes to SDSs are discussed with Mosquito Management Officers to ensure appropriate measures are taken for safety and for the environment. This review will continue in the new permit in line with the Mosquito Management Operational Plan.

Safe work method statement (SWMS)

There are processes conducted by Mosquito Management Officers that carry inherent risks to their person. In such cases, a SWMS form is completed that includes the department, business unit, and responsible persons for ensuring compliance as well as date of completion, location where the processes take place and a description of the process.

Each step within the process is analysed to determine the hazard, hazard source and the level of risk it poses. Following the analysis, each hazard has a control measure put into practice to minimise or remove the hazard or its associated risk.

The SWMS are reviewed and updated as required and in line with the Mosquito Management Operational Plan.

8. Social and economic

8.1 Purpose

The preliminary documentation must address the economic and social impacts (both positive and negative) of the proposed action. This may include:

– *Details of any public consultation activities undertaken, and their outcomes*
– *Projected costs and benefits of the proposed action, e.g. employment opportunities expected to be generated by the project at each stage of the project. This must include thebasis for their estimation through cost/benefit analysis or similar studies.*
– *Employment opportunities expected to be generated by the project at each phase of the proposed action*
– *Benefits to the local and wider community as a result of the proposed action, includinghealth benefits*

Economic and social impacts should be considered at the local, regional and national level.

8.2 Public consultation activities

The City has not undertaken formal consultation with the community since the program started in 2005, however the City engages with the community in multiple ways to achieve and improve upon its integrated mosquito management program.

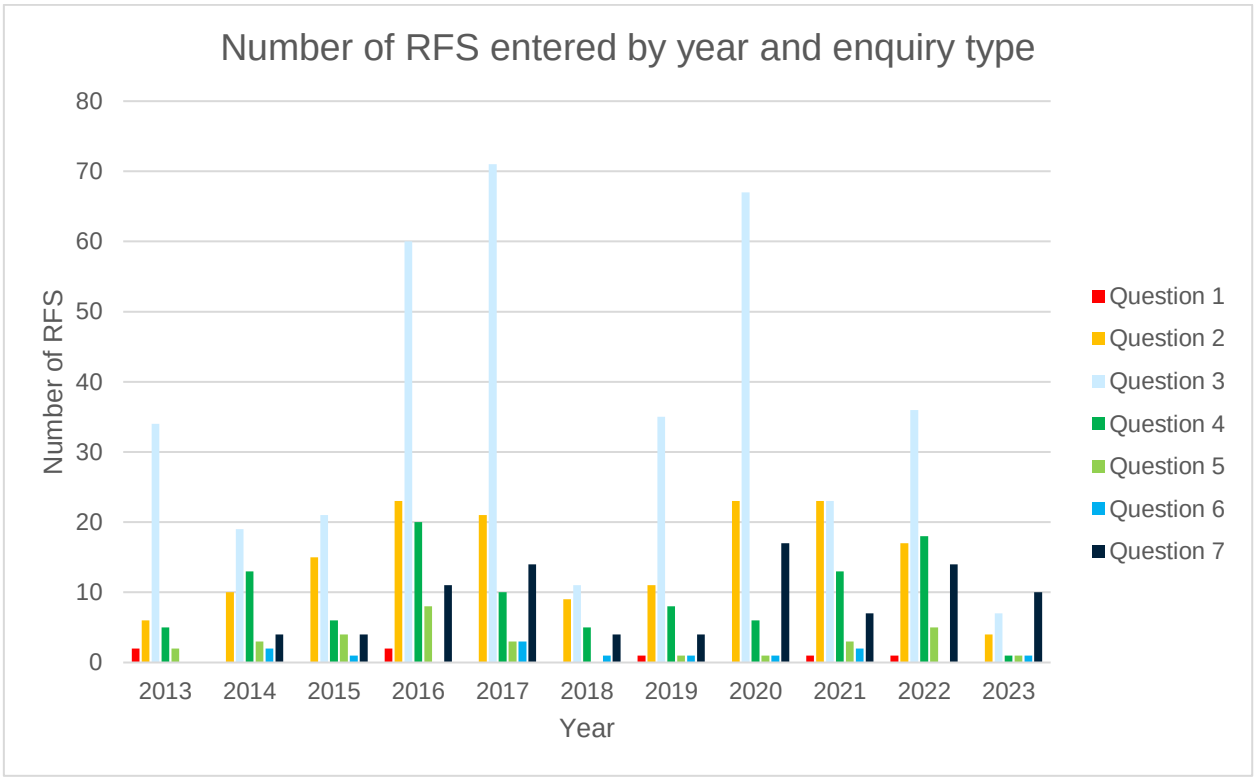
Members of the public can engage with the City's Officers throughout the year via email, phone or online request, with the majority of contact occurring during the mosquito season. These requests are either directly responded to via return email if it is a standard request; or it is logged in the corporate system called 'Pathway' as a 'request for service' (RFS). This allows the City to categorise and address enquiries or concerns about the mosquito management program.

An RFS is also generated when the public call the City directly. During this initial contact, the customer service team will ask a series of questions to determine which officer can best address the concern or information request. Once an RFS is generated, the relevant officer will contact the customer regarding their request and/or concern. Using the RFS system allows the City to directly engage with the community regarding the current mosquito management program and specific sites of interest.

Each RFS is categorised according to the following questions:

– Question 1 – Dissatisfaction with program
– Question 2 – General enquiry about program and/or product
– Question 3 – Report high mosquito levels in specific area
– Question 4 – Report potential breeding site
– Question 5 – Request to spray private property
– Question 6 – Disease related enquiry
– Question 7 – Other

A column chart displaying all entered RFS from 2013 to 2023 is shown below (Graph 48).



Graph 48 ***Number of requests for service entered into Pathway by year and enquiry type***

The highest number of RFS were general enquiries about the mosquito management program and the products that the City uses to reduce mosquito numbers (Question 2). When members of the public contact the City to report experiencing high mosquito levels in their area (Question 2), this can often be attributed to a nearby known breeding site, and the officer will explain this during the return phone call.

The least frequent RFS received was for dissatisfaction with the program (Question 1).

The City has also engaged in educating the community through:

– Submitting regular social/physical media releases that inform the public about the start and end dates of any aerial treatments, as well as the best ways to protect their properties and persons from mosquitoes
– Updating information regarding the mosquito management program on the City's website, including areas that have historically shown high levels of mosquitoes on maps
– An educational film clip about the mosquito management program which provides an explanation of how aerial treatments are conducted and can be found on the City's website
– Maintaining a 'Frequently Asked Questions' webpage to answer the most common questions from the public. These can also be downloaded from the City's website in either PDF or Word format
– Developing a 'Mosquito Education Activity Pack' for primary schools around Geelong to provide information to staff and students

In 2006, after obtaining EPBC approval 2005/2132 in November 2005, officers from the City presented at five community information meetings around the Bellarine Peninsula regarding the aerial application of larvicide to the Swan Bay and Lake Connewarre wetland areas. The presentations occurred during the 2006-2007 mosquito breeding season and were followed up with community satisfaction surveys in 2007 and 2008, where the community expressed high levels of satisfaction with the City undertaking a mosquito management program.

8.3 Projected costs and benefits of the proposed action, and the benefits to the local and wider community as a result of the proposed action

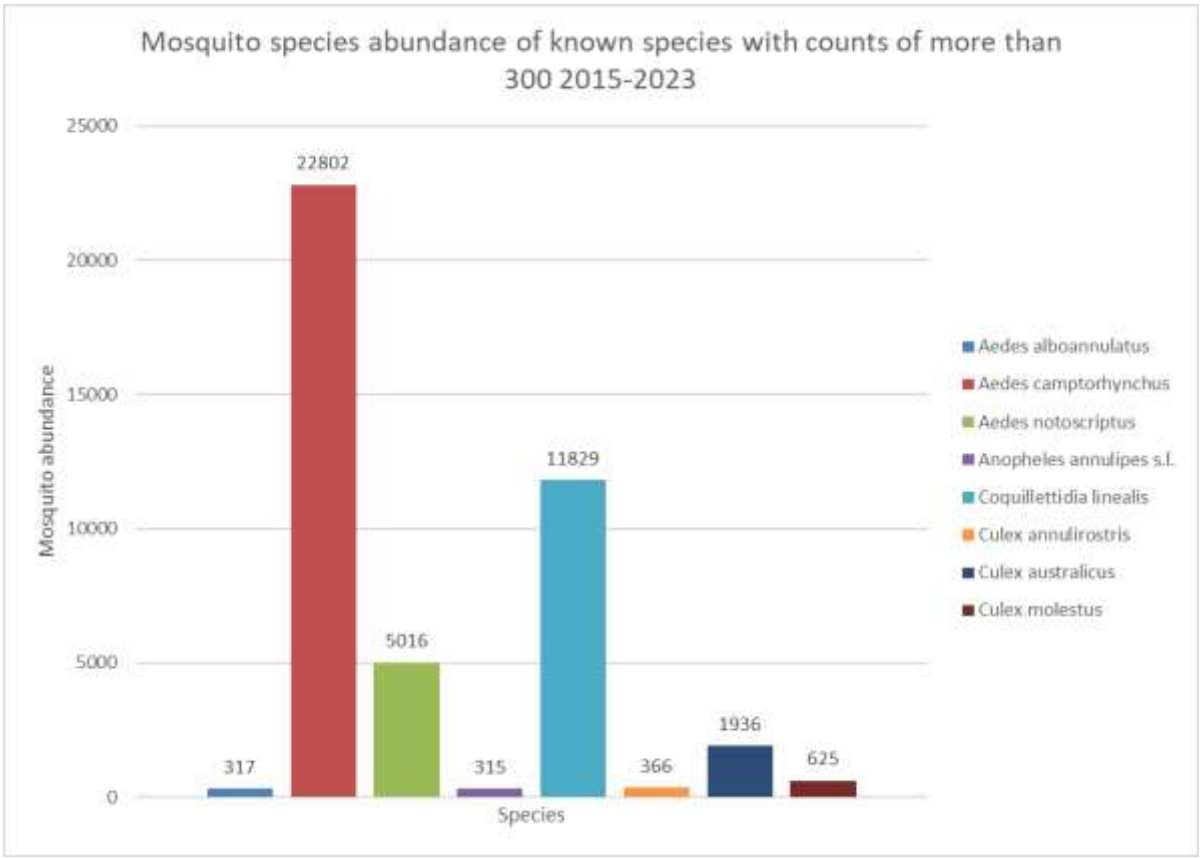
8.3.1 Mosquito-borne disease within the City of Greater Geelong

Within the Australasian region of the world, almost 300 species of mosquito exist, each with their own biology, ecology and risk to public health. There are three types of pathogens that are the causative agents of mosquito-borne diseases, which are:

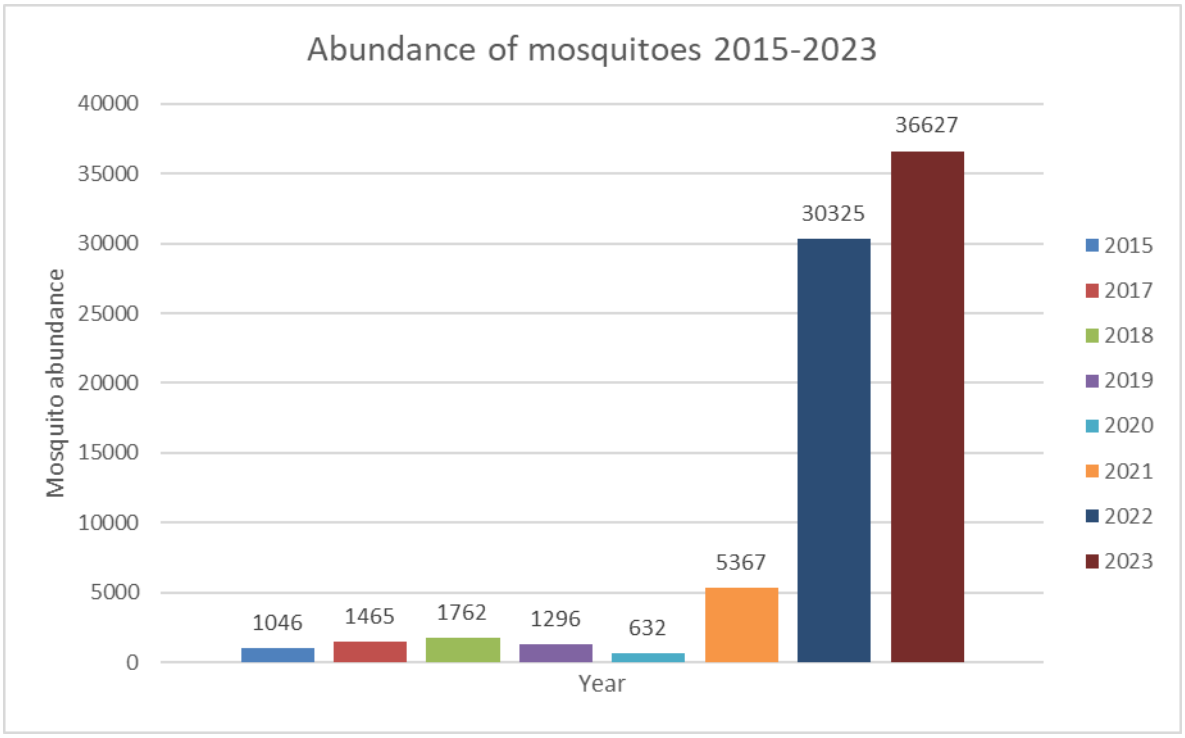
– Filarial “worms” (nematodes)
– Plasmodia
– Arboviruses

Arboviruses are the major public health concern in Australia, of which RRV has become increasingly common, particularly around rural and peri-urban environments (Webb et al. 2016).

The main vector of RRV is *Aedes camptorhynchus* (subgenus Ochlerotatus), a mosquito that has accounted for 22,802 of all mosquitoes trapped and identified through mosquito monitoring activities undertaken by the City of Greater Geelong since 2015 (Graph 49). As a result, *A. camptorhynchus* has been the predominant mosquito species targeted by the City of Greater Geelong’s mosquito management program, which has effectively kept the population of this vector under control using application of larvicidal products (such as *Bacillus thuringiensis israelensis* (Bti) and S-methoprene) by ground officers and aerial application in wetlands. It is also evident that mosquito abundance is climbing rapidly in the City of Greater Geelong (Graph 50).



Graph 49 ***Mosquito abundance by known species where trap counts were 300 or above from the 2015-2023 seasons.***



Graph 50 *Abundance of mosquitoes 2015-2023*

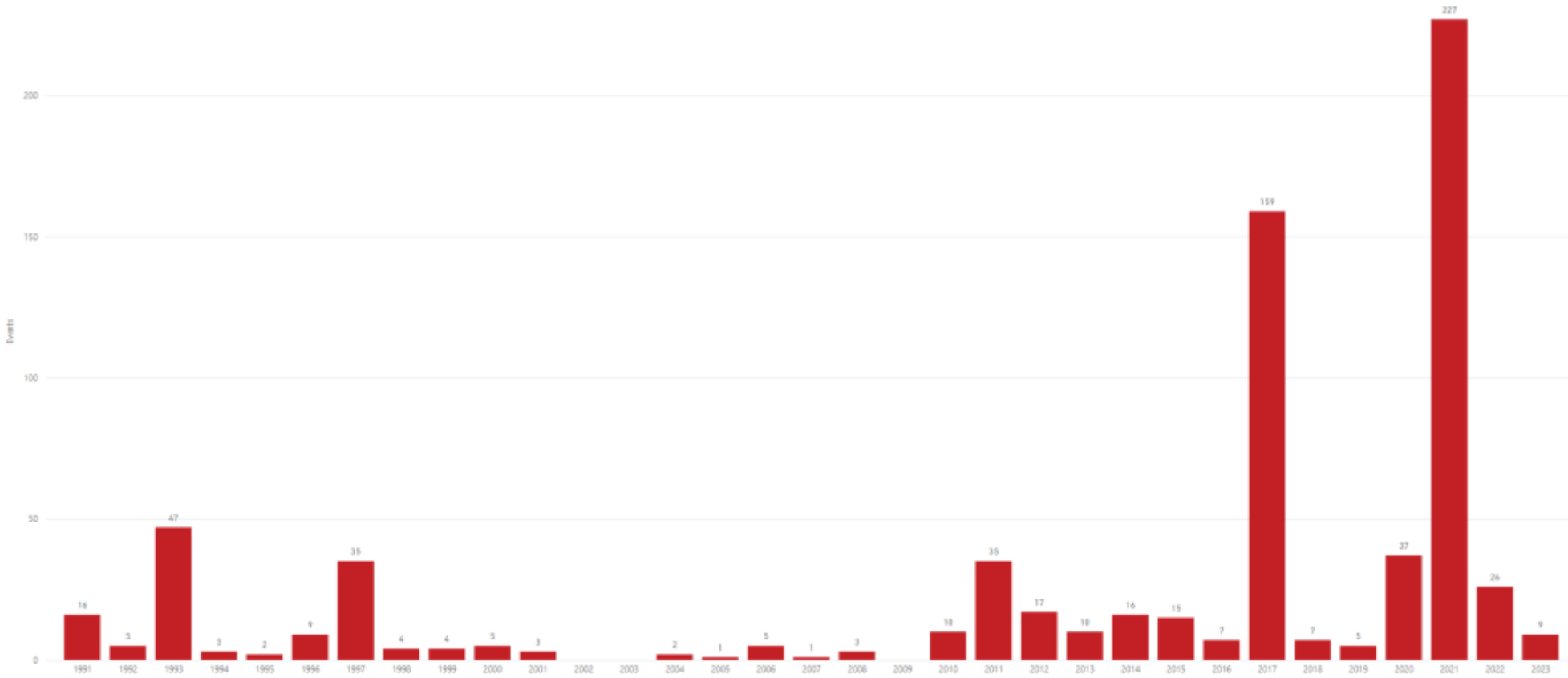
Table 64 shows the occurrence of RRV and *Mycobacterium ulcerans* (Buruli ulcer) infections of individuals (events) that are confirmed through serological testing. Since the 1st of January 2024 (YTD) there have been two events of RRV reported in the areas of Greater Geelong, Surf Coast Shire and Borough of Queenscliffe (Department of Health, 2024). In comparison, the Greater Geelong area is reporting higher levels of Buruli ulcer infections, which have been linked to mosquitoes (Mee et. al. 2024).

Table 64 *Events of notifiable conditions for RRV in Greater Geelong, Surf Coast Shire and Borough of Queenscliffe areas (DHHS, n.d.)*

Notifiable condition	Past 12M	YTD	2023	2022	2021	2020	2019	2018	2017	2016
RRV infection	4	2	9	26	227	37	5	7	159	7
Mycobacterium ulcerans	52	3	52	54	47	40	26	29	24	13

In 2017 there was unprecedented flooding in Victoria, which resulted in 159 cases of RRV in the Greater Geelong, Queenscliffe and Surf Coast areas. Flooding leads to increased mosquito breeding due to the presence of water that remains on the ground for extended periods of time. An increase also occurs around stormwater pipelines, curb side drains, retention basins and artificial wetlands in residential areas.

In 2021, there were 227 cases of RRV in the Greater Geelong, Queenscliffe and Surf Coast areas, which was almost as many cases as occurred in total across the preceding five years. This coincided with the COVID-19 pandemic and stay-at-home orders, which saw the City decrease its number of treatments. The City was only able to treat eight times during the 2020-2021 season, which is low in comparison to other seasons, where upwards of 30 treatments to the wetlands have occurred. This was most likely a significant contributing factor to the rise of RRV, as reduction in mosquito numbers to the same extent as pre-pandemic years was not conducted. Discounting natural events such as flooding, it can be seen that the mosquito management program plays an important part in preventing the transmission of RRV in the community.



Graph 51 Occurrence of RRV in the Greater Geelong, Queenscliffe and Surf Coast 1991-2023 to date (DHHS n.d.)

RRV infections are typically characterised by the following symptoms:

– Slight fever
– Rash
– Arthritis
– Arthralgia
– Swelling of the lymph nodes around the neck
– Tingling/pins and needles of the palms and soles

Although these symptoms are often subclinical, in approximately 40% of cases these symptoms will manifest in patients. RRV can cause incapacity and inability to work for two to three months, with 25% of patients having joint pain that persists for a year or more. Treatment for patients is supportive, as there is no antiviral available to treat infection and no vaccine to immunise the community against the virus (Webb et al. 2016).

Unfortunately, the data for the number of individuals infected with RRV is not believed to be a true reflection of the levels in the community. Only cases that have been confirmed through serological testing are reported to DHHS, with many cases remaining unreported. The number of RRV infections is likely to be higher than statistics obtained and presented in this report. Reports are based on where an individual resides, so reports for the City will be inaccurate when regarding visitors to the region.

8.3.2 Mosquito management expenditure

Over the 2015 to 2021 financial years, the mosquito management program within the City of Greater Geelong and the bordering Borough of Queenscliffe and Surf Coast Shire has had a total expenditure of $1,004,054.71. The expenditure breakdown for each year is provided in Table 65.

Table 65 Annual expenditure of the mosquito management program and annual expenditure for aerial larvicide treatment

Expenditure	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
Mosquito management program	$137,072.90	$227,904.30	$173,338.45	$147,610.45	$207,227.81	$110,900.80

The expenditure for the program includes salaries, health and safety provisions, contractors and products.

The City has a formal contract with a regional based aerial agricultural services company to conduct aerial treatments using mosquito larvicide products. During financial years 2015/16 to 2019/20, $223,922.76 has been spent with this company.

Annual expenditure does not correlate with an increase or decrease of RRV when comparing Table 65 and Graph 51. This is due to a multitude of factors, such as the expiration date of products, purchase of new equipment or interruptions such as the COVID-19 pandemic.

The City's mosquito management program has been heavily reduced, so recent expenditure data from the 2022/23 financial year has not been included. Expenditure is expected to increase to accommodate for the purchases of the drone, licencing and ecological studies.

Cost benefit analysis

Estimating the true benefits of mosquito management in the City of Greater Geelong has its limitations. These relate to:

– The true prevalence rate of the RRV in the community not being known, such that the City must rely on the number of reported cases
– RRV impacts people in different ways, with not all cases experiencing the same combination, type and severity of symptoms
– Depending on the combination, type and severity of symptoms, the medical costs and the extent of disability (i.e. number of workdays missed) is variable amongst cases

– The social costs associated with RRV (i.e. wellbeing, quality of life, ability to care for others) are not captured in reporting and are difficult to quantify

Considering these limitations, the City has undertaken a cost-benefit analysis focusing on the loss of income associated with the inability to work after becoming infected with RRV, using data obtained from the Australian Bureau of Statistics (ABS) and the Victorian Department of Health and Human Services (DHHS). The City has also drawn upon peer-reviewed literature to provide additional estimates of the social costs (health care resources, lost production, health-related quality of life) as a complementary line of evidence.

The City has included the calculations below (Method #1). The following assumptions were made for these calculations:

– The number of symptomatic cases is 40% of reported cases (based on Webb et al. 2016)
– All symptomatic cases are unable to work for the prescribed period
– The calendar year has a total of 365.2425 days
– Average weekly earnings are taken to be only on workdays, of which there are five in any given week
– Not all months have the same number of days; this calculation averages out the number of days in a month

Estimated earnings lost due to RRV in City of Greater Geelong, Surf Coast Shire and Borough of Queenscliffe

Number of days in a year = 365.2425 days

Number of weekend days in a year $= 52 \times 2 = 104$ days

Number of work days in a year =$365.2425 - 104 = 261.2425$ days

Average number of work days in a month = $\frac{261.2425}{12} = 21.77$ days

Average number of work weeks in a month $= \frac{21.77}{5} = 4.354$ work weeks

Average weekly earnings = $1305.80

Average earnings (per work week) in two months $= 4.354 \times 2 \times \$1305.80 = \$11370.91$

Approximate number of symptomatic RRV cases in 2021 = $219 \times 40\% = 87.6$ cases

Estimated amount of earnings lost in 2021 due to RRV $= 87.6 \times \$11370.91 = \$996091.72$

The estimate is between $996,091.72 (figure for two months lost earnings) and $1,494,137.10 (figure for three months) of earnings lost due to the health implications of contracting RRV for the City of Greater Geelong, Surf Coast Shire and Borough of Queenscliffe local government areas (LGAs) during 2021. The average of lost earnings is $1,245,114.41.

As this estimate is based on the number of events reported to DHHS, the previously described data inconsistencies apply, i.e. not all cases are serologically confirmed and each case is attributed to the LGA where the individual normally resides, as opposed to where they contracted RRV.

The City completed a separate cost benefit analysis using a 2006 PhD paper by Ratnayake (2006) (Method #2). This paper calculated that the average social costs of RRV were between $706 and $1,378 per individual, with an average of $1,070. Social costs are defined by the paper as including:

– Health care resources
– Lost production
– Health-related quality of life impacts

Using the inflation calculator provided by the Reserve Bank of Australia, the average social costs in 2020 would be $1,412.87 for the median amount of lost earnings. Applying this cost to the total number of cases across the Greater Geelong, Surf Coast Shire and Borough of Queenscliffe LGAs (total number of events used same as the referenced paper), it equates to an amount of full social costs of $310,831.40 (Table 66).

Table 66 Associated costs of RRV infection summary

Year	Costs	
	Method #1	**Method #2**
2021	$1,245,114.41	$310,831.40
2010-2016	$167,314.89	$131,081.72

Outside of the major peaks of RRV seen in Graph 51, the mosquito management program still shows that the benefit outweighs the cost. Applying Method #1 across the years of 2010 to 2016 in Graph 51 approximately $167,314.89 has been lost in earnings due to RRV using the City's method for calculating lost earnings. Using Method #2 − $131,081.72 incurred in adjusted social costs has been calculated. Compared to the average expenditure from 2015 to 2021, both methods show that investment into the mosquito management program is not an excessive expense.

As the data from DHHS regarding the number of events for RRV does not accurately reflect the true incidence of RRV in the community, actual social costs from both the City's method and Ratnayake method are expected to be greater than what is presented in this analysis. It is unknown how much greater the true incidence rate is, but given the costs are based upon data from DHHS, the mosquito management program successfully mitigates the incidence of RRV within the Greater Geelong, Surf Coast Shire and Borough of Queenscliffe LGA.

Mosquito nuisance impact on aesthetics of recreational and tourism areas

Nuisance mosquito bites are an ongoing problem within the City of Greater Geelong. Through engagement with the community, it can be reasoned that nuisance mosquito populations in outdoor recreational settings can have an impact on the aesthetic value, and the ability of the local and broader community to enjoy the City of Greater Geelong and surrounds.

With a population of nearly 265,000 people, the City of Greater Geelong is Victoria's largest regional municipality. Located 75 kilometres south-west of Melbourne, the municipality covers an area of 1,252 km^2, comprising suburban, coastal and country areas.

Greater Geelong is bounded by the Moorabool Shire in the north, Wyndham City Council and the Borough of Queenscliffe in the east, Surf Coast Shire and Golden Plains Shire in the west, and Bass Strait to the south.

The City's coastal area is mainly made up of the Bellarine Peninsula which is home to a large permanent population and is also a popular tourist destination. The Bellarine Peninsula is located approximately 12 kilometres to the east of the urban area of Geelong. It features significant wetland areas and open farmed landscapes with the distinct townships of Barwon Heads, Drysdale, Clifton Springs, Indented Head, Leopold, Ocean Grove, Point Lonsdale, Portarlington, Queenscliff, St Leonards and the rural living area around Wallington. The Bellarine Peninsula is surrounded by Port Phillip Bay to the east, Corio Bay to the north and Bass Strait to the south. The western boundary of the Bellarine Peninsula follows an irregular alignment running generally north-south along the suburban boundary of Leopold, west of Reedy Lake and to the coast at Breamlea. The resident population is estimated at 49,680, increasing to a peak population over the summer period of 79,403.

In 2023, visitors spent 4.4 million nights in the Greater Geelong region. This is an increase of 10.3% year on year (Tourism Greater Geelong and the Bellarine 2023).

The broader Greater Geelong and the Bellarine tourism region attracted 5.8 million visitors in 2018, comprised of 2.3 million overnight visitors and 3.5 million daytrip visitors.

Table 67 Number of visitors to the Greater Geelong and Bellarine including economic value and jobs attributed

Visitation	Economic value of tourism industry (output)	Jobs attributed to tourism industry
5.8 million visitors	$2.2 billion	11,264

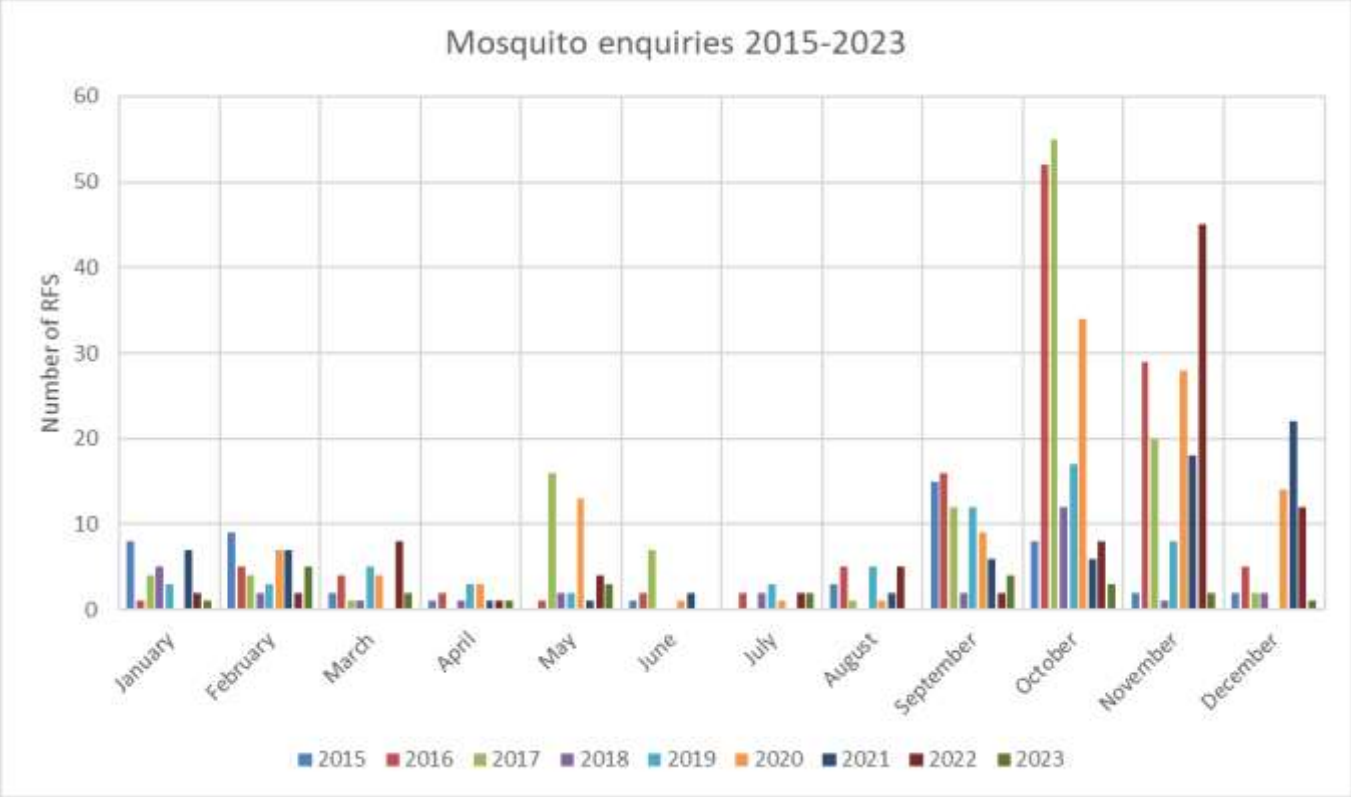
Greater Geelong and the Bellarine Peninsula has always been a favourite for the domestic short break market. When tourists come to the region, 49% stay at a friend's/relative's property, 12% caravan parks, 9% rentals and 8% in personal holiday houses. While these visitors are in the region, 59% ate out, 52% visited a friend/relative, 38% went to the beach, 24% went sightseeing and 19% went shopping (Tourism Geelong Bellarine 2021).

Lake Connewarre State Game Reserve features a variety of swamps, marshes, lakes and river areas and provides habitat to a wide range fauna which provides numerous outdoor recreational activities for locals and visitors to the area. There are several entry points to the lake and some sections feature walking paths including viewing platforms. There are a variety of picnic areas, fishing platforms and a small boat ramp suitable for launching, small craft – canoes, kayaks and small fishing boats.

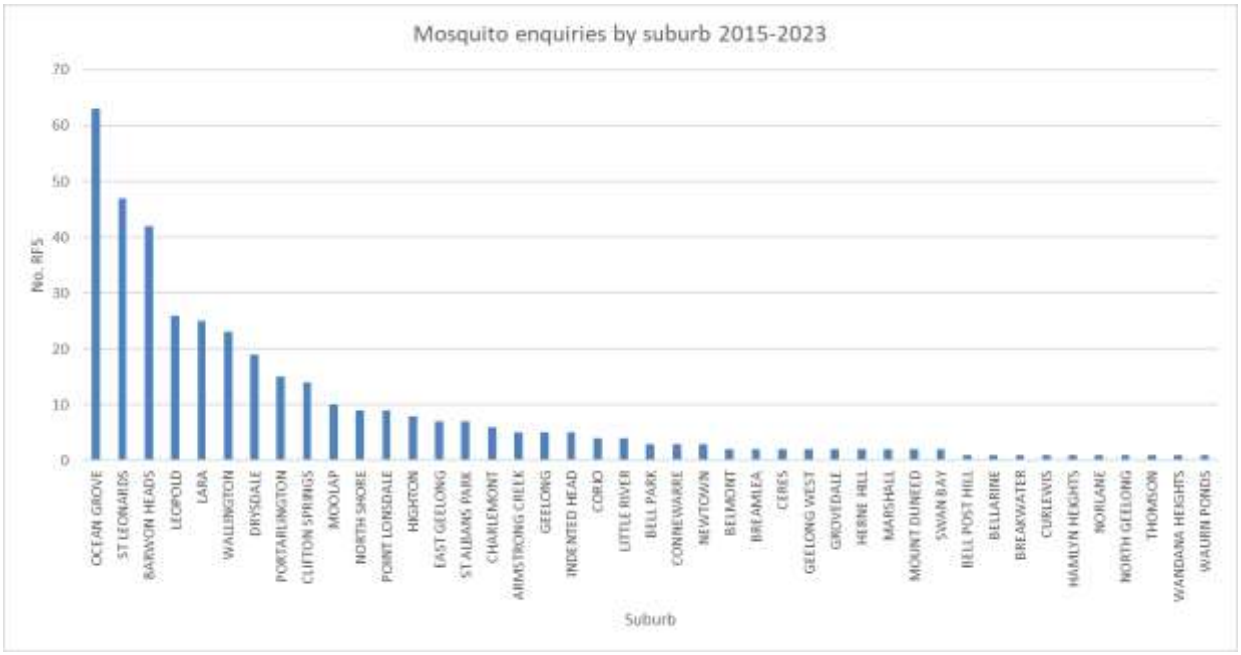
The reserve areas in Swan Bay are known for their coastal woodlands along a magnificent coastline and being home to a vast array of indigenous plants and animals. There are several walking/cycle paths and boardwalks throughout the reserve which can be enjoyed by locals and visitors to the area.

Geelong and the Bellarine Peninsula is known for its outdoor activities all year round, but mostly during spring and the peak summer season when the area booms with locals and visitors. An influx of tourists visiting the region to participate in numerous coastal walks/bike rides, recreational fishing trips, water sports and picnics. These activities make the most of our region's natural environment, acting as a social gathering place and somewhere to exercise outside of more built-up areas. Over 83% of travellers are from within Victoria, half of which are coming from Western and Central suburbs of Melbourne. Visitors to the region could be affected by higher levels of mosquitoes than what they experience at home.

September to November is when the City receives most of its mosquito enquires (refer to Graph 52), Graph 52with the majority of those coming from residents in the Bellarine Peninsula; Ocean Grove, St Leonards, Barwon Heads, Leopold, Lara and Wallington (refer to Graph 53).



Graph 52 Number of mosquito enquiries by month from 2015 – 2023



Graph 53 Number of mosquito enquiries received by the City by customer location from 2015 to 2023.

The proposed action will benefit the residents and visitors to the Bellarine Peninsula and its surrounds by contributing to creating a safe and healthy environment by reducing the number of mosquitoes to mitigate the potential health implications of vector-borne diseases.

Employment opportunities expected to be generated by the project at each phase of the proposed action

The Environmental Health Department in the City currently employs three permanent staff members to deliver the mosquito management program: two Mosquito Management Officers and a Health Development Officer. Supporting these roles are the Environmental Health Team Leaders (three positions) and the Coordinator.

The Mosquito Management Officers provide assistance to the Environmental Health Department in carrying out an efficient and effective mosquito management program that minimises the negative public health impacts on the community resulting from mosquitoes, by:

– Assisting the Team Leader Environmental Health and the Health Development Officer in the daily operation of the mosquito management program
– Carrying out and recording larval and adult monitoring of mosquitoes and sample collection
– Carrying out and recording ground-based treatments of adult mosquitoes and larvae using approved products and equipment
– Assisting aerial treatments of mosquito larvae using approved products and equipment
– Investigating complaints received in relation to mosquito infestations and other environmental health matters
– Establishing positive communications with the general public and educate and positively promote the mosquito management program and other environmental health matters
– Assisting with the implementation of education packages and proactive measures

The Health Development Officer supervises the routine management of the mosquito management program, by:

– Overseeing Contractor and Mosquito Management Officers, program verification including data management and reporting to internal and external agencies, permit applications and community consultation/liaison
– Providing support and guidance to customers in rectifying non-compliances
– Developing educational presentations, materials and strategies based on emerging issues, customer requests and/or industry trends
– Assisting with the implementation of education packages and proactive measures
– Maintaining appropriate administrative and information recording systems

– Establishing positive communications with the general public to educate, promote and assist with the need for compliance with various statutes, legislation and local laws
– The Team Leaders and Coordinator support the program by ensuring other roles are adequately trained, that other departments are notified or involved where necessary, and that all procedures, policies and directions are adhered to

In addition to the above staff members directly involved with the mosquito management program, there are three System Administration Specialists (part-time). These positions support the administration and customer service component of the mosquito management program by acting as a point of contact for the public and generating RFS's where required. The City's customer service team also support the program as they are the first point of call for the public. Where suitable the customer service team will provide mosquito related advice via phone or email to action the request in a timely manner and remove the requirement for the customer to be passed between departments.

As of the 2021 Census, the City of Greater Geelong has a population of 271,057; with forecasts for population growth predicting the population to increase to 327,591 by the end of the proposed permit's lifespan in 2030, and 396,388 by the end of 2041. This is an increase in population of 20.85% in 2031 and 46.24% by 2041 (Informed Decisions, 2023). A significant proportion of the population growth is expected to inhabit the growth areas of Armstrong Creek, Mount Duneed, Curlewis, Leopold, Ocean Grove, St Leonards and Point Lonsdale. These areas are close to multiple known mosquito breeding sites, including the RAMSAR wetlands.

The increase in population will result in further development of land in new estates. It has become common for new estates to build artificial wetlands that are to be maintained initially by the private developer, before maintenance responsibilities are transferred to the City. These wetlands often provide a habitat for mosquitoes to breed, within proximity to residential properties. Many lack any buffer zone between the wetland and surrounding properties to mitigate public health concerns.

With the increase in viable sites for mosquito breeding brought on by the population increase, it is expected that the number of Request for Service (RFS) generated will increase proportionally. This will result in more resources being diverted from other tasks within the mosquito management program into responding to customer enquiries. At current staffing levels, this has the potential to prevent the program from developing items of educational value, which has been an important facet of the City's mosquito management program.

With the expected increase in population it is feasible that the City will require more resources for the mosquito management program. The resources that may be required include:

– An additional Mosquito Management Officer
– An additional Health Development Officer
– Increase of Mosquito Management Officer to full-time
– Increase of Health Development Officer to full-time
– An additional System Administration Specialist
– Increase of a System Administration Specialist to full-time

9. Environmental record of person proposing to take action

9.1 Purpose

Please provide the following information if updated from that provided with the referral document, details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

– *The person proposing to take the action*
– *For an action for which a person has applied for a permit, the person making the application*

If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework should be described.

To the best of the City's knowledge, after making due inquiry, there is no further update to the information provided in the original submission.

The City of Greater Geelong has a detailed, up to date and informed environmental policy and planning framework. Council adopted Our Community Plan 2021-25 as the City's four-year strategic plan for the future of the region.

The City's Our Community Plan has 4 strategic directions, one of which is Sustainable Growth and Environment. It outlines priorities related to the environment, which include:

– Deliver best-practice Environmentally Sustainable Design principles and vibrant neighbourhoods
– Achieve carbon neutral in all City-managed operations by 2025 and manage our climate change risks
– Support our community and region to reduce emissions and build resilience to climate change
– Reduce the impact of waste
– Support greater indigenous biodiversity

The Environment Strategy 2020-2030 is a major strategy in the City's planning hierarchy. It details the City's environmental sustainability goals, how the City will act to protect the environment and reduce its environmental footprint. The Environment Strategy 2020–30 will be implemented in conjunction with other adopted environmental strategies including:

– Sustainability Framework – a framework and policy that embeds sustainability within the City, so it is considered in everything the City does
– Waste and Resource Recovery Strategy 2020–30
– Stormwater Services Strategy 2020–30
– Urban Forest Strategy 2015-25

The Environment Strategy 2020-2030 defines five key goals to guide the City's planning and decision making. These goals are:

1. Become a zero-emission, climate-ready city and region
2. Create greener community spaces
3. Contribute to a circular economy by reducing waste
4. Protect, enhance and restore our region's biodiversity
5. Achieve better integrated water management through planning and design.

Protecting the environment is a key priority of the City's Sustainability Framework 2020, with the City committed to achieving zero emissions, using the planning framework to influence sustainable growth in the built environment, increasing green spaces, supporting biodiversity and leading the community to mitigate the impacts of climate change.

The City's Environment Strategy Action Plan 2020-2022 sets out the plan to achieve the goals, directions and targets established in the Environment Strategy 2020-2030.

The actions in this plan are reported on, and updated, every two years. This enables the City to keep pace with the rapid changes occurring in environmental management.

The strategy and supporting action plan have been informed by local and international environmental trends, and by the knowledge and ideas of the community and regional stakeholders. These documents guide the City's planning, decision-making and actions as it strives to improve the health of the local environment, reduce its environmental footprint and protect the lifestyle the community enjoys.

10. Ecologically Sustainable Development

10.1 Purpose

The preliminary documentation package must provide a description of the proposed action in relation to the principles of ecologically sustainable development and the objects and requirements of the EPBC Act:

- The long-term and short-term economic, environmental, social and equitable considerations
- *The precautionary principle which states that a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation where there are threats of serious or irreversible environmental damage*
- *The principle of inter-generational equity which states that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations*
- *The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making*
- *Improved valuation, pricing and incentive mechanisms should be promoted*

Section 3A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) defines the principles of ecological sustainable development. Table 68 provides an assessment of the proposed action against these principles.

Table 68 Assessment of proposed action against the EPBC Act principles of Ecologically Sustainable Development

No.	Principle	Consideration of principle in the proposed action
a)	Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations	This response to a Preliminary Documentation Request for the proposed action documents the careful consideration of the potential social and environmental trade-offs. Alternative options have been considered as part of this process. The impact assessment and social and economic considerations outlined in section 8 of this document demonstrate the implications of doing nothing. **Program purpose** The central purpose of the proposed action is to achieve ongoing public health outcomes for the local and broader community, with the complementary benefit of enhancing the ongoing recreational and social values of the Ramsar and adjacent wetlands. By reducing the risk of illness from mosquito-borne arboviruses, and by reducing the discomfort associated with nuisance mosquito populations, the local and broader community can continue to appreciate and enjoy the ecosystem services provided by Ramsar site and surrounds. The integration of environmental and social considerations is inherent in the overall purpose of the program and is maintained through on-going monitoring and risk-based prioritisation of mosquito-treatment sites. **Continuous improvement** Incorporating new knowledge to enhance long-term program effectiveness is termed adaptive management and is at the core of the program. The City of Greater Geelong are endeavouring to enhance future outcomes by adaptively managing the program to ensure that public health benefits are achieved in the future. In 2019, the City of Greater Geelong had the mosquito management program externally reviewed, which included giving due consideration to the potential effects that changing climate conditions may have on the long-term effectiveness of the traditional operational schedule. The review indicated that long-term climate change can influence mosquito management operations, and thus to ensure on-going effectiveness, the City proposes to extend the treatment period to end of May in order to protect public health and reduce levels of mosquitoes and mosquito-borne diseases in the community. The City acknowledges that, as the local population increases, the number of ground sites requiring monitoring and treatment will likely grow, with some of the previously assessed sites changing from low to medium risk or medium to high risk. This will require further assessments to be completed to ensure the City's mosquito management program is reducing the potential for public health risks for the community, and ensuring that public assets (i.e. Ramsar site, reserves) can be enjoyed without risk of illness or discomfort.

No.	Principle	Consideration of principle in the proposed action
b)	If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation	**Literature review** In stochastic ecological systems, obtaining full scientific certainty is often unachievable. A systematic review of the contemporary literature can be used to reduce the uncertainty of an ecological response to an intervention and effectively identify the residual uncertainties which can then be used to inform project risk assessment. The proposed action has been the subject of a robust systemic literature review (see section 4 and Appendix F), which focused on the potential direct and indirect impacts to MNES from the use of the two proposed larvicide products (*Bacillus thuringensis israelensis* (Bti) and S-methoprene). The literature review indicated that residual uncertainty associated with the application of S-methoprene relates to its non-specificity in the aquatic environment. S-Methoprene can negatively impact non-target insect larvae, crustaceans, and potentially amphibians and fish. However, S-methoprene's low persistence in the environment reduces the potential for impacts on non-target organisms and evolution of resistance, and previous studies indicated that while negative impacts on some organisms were observed, recovery after application was rapid. The literature review indicated that the use of Bti as a larvicide appears to be widely supported. Bti is considered an essential tool for mosquito control agent because there has been no observed development of resistance against it, unlike other pesticides, including S-methoprene. There are residual uncertainties associated with the use of Bti, of most concern are the indirect food-chain effects reported for birds (House Martins), and sub-lethal behavioural responses by tadpoles. The literature is relatively consistent in the conclusion that, among the products used for mosquito control, Bti and S-methoprene are among the safest for the environment and for non-target organisms, particularly vertebrates. **Former mosquito management program** The former mosquito control program (refer permit EPBC 2005/2132) operating in the Greater Geelong Area operated for 10 years, with no reported adverse effects on MNES, biota, humans or the broader community. **Impact assessment and program design** Information gathered from the systematic literature review and former mosquito control program were used to inform the environmental impact assessment for the proposed action. The proposed action has been designed to avoid serious or irreversible damage to the environment including MNES. Direct and indirect impacts to MNES and other biota and habitat have been identified and minimised by limiting the period of aerial treatment at certain times of the year.
c)	The principle of intergenerational equity - that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	**Maintaining environmental values** The timing, location, frequency, and concentration(s) of the treatments has been determined by an impact assessment based on a review of international evidence and local knowledge. This has been done to ensure that any potential short-term or long-term adverse outcomes to the environment, including to biodiversity and threatened species, productivity (macroinvertebrates) and wetland health, is identified, carefully considered, and compared against the benefits of the proposed action. The impact assessment and literature review has found that there are no predicted long-term ecological impacts associated with the proposed action. Therefore, the environmental values of the treatment area will be maintained for the use and enjoyment for future generations. It can also be inferred that reduced local mosquito populations will enable future generations to continue to enjoy the biological diversity and productivity of the wetlands in comfort and with minimised risk of injury (from bites) or illness (diseases).
d)	The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	The proposed action has been the subject of a systematic literature review and impact assessment which has identified and evaluated potential impacts on biological diversity and ecological integrity. This assessment included the careful consideration of the implications of the proposed action on MNES, including the Ecological Character of the impacted Ramsar Site, listed threatened species and communities, migratory birds, and other local biota. This knowledge has been used to inform decisions concerning the timing, location, frequency, and concentration(s) of the proposed treatments in order to mitigate potential impacts on biological diversity and ecological integrity. For example, to avoid impacts to the critically endangered Orange-bellied Parrot, the City is limiting the time period in which aerial treatments are undertaken during times when the species is reported to be present along the Bellarine Peninsula. This is due to the Orange Bellied Parrot migrating to Victorian coastal regions during autumn and winter.

No.	Principle	Consideration of principle in the proposed action
e)	Improved valuation, pricing and incentive mechanisms should be promoted	The City acknowledges the need for improved valuation, pricing and incentive mechanisms and endeavours to pursue and leverage off these principles where applicable. For instance, on 14 December 2019, the Public Health and Wellbeing Regulations 2019 replaced the Public Health and Wellbeing Regulations 2009. The new regulations are aimed at further reducing the risk of vector-borne diseases by broadening the scope of the existing regulations. An important change includes establishing obligations on owners and occupiers of premises to take reasonable steps to control mosquito breeding grounds and abate conditions conducive to their establishment. This complements the existing non-regulatory measures to control mosquito breeding under the Victorian Arbovirus (mosquito-borne) Disease Control Program. The City aims to leverage the new regulations by using existing and ongoing engagement processes to educate and raise awareness around owner and occupiers' obligations to take reasonable steps to control mosquitoes under Public Health and Wellbeing Regulations 2019, with an overall goal of improving program efficiency through complementary measures that do not come at a cost to the City. The City provides education for owners and occupiers about how they can reduce the potential for mosquito breeding around their property. This education can take the form of: Media releases at the beginning of a season, providing instructions on how best to keep property and persons safe In-person education specific for a location when attending a breeding site in a residential property Information packs and webpages that cover the life cycle, common species of mosquitoes and steps that can be taken to prevent breeding around the home. The City endeavours to utilise the powers delegated under the Public Health and Wellbeing Regulations sparingly with regards to directing owners and occupiers to take steps in reducing mosquitoes; education about mosquitoes, how they breed and how to deter them will be the major complementary measure the City utilises outside of the direct actions of the mosquito management program.

11. Conclusion

This response to a Preliminary Documentation Request for the proposed action is evidence of due process and careful consideration of the potential social and environmental trade-offs. Alternative options have also been considered. The impact assessment and social and economic considerations as detailed in this document demonstrate the implications of doing nothing.

The integration of environmental and social considerations is inherent in the overall purpose of the program and will be maintained through ongoing monitoring and risk-based prioritisation of mosquito-treatment sites.

The literature review indicated that residual uncertainty associated with the application of S-methoprene relates to its non-specificity in the aquatic environment. S-Methoprene can negatively impact non-target insect larvae, crustaceans, and potentially amphibians and fish. However, S-methoprene's low persistence in the environment reduces the potential for impacts on non-target organisms and evolution of resistance, and previous studies indicated that while negative impacts on some organisms were observed, recovery after application was rapid.

The literature review indicated that the use of Bti as a larvicide appears to be widely supported. Bti is considered an essential tool for mosquito control because there has been no observed development of resistance against it, unlike other pesticides, including S-methoprene. There are residual uncertainties associated with the use of Bti, of most concern are the indirect food-chain effects reported for birds, and sub-lethal behavioural responses by tadpoles. However, for all areas of concern, there are other studies that show contrasting results, and neither area of concern has been conclusively demonstrated or reinforced by additional studies from other systems, so conjecture remains. Furthermore, there appear to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.

Furthermore, the literature is relatively consistent in the conclusion that, among the products used for mosquito control, Bti and S-methoprene are among the safest for the environment and for non-target organisms, particularly vertebrates.

The potential for incremental cumulative impacts (direct and indirect) over the six-year mosquito management program is expected to be negligible for the following key reasons:

- None of the other projects identified from the review resulted in significant impacts or controlled actions. The other projects propose direct and indirect impacts that occur outside of the mosquito program's proposed action area.
- The other projects propose minor impacts on a few of the same MNES potentially impacted by the City's proposed action. In consideration of the potential incremental cumulative impact of these projects in combination of the proposed action, potential impacts on MNES are considered low or negligible
- No habitat will be directly removed or modified by the proposed action over the course of the six-year program
- The intended seasonal application rate and the maximum intended application rate (cumulative total for the six-season program) of S-methoprene and Bti of treatment area (all sites combined) proposed by the City are invariably low, compared with lethal doses identified from the review of literature
- Although there are knowledge gaps with regards to use of the larvicide products as identified by the literature review (e.g. potential for long term endocrine disruption from the use of S-methoprene, potential for S-methoprene to accumulate in the food web) the potential direct and indirect impacts on MNES as a result of the proposed action are in part mitigated because of the following key factors:
    - There are substantial time periods where no treatment occurs. This would result in a gap of at least six months between treatments for the majority of sites allowing for a period of recovery and recruitment.
    - Not all available mosquito habitats are treated each season within the proposed action area and therefore large areas of untreated habitat remain for mosquitos, natural mosquito predators and threatened and migratory species discussed in this report
    - The recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function from short term loss of a portion of the local invertebrate fauna, are not expected within the proposed action area or within the local area

- The threatened and migratory species discussed in this report are at low risk of indirect or direct exposure to larvicide products over the course of each season and the cumulative risk of exposure of the course of the six season program is low for the majority of species and medium for four species

The impact assessment and literature review has found that there are no predicted long-term ecological impacts associated with the proposed action. Therefore, the environmental values of the treatment area will be maintained.

The City supports the implementation of the measures detailed in section 5 in order to avoid and minimise ongoing impacts to MNES as far as practicable.

These measures will be adaptive to provide continuing improvement in the minimisation of impacts. Adaptive management will enable measures to be optimised, building upon information collected from long-term monitoring throughout the proposed six-year mosquito management program. Particular focus will be given to measures for the Orange-bellied Parrot and aquatic invertebrates.

With the implementation of the mitigation measures and mechanisms for adaptive management, significant residual impacts to MNES are expected to be negligible and unlikely.

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Appendices

Appendix A

Figure 1 - Proposed action area and treatment sites

PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1a

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Removal
- Proposed Ground Site Removal

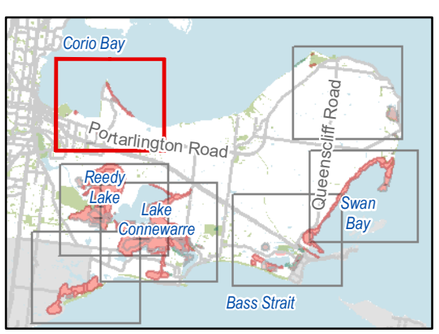


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PREVIOUS REFERAL & PROPOSED SITE ADDITIONS

FIGURE - 1b

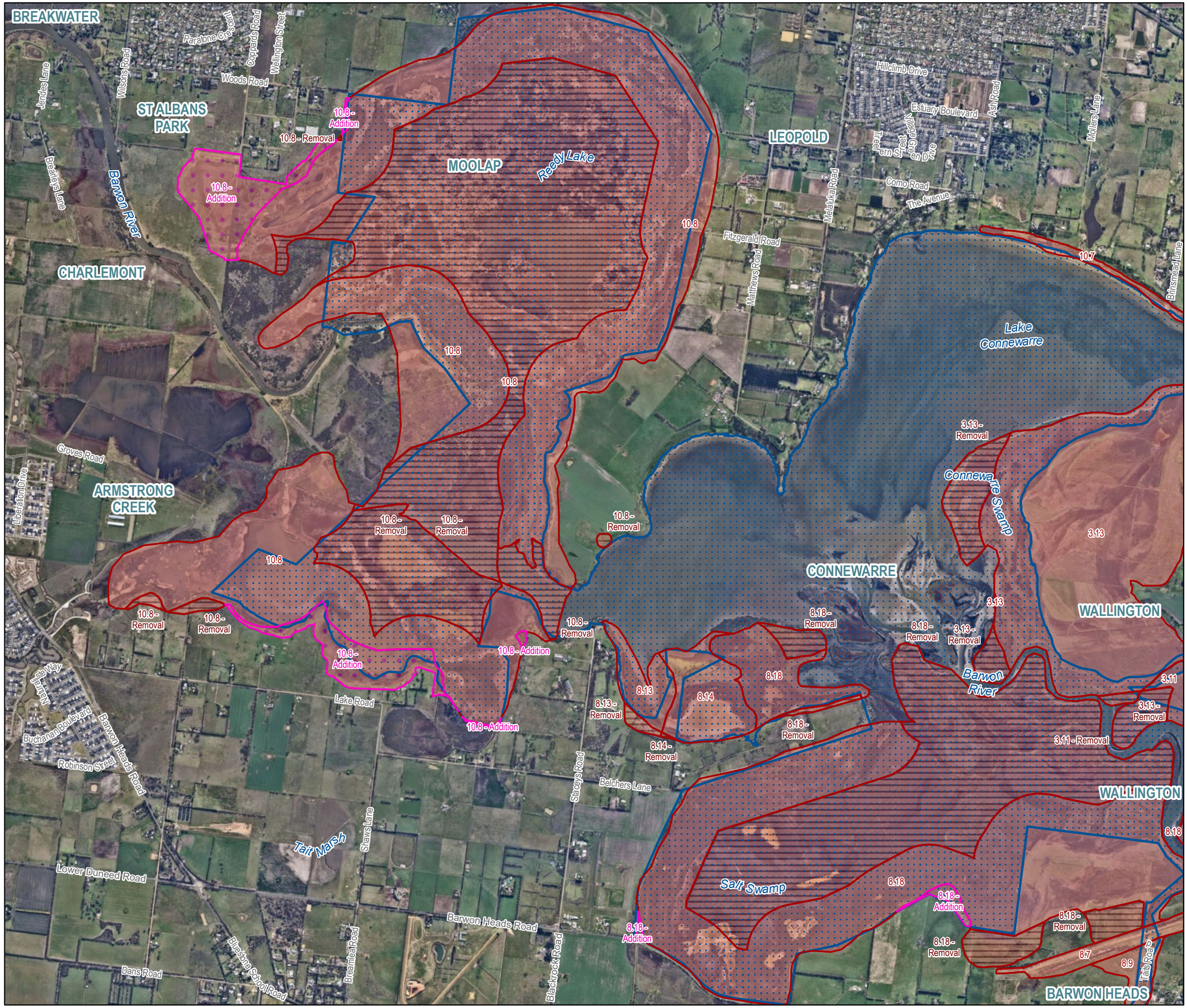
Ramsar Wetland

Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site Addition

Proposed Aerial Site Removal

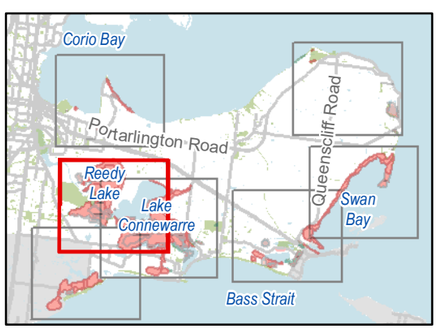


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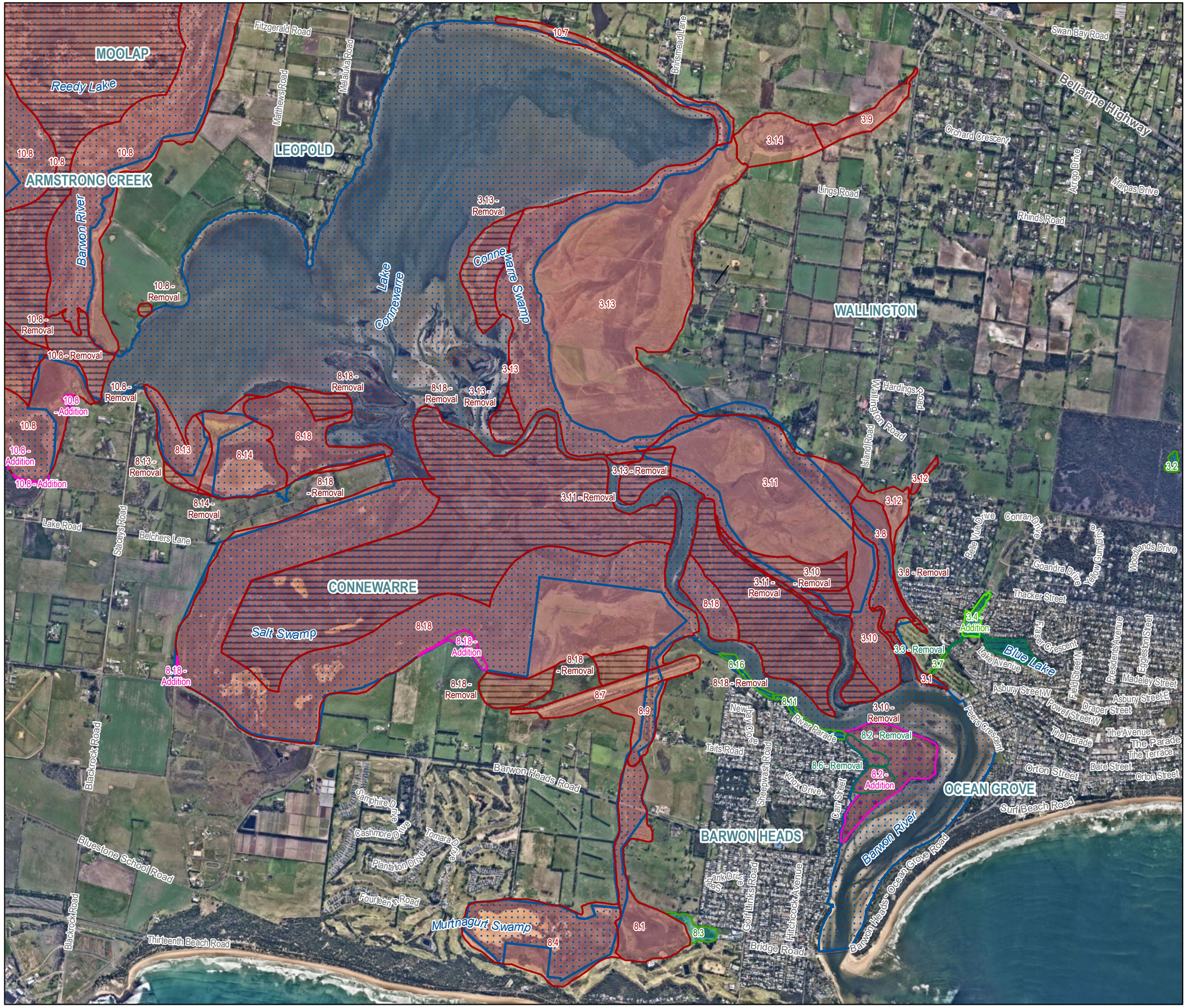
PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1c

Ramsar Wetland

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Addition
- Proposed Aerial Site Removal
- Existing Ground Site
- Proposed Ground Site Addition
- Proposed Ground Site Removal

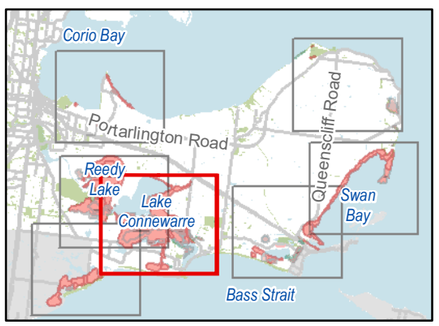


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PREVIOUS REFERAL & PROPOSED SITE ADDITIONS

FIGURE - 1d

Ramsar Wetland

Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site Addition

Proposed Aerial Site Removal

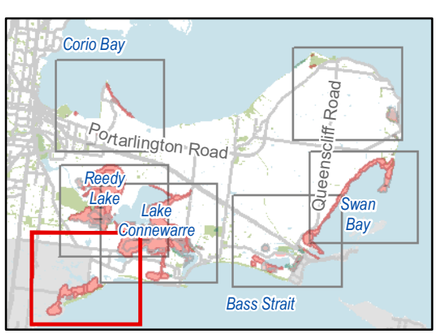


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PREVIOUS REFERAL & PROPOSED SITE ADDITIONS

FIGURE - 1e

Site 1.7- Ground Treatment

Ramsar Wetland

Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site Addition

Proposed Aerial Site Removal

Existing Ground Site

Proposed Ground Site Addition

Proposed Ground Site Removal

Marine National Park

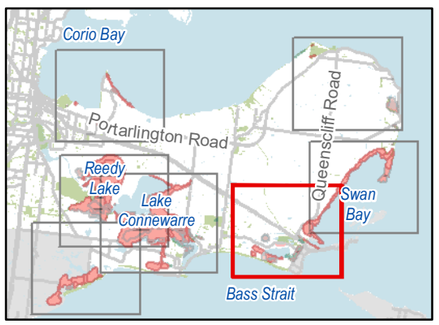


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PREVIOUS REFERAL & PROPOSED SITE ADDITIONS

FIGURE - 1f

Ramsar Wetland

Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site Removal

Proposed Ground Site Removal

Marine National Park

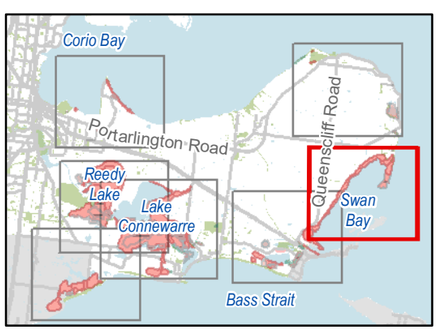


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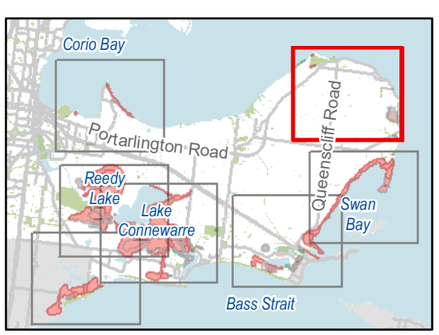
PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1g

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Addition
- Existing Ground Site
- Proposed Ground Site Removal





0 400 800 1,600 m

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PROPOSED ACTION AREAS

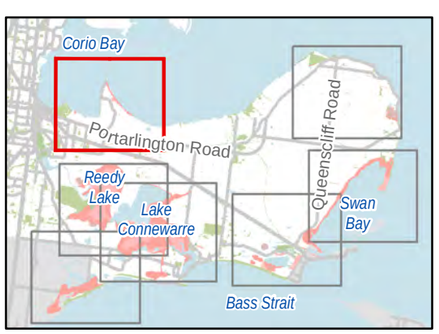
FIGURE - 2a

Proposed Treatment Site

Aerial



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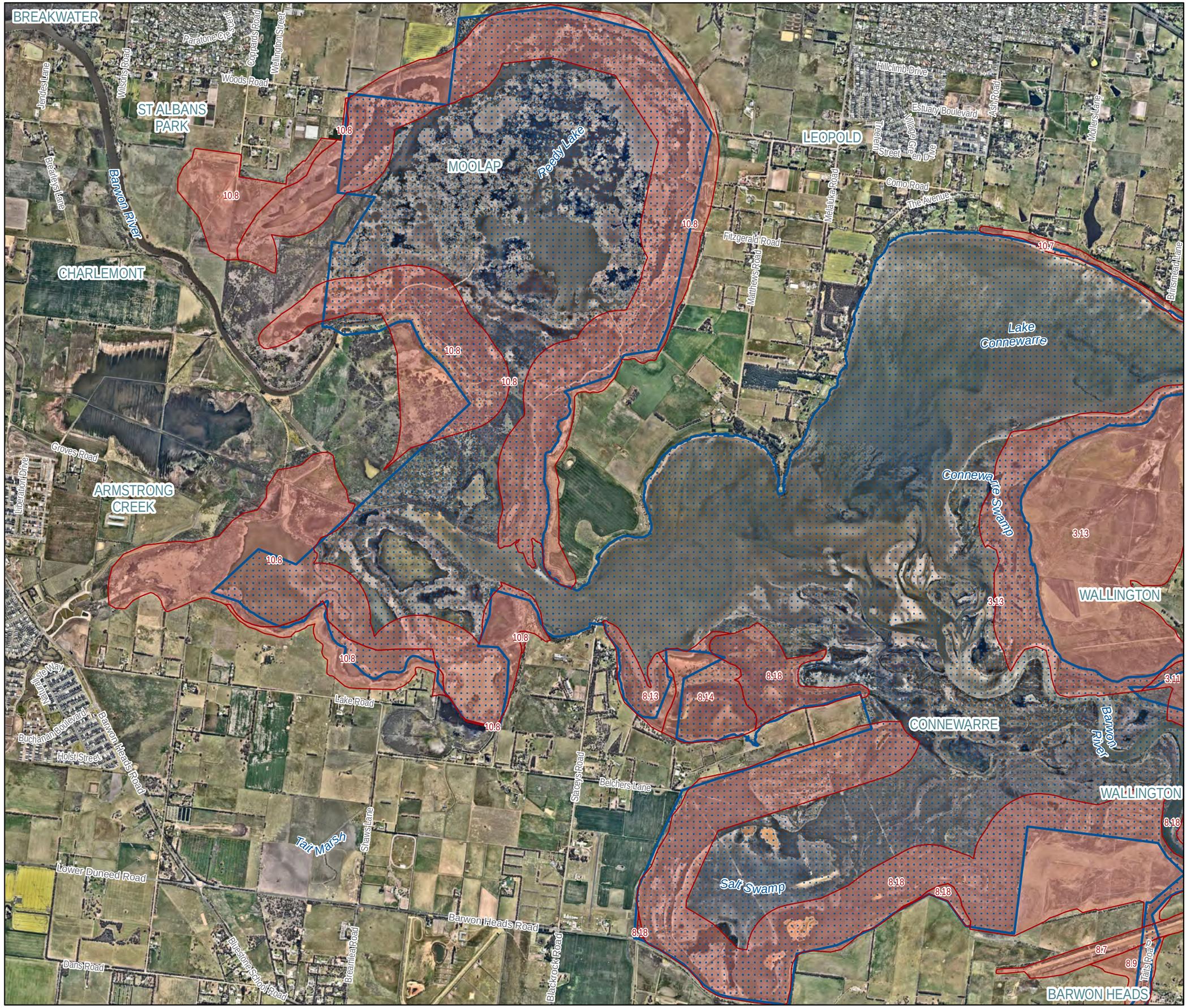
PROPOSED ACTION AREAS

FIGURE - 2b

Ramsar Wetland

Proposed Treatment Site

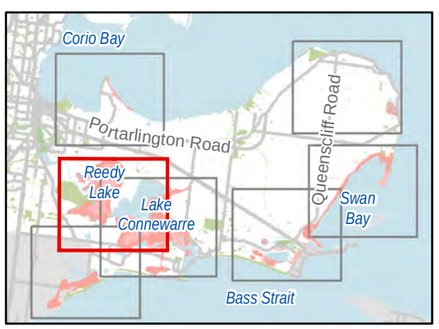
Aerial



0 400 800 1,600 m

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PROPOSED ACTION AREAS

FIGURE - 2c

Ramsar Wetland

Proposed Treatment Site

Aerial

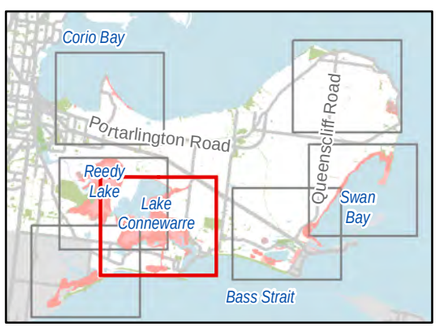
Ground

0 425 850 1,700 m

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PROPOSED ACTION AREAS

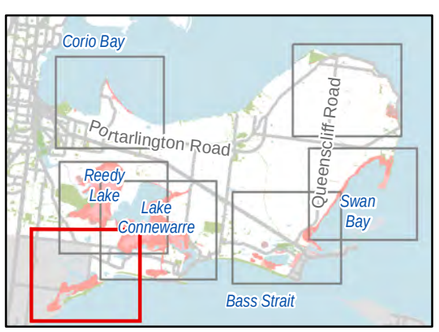
FIGURE - 2d

Ramsar Wetland

Proposed Treatment Site

Aerial





0 400 800 1,600 m

N

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PROPOSED ACTION AREAS

FIGURE - 2e

Site 1.7- Ground Treatment

Ramsar Wetland

Proposed Treatment Site

Aerial

Ground

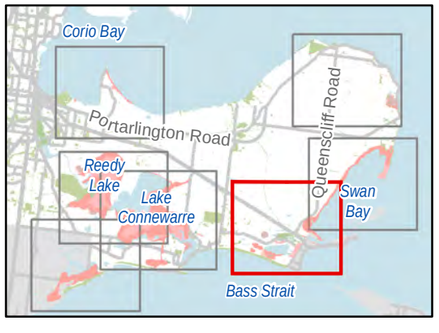
Marine National Park

0 400 800 1,600 m

N

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PROPOSED ACTION AREAS

FIGURE - 2f

Ramsar Wetland

Proposed Treatment Site

Aerial

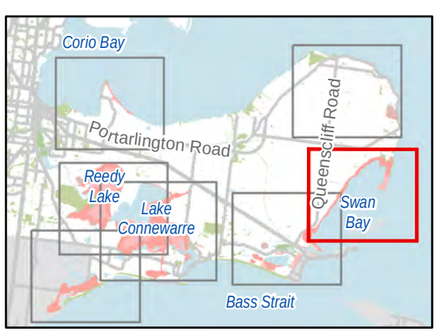
Marine National Park



0 400 800 1,600 m

N

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PROPOSED ACTION AREAS

FIGURE - 2g

Proposed Treatment Site

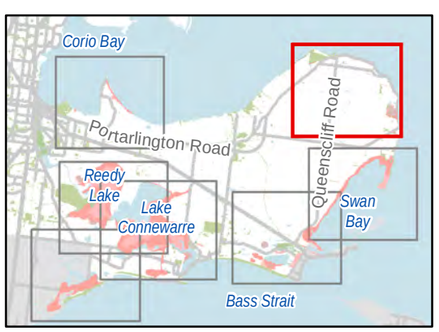
- Aerial
- Ground



0 400 800 1,600 m

N

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Appendix B

Figure 2 - Aerial treatment sites and flight data

PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3a

Treatment Flightpath Season

- 2012-2013
- 2014-2015
- 2015-2016

Proposed Treatment Site Changes

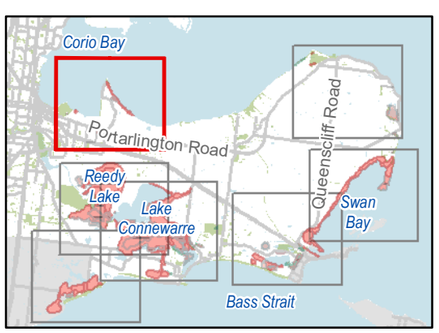
- Existing Aerial Site
- Proposed Aerial Site Removal
- Proposed Ground Site Removal

0 400 800 1,600 m

N

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PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3b

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site Changes

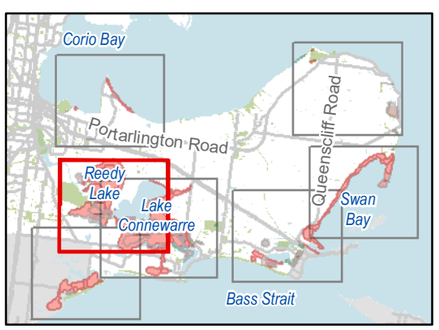
- Existing Aerial Site
- Proposed Aerial Site Addition
- Proposed Aerial Site Removal

0 400 800 1,600 m

N

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BREAKWATER
ST ALBANS PARK
CHARLEMONT
ARMSTRONG CREEK
MOOLAP
LEOPOLD
CONNEWARRE
WALLINGTON
BARWON HEADS
Reedy Lake
Lake Connewarre
Connewarre Swamp
Barwon River
Tait Marsh
Salt Swamp
Paraione Crescent
Coppards Road
Wellington Street
Woods Road
Wilsons Road
Jandes Lane
Brearleys Lane
Hillclimb Drive
Estuary Boulevard
Ash Road
Mollers Lane
Tree Fern Street
Village Green Drive
Como Road
The Avenue
Melaluka Road
Fitzgerald Road
Matthews Road
Brinsmead Lane
Groves Road
Liberation Drive
Lake Road
Marine Isle Way
Buchanan Boulevard
Robinson Street
Barwon Heads Road
Shaws Lane
Staceys Road
Belchers Lane
Lower Duneed Road
Dans Road
Bluestone School Road
Breamlea Road
Blackrock Road
Tails Road
10.8 - Addition
10.8 - Removal
10.8
10.7
3.13 - Removal
3.13
8.18 - Removal
8.18 - Addition
8.18
8.14 - Removal
8.14
8.13 - Removal
8.13
3.11 - Removal
3.11
8.9
8.7

PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3c

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site Changes

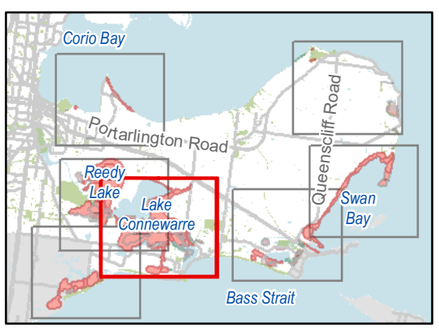
- Existing Aerial Site
- Proposed Aerial Site Addition
- Proposed Aerial Site Removal
- Existing Ground Site
- Proposed Ground Site Addition
- Proposed Ground Site Removal

0 435 870 1,740 m

N

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MOOLAP
Reedy Lake
LEOPOLD
ARMSTRONG CREEK
Barwon River
Lake Connewarre
Connewarre Swamp
WALLINGTON
CONNEWARRE
Salt Swamp
Murtnaguri Swamp
BARWON HEADS
OCEAN GROVE
Blue Lake
Fitzgerald Road
Matthews Road
Melaluka Road
Brimsmead Lane
Swan Bay Road
Bellarine Highway
Orchard Crescent
Arrigo Drive
Maipas Drive
Lings Road
Rhinds Road
Wallington Road
Island Road
Hardings Road
Lake Road
Staceys Road
Belchers Lane
Blackrock Road
Bluestone School Road
Thirteenth Beach Road
Barwon Heads Road
Tallis Road
Sheepwash Road
Knox Drive
Carr Street
Golf Links Road
Hitchcock Avenue
Bridge Road
Barwon Heads-Ocean Grove Road
Surf Beach Road
Orton Street
Dare Street
The Parade
The Terrace
The Avenue
Peers Crescent
River Parade
Lake Avenue
Asbury Street W
Asbury Street E
Draper Street
Madeley Street
Eggleston Street
Presidents Avenue
Field Street W
Power Street W
Fraser Crescent
Thacker Street
Goandra Drive
Yellow Gum Drive
Woodlands Drive
Bella Vue Drive
Conran Drive
Cashmore Drive
Tomara Drive
Plantation Drive
Fourteenth Road
Gamphire Drive
10.7
3.9
3.14
10.8
10.8 - Removal
10.8 - Addition
3.13 - Removal
3.13
8.18 - Removal
8.18
8.13
8.14
8.13 - Removal
8.14 - Removal
3.11 - Removal
3.11
3.12
3.8
3.8 - Removal
3.10
3.10 - Removal
3.4 - Addition
3.3 - Removal
3.7
3.1
8.18 - Addition
8.7
8.9
8.16
8.11
8.2 - Removal
8.6 - Removal
8.2 - Addition
8.1
8.3
8.4
3.2

PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3d

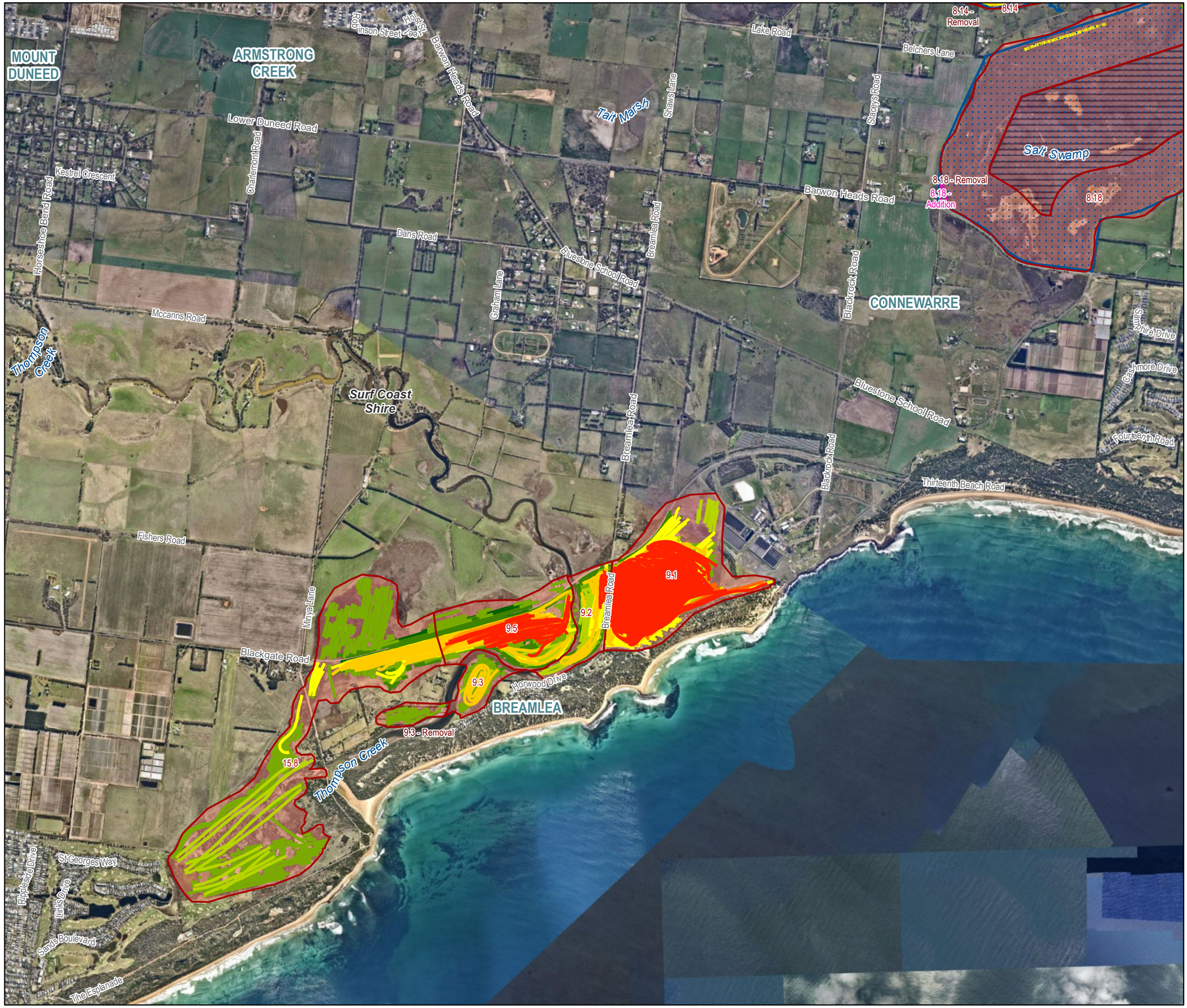
Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Addition
- Proposed Aerial Site Removal

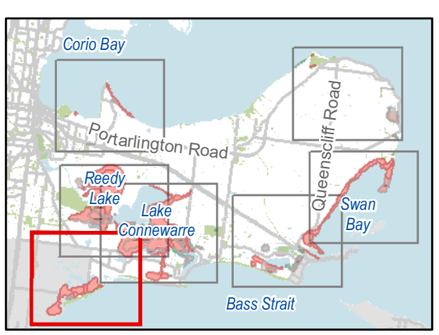


0 400 800 1,600 m

N

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PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3e

Site 1.7- Ground Treatment

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Addition
- Proposed Aerial Site Removal
- Existing Ground Site
- Proposed Ground Site Addition
- Proposed Ground Site Removal

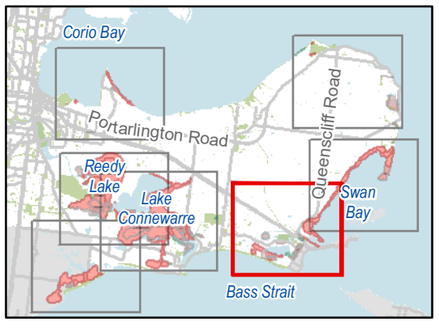
Marine National Park

0 400 800 1,600 m

N

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WALLINGTON
MARCUS HILL
MANNERIM
POINT LONSDALE
OCEAN GROVE
SWAN BAY
Borough Of Queenscliffe
Lake Victoria
Maddens Lane
Yarram Creek
Banks Road
Swan Bay Road
Knights Road
Queenscliff Road
Bellarine Highway
Janelle Way
Coastal Boulevard
Dunview Drive
Oakdean Boulevard
Shorebreak Way
Creswell Road
Higgins Lane
Ocean Grand Drive
Teneda Way
Endeavour Drive
Sunset Strip
Somerdale Avenue
Bonnyvale Road
Shell Road
Clows Lane
Coquina Drive
Point Boulevard
Petrono Boulevard
Yarram Creek Lane
Fellows Road
Macdonald Road
Murrey Road
Nelson Road
Grimes Road
Jordan Road
Williams Road
Point Lonsdale Road
Gill Road
Kirk Road
Garretsa Road
Buckleys Road
Whiteley Road
Ballard Street
Ocean Road
King Street
Flinders Street
Port Phillip Heads Marine National Park
7.5
7.2
7.1
14.3
14.7 - Removal
1.1 - Removal
14.8
14.4
14.11
14.1
1.7 - Removal
1.7 - Addition
1.4
2.7 - Addition
2.5
2.4
2.17
2.17 - Addition
2.17 - Removal

PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3f

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Removal
- Proposed Ground Site Removal

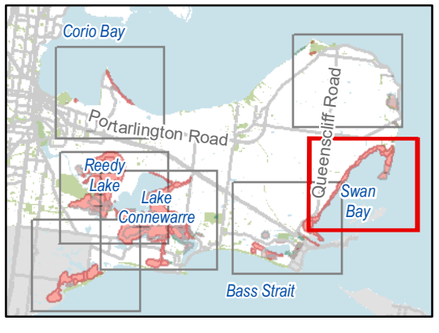
Marine National Park

0 400 800 1,600 m

N

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DRYSDALE
ST LEONARDS
MANNERIM
SWAN BAY
Port Phillip
Bluff Road
Beach Road
Cliff Street
Andersons Road
Manifold Road
Burrows Road
Sheppards Road
Queenscliff Road
Swan Bay Road
Knights Road
Main Road
Port Phillip Heads Marine National Park
4.2 - Removal
7.3
4.1
4.6
4.6 - Removal
7.5
7.2
7.1
14.3
14.4

PREVIOUS REFERRAL AREAS & PROPOSED ACTION AREAS SHOWING HISTORICAL TREATMENT FLIGHTPATHS 2012-2021

FIGURE - 3g

Treatment Flightpath Season

- 2016-2017

Proposed Treatment Site Changes

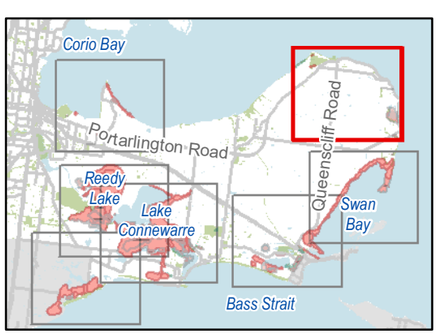
- Existing Aerial Site
- Proposed Aerial Site Addition
- Existing Ground Site
- Proposed Ground Site Removal

0 400 800 1,600 m

N

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4a

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

- Aerial

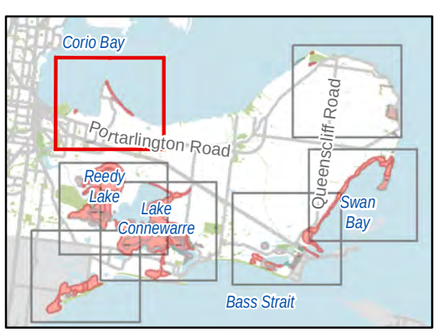


0 400 800 1,600 m

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4b

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

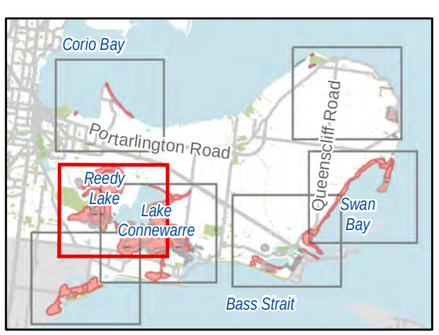
Aerial

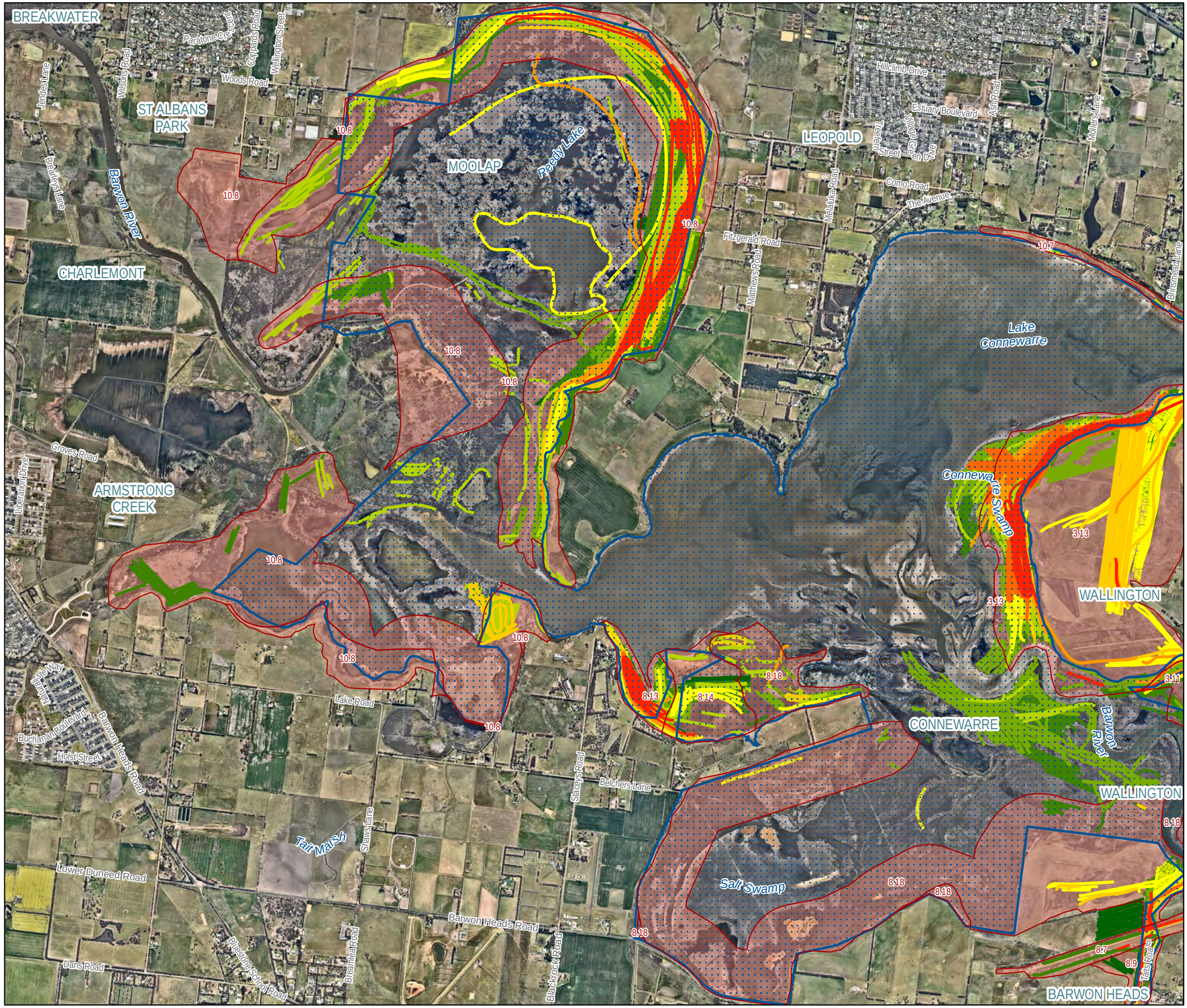
0 400 800 1,600 m

N

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4c

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

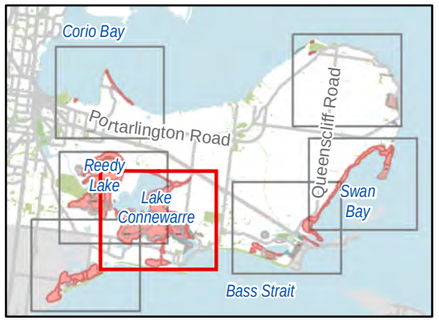
- Aerial
- Ground

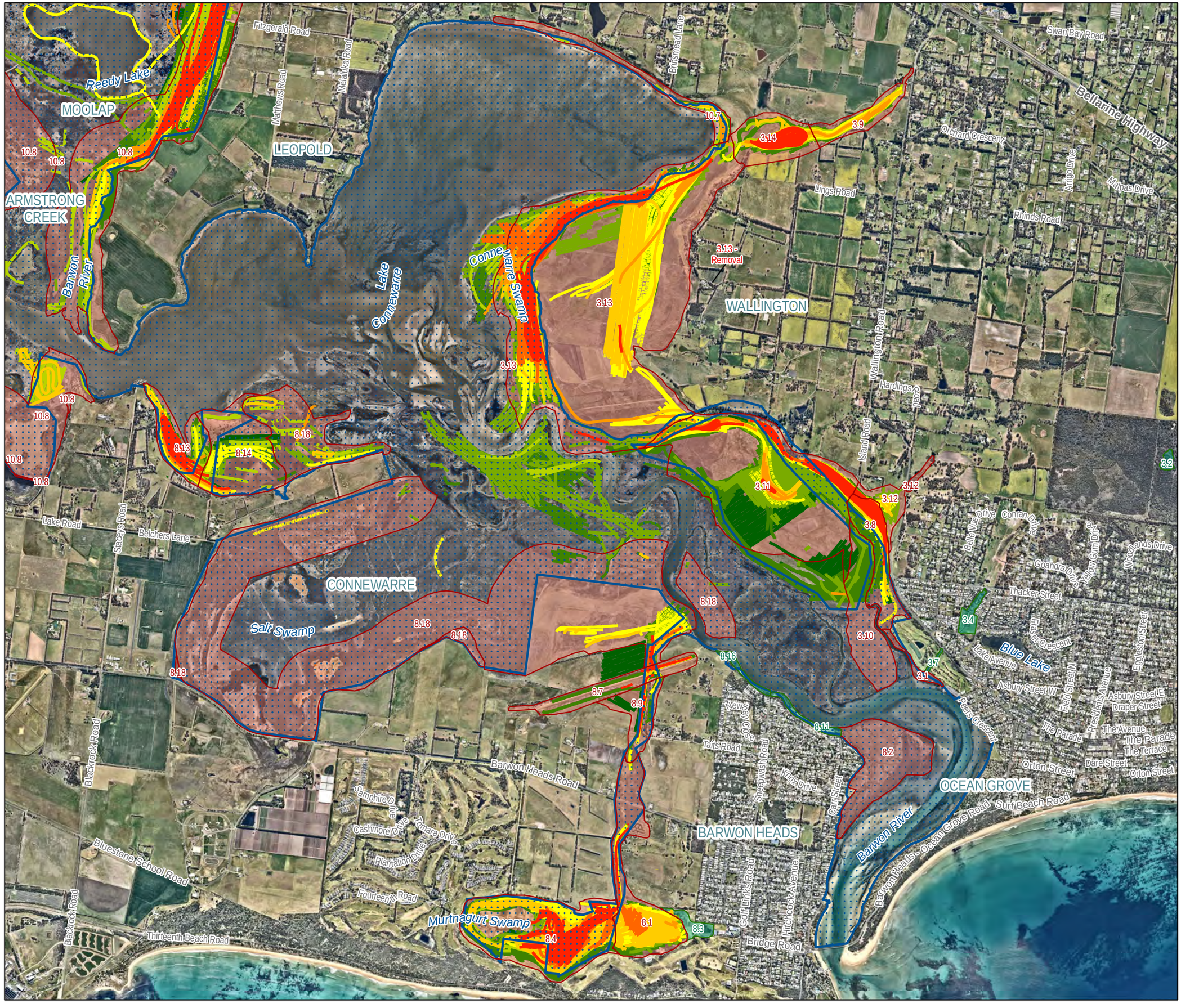
0 425 850 1,700 m

N

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4d

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

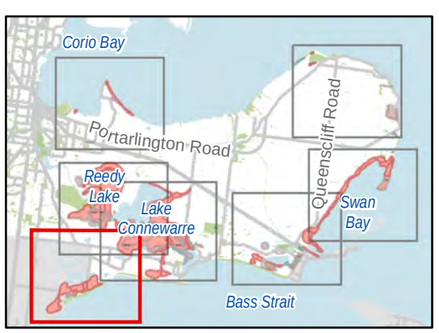
Proposed Treatment Site

Aerial

0 400 800 1,600 m

N

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4e

Site 1.7- Ground Treatment

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

- Aerial
- Ground

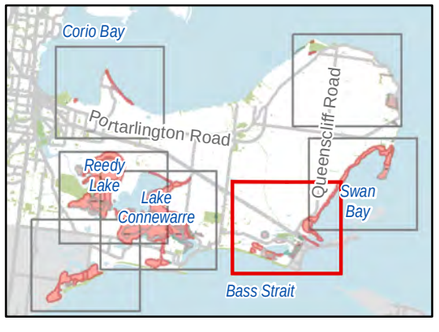
Marine National Park

0 400 800 1,600 m

N

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PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4f

Ramsar Wetland

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

Aerial

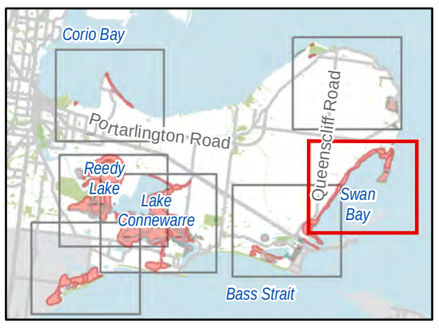
Marine National Park

0 400 800 1,600 m

N

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DRYSDALE
Manifold Road
Andersons Road
Burrows Road
Sheppards Road
MANNERIM
Queenscliff Road
Swan Bay Road
Knights Road
ST LEONARDS
Bluff Road
Beach Road
Cliff Street
7.3
4.1
4.6
7.5
7.2
7.1
14.3
14.4
Port Phillip Heads Marine National Park
SWAN BAY
Main Road
Port Phillip

PROPOSED ACTION AREAS
SHOWING HISTORICAL TREATMENT
FLIGHTPATHS 2012-2021

FIGURE - 4g

Treatment Flightpath Season

- 2012-2013
- 2013-2014
- 2014-2015
- 2015-2016
- 2016-2017
- 2017-2018
- 2018-2019
- 2019-2020
- 2020--2021

Proposed Treatment Site

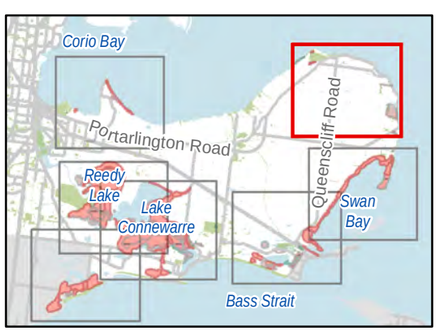
- Aerial
- Ground

0 400 800 1,600 m

N

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Appendix C

PMST search

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 31-Jan-2024

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	3
Wetlands of International Importance (Ramsar	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	8
Listed Threatened Species:	99
Listed Migratory Species:	72

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	26
Commonwealth Heritage Places:	4
Listed Marine Species:	117
Whales and Other Cetaceans:	13
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	18
Regional Forest Agreements:	1
Nationally Important Wetlands:	4
EPBC Act Referrals:	79
Key Ecological Features (Marine):	None
Biologically Important Areas:	18
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

National Heritage Places [Resource Information]

Name	State	Legal Status	Buffer Status
Historic			
Great Ocean Road and Scenic Environs	VIC	Listed place	In buffer area only
Point Nepean Defence Sites and Quarantine Station Area	VIC	Listed place	In buffer area only
Quarantine Station and Surrounds	VIC	Within listed place	In buffer area only

Wetlands of International Importance (Ramsar Wetlands) [Resource Information]

Ramsar Site Name	Proximity	Buffer Status
Port phillip bay (western shoreline) and bellarine peninsula	Within Ramsar site	In feature area

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name	Buffer Status
Commonwealth Marine Areas (EPBC Act)	In buffer area only

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text	Buffer Status
Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria ecological community	Endangered	Community likely to occur within area	In feature area
Giant Kelp Marine Forests of South East Australia	Endangered	Community may occur within area	In feature area
Grassy Eucalypt Woodland of the Victorian Volcanic Plain	Critically Endangered	Community known to occur within area	In feature area
Natural Damp Grassland of the Victorian Coastal Plains	Critically Endangered	Community likely to occur within area	In feature area
Natural Temperate Grassland of the Victorian Volcanic Plain	Critically Endangered	Community likely to occur within area	In feature area

Community Name	Threatened Category	Presence Text	Buffer Status
Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains	Critically Endangered	Community likely to occur within area	In feature area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area	In buffer area only
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland	Critically Endangered	Community likely to occur within area	In feature area

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Anthochaera phrygia Regent Honeyeater [82338]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Aphelocephala leucopsis Southern Whiteface [529]	Vulnerable	Species or species habitat known to occur within area	In feature area
Ardenna grisea Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area	In feature area
Arenaria interpres Ruddy Turnstone [872]	Vulnerable	Roosting known to occur within area	In feature area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Roosting known to occur within area	In feature area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area	In feature area
Callocephalon fimbriatum Gang-gang Cockatoo [768]	Endangered	Species or species habitat known to occur within area	In feature area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area	In feature area
Climacteris picumnus victoriae Brown Treecreeper (south-eastern) [67062]	Vulnerable	Species or species habitat may occur within area	In feature area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Fregetta grallaria grallaria White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat known to occur within area	In feature area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area	In feature area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Limosa lapponica baueri Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit [86380]	Endangered	Species or species habitat known to occur within area	In feature area
Limosa limosa Black-tailed Godwit [845]	Endangered	Roosting known to occur within area	In feature area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Melanodryas cucullata cucullata South-eastern Hooded Robin, Hooded Robin (south-eastern) [67093]	Endangered	Species or species habitat likely to occur within area	In feature area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Migration route known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Neophema chrysostoma Blue-winged Parrot [726]	Vulnerable	Species or species habitat known to occur within area	In feature area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pedionomus torquatus Plains-wanderer [906]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area	In feature area
Pterodroma leucoptera leucoptera Gould's Petrel, Australian Gould's Petrel [26033]	Endangered	Species or species habitat may occur within area	In feature area
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area	In feature area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area	In feature area
Stagonopleura guttata Diamond Firetail [59398]	Vulnerable	Species or species habitat known to occur within area	In feature area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche bulleri platei Northern Buller's Albatross, Pacific Albatross [82273]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area	In feature area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour known to occur within area	In feature area
Thinornis cucullatus cucullatus Eastern Hooded Plover, Eastern Hooded Plover [90381]	Vulnerable	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Tringa nebularia](#) Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area	In feature area
[Xenus cinereus](#) Terek Sandpiper [59300]	Vulnerable	Roosting known to occur within area	In feature area
FISH			
[Galaxiella pusilla](#) Eastern Dwarf Galaxias, Dwarf Galaxias [56790]	Endangered	Species or species habitat may occur within area	In buffer area only
[Nannoperca obscura](#) Yarra Pygmy Perch [26177]	Endangered	Species or species habitat known to occur within area	In feature area
[Prototroctes maraena](#) Australian Grayling [26179]	Vulnerable	Species or species habitat known to occur within area	In feature area
[Seriolella brama](#) Blue Warehou [69374]	Conservation Dependent	Species or species habitat known to occur within area	In feature area
[Thunnus maccoyii](#) Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat known to occur within area	In feature area
FROG			
[Litoria raniformis](#) Southern Bell Frog,, Growling Grass Frog, Green and Golden Frog, Warty Swamp Frog, Golden Bell Frog [1828]	Vulnerable	Species or species habitat known to occur within area	In feature area
INSECT			
[Synemon plana](#) Golden Sun Moth [25234]	Vulnerable	Species or species habitat likely to occur within area	In feature area
MAMMAL			
[Antechinus minimus maritimus](#) Swamp Antechinus (mainland) [83086]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat may occur within area	In feature area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area	In feature area
Isoodon obesulus obesulus Southern Brown Bandicoot (eastern), Southern Brown Bandicoot (south-eastern) [68050]	Endangered	Species or species habitat likely to occur within area	In feature area
Petaurus australis australis Yellow-bellied Glider (south-eastern) [87600]	Vulnerable	Species or species habitat may occur within area	In feature area
Pseudomys novaehollandiae New Holland Mouse, Pookila [96]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area	In feature area
PLANT			
Amphibromus fluitans River Swamp Wallaby-grass, Floating Swamp Wallaby-grass [19215]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Caladenia pumila Dwarf Spider-orchid [4155]	Critically Endangered	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Dianella amoena Matted Flax-lily [64886]	Endangered	Species or species habitat likely to occur within area	In feature area
Diuris basaltica Small Golden Moths Orchid, Early Golden Moths [64654]	Endangered	Species or species habitat may occur within area	In buffer area only
Dodonaea procumbens Trailing Hop-bush [12149]	Vulnerable	Species or species habitat may occur within area	In feature area
Glycine latrobeana Clover Glycine, Purple Clover [13910]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Lachnagrostis adamsonii Adamson's Blown-grass, Adamson's Blowngrass [76211]	Endangered	Species or species habitat known to occur within area	In feature area
Lepidium aschersonii Spiny Peppercress [10976]	Vulnerable	Species or species habitat known to occur within area	In feature area
Lepidium hyssopifolium Basalt Pepper-cress, Peppercress, Rubble Pepper-cress, Pepperweed [16542]	Endangered	Species or species habitat may occur within area	In feature area
Leucochrysum albicans subsp. tricolor Hoary Sunray, Grassland Paper-daisy [89104]	Endangered	Species or species habitat may occur within area	In feature area
Pimelea spinescens subsp. spinescens Plains Rice-flower, Spiny Rice-flower, Prickly Pimelea [21980]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Prasophyllum spicatum Dense Leek-orchid [55146]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Pterostylis chlorogramma Green-striped Greenhood [56510]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Pterostylis cucullata](#) Leafy Greenhood [15459]	Vulnerable	Species or species habitat known to occur within area	In feature area
[Rutidosis leptorhynchoides](#) Button Wrinklewort [67251]	Endangered	Species or species habitat may occur within area	In feature area
[Senecio macrocarpus](#) Large-fruit Fireweed, Large-fruit Groundsel [16333]	Vulnerable	Species or species habitat likely to occur within area	In feature area
[Senecio psilocarpus](#) Swamp Fireweed, Smooth-fruited Groundsel [64976]	Vulnerable	Species or species habitat likely to occur within area	In feature area
[Thelymitra epipactoides](#) Metallic Sun-orchid [11896]	Endangered	Species or species habitat may occur within area	In feature area
[Thelymitra matthewsii](#) Spiral Sun-orchid [4168]	Vulnerable	Species or species habitat likely to occur within area	In feature area
[Thelymitra orientalis](#) Hoary Sun-orchid [88011]	Critically Endangered	Species or species habitat may occur within area	In feature area
[Xerochrysum palustre](#) Swamp Everlasting, Swamp Paper Daisy [76215]	Vulnerable	Species or species habitat known to occur within area	In feature area
REPTILE			
[Caretta caretta](#) Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
[Chelonia mydas](#) Green Turtle [1765]	Vulnerable	Species or species habitat may occur within area	In feature area
[Delma impar](#) Striped Legless Lizard, Striped Snake-lizard [1649]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Lissolepis coventryi Swamp Skink, Eastern Mourning Skink [84053]	Endangered	Species or species habitat known to occur within area	In feature area
Tympanocryptis pinguicolla Victorian Grassland Earless Dragon [66727]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
SHARK			
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area	In feature area
Galeorhinus galeus School Shark, Eastern School Shark, Snapper Shark, Tope, Soupfin Shark [68453]	Conservation Dependent	Species or species habitat may occur within area	In feature area

Listed Migratory Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area	In feature area
Ardenna grisea Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area	In feature area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Diomedea epomophora](#) Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
[Diomedea exulans](#) Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
[Diomedea sanfordi](#) Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
[Hydroprogne caspia](#) Caspian Tern [808]		Breeding known to occur within area	In buffer area only
[Macronectes giganteus](#) Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
[Macronectes halli](#) Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
[Phoebetria fusca](#) Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area	In feature area
[Sternula albifrons](#) Little Tern [82849]		Species or species habitat may occur within area	In feature area
[Thalassarche bulleri](#) Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area	In feature area
[Thalassarche carteri](#) Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area	In feature area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour known to occur within area	In feature area
Migratory Marine Species			
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area	In feature area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area	In feature area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat may occur within area	In feature area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area	In feature area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area	In feature area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat likely to occur within area	In feature area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area	In feature area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat likely to occur within area	In feature area
Migratory Terrestrial Species			

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Hirundapus caudacutus](#) White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area	In feature area
[Monarcha melanopsis](#) Black-faced Monarch [609]		Species or species habitat may occur within area	In buffer area only
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat likely to occur within area	In feature area
[Myiagra cyanoleuca](#) Satin Flycatcher [612]		Species or species habitat known to occur within area	In feature area
[Rhipidura rufifrons](#) Rufous Fantail [592]		Species or species habitat known to occur within area	In feature area
Migratory Wetlands Species			
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
[Arenaria interpres](#) Ruddy Turnstone [872]	Vulnerable	Roosting known to occur within area	In feature area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]	Vulnerable	Roosting known to occur within area	In feature area
[Calidris alba](#) Sanderling [875]		Roosting known to occur within area	In feature area
[Calidris canutus](#) Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area	In feature area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area	In feature area
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area	In feature area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area	In buffer area only
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area	In feature area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area	In feature area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat known to occur within area	In feature area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area	In feature area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area	In feature area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area	In feature area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area	In feature area
Limosa limosa Black-tailed Godwit [845]	Endangered	Roosting known to occur within area	In feature area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area	In feature area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area	In feature area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area	In feature area
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area	In feature area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area	In buffer area only
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area	In feature area
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area	In feature area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area	In buffer area only
Tringa brevipes Grey-tailed Tattler [851]		Roosting known to occur within area	In feature area
Tringa glareola Wood Sandpiper [829]		Roosting known to occur within area	In buffer area only
Tringa nebularia Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area	In feature area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area	In feature area
Xenus cinereus Terek Sandpiper [59300]	Vulnerable	Roosting known to occur within area	In feature area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State	Buffer Status
Defence		
Defence - AIRTC GEELONG [21354]	VIC	In buffer area only
Defence - AVALON AIRFIELD [21410]	VIC	In buffer area only
Defence - AVALON AIRFIELD [21397]	VIC	In buffer area only
Defence - AVALON AIRFIELD [21404]	VIC	In buffer area only
Defence - CROWS NEST CAMP - QUEENSCLIFF [21029]	VIC	In feature area
Defence - CROWS NEST CAMP - QUEENSCLIFF [21028]	VIC	In feature area
Defence - CROWS NEST CAMP - QUEENSCLIFF [21027]	VIC	In feature area
Defence - CROWS NEST CAMP - QUEENSCLIFF [21026]	VIC	In feature area
Defence - Myers Street (opp. Geelong Hospital) [20450]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21439]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21444]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21440]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21443]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21441]	VIC	In buffer area only
Defence - POINT WILSON EXPLOSIVES AREA [21442]	VIC	In buffer area only
Defence - STAFF COLLEGE-FORT QUEENSCLIFF [21030]	VIC	In feature area
Defence - STAFF COLLEGE-FORT QUEENSCLIFF [21034]	VIC	In feature area
Defence - STAFF COLLEGE-FORT QUEENSCLIFF [21032]	VIC	In feature area
Defence - STAFF COLLEGE-FORT QUEENSCLIFF [21031]	VIC	In feature area
Defence - STAFF COLLEGE-FORT QUEENSCLIFF [21033]	VIC	In feature area
Defence - SWAN ISLAND TRAINING AREA [21447]	VIC	In feature area
Defence - SWAN ISLAND TRAINING AREA [21448]	VIC	In feature area

Commonwealth Land Name	State	Buffer Status
Defence - SWAN ISLAND TRAINING AREA [21446]	VIC	In feature area
Defence - TRAINING CENTRE (Norris Barracks) - Portsea [21025]	VIC	In buffer area only
Unknown		
Commonwealth Land - [22391]	VIC	In buffer area only
Commonwealth Land - [21570]	VIC	In buffer area only

Commonwealth Heritage Places [Resource Information]

Name	State	Status	Buffer Status
Historic			
Fort Queenscliff	VIC	Listed place	In feature area
Swan Island Defence Precinct	VIC	Listed place	In feature area
Natural			
Point Wilson Defence Natural Area	VIC	Listed place	In buffer area only
Swan Island and Naval Waters	VIC	Listed place	In feature area

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
Ardenna carneipes as Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area	In feature area
Ardenna grisea as Puffinus griseus Sooty Shearwater [82651]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Arenaria interpres Ruddy Turnstone [872]	Vulnerable	Roosting known to occur within area	In feature area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Breeding likely to occur within area overfly marine area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Roosting known to occur within area	In feature area
Calidris alba Sanderling [875]		Roosting known to occur within area	In feature area
Calidris canutus Red Knot, Knot [855]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area overfly marine area	In feature area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area overfly marine area	In feature area
Calidris subminuta Long-toed Stint [861]		Roosting known to occur within area overfly marine area	In buffer area only
Calidris tenuirostris Great Knot [862]	Vulnerable	Roosting known to occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area overfly marine area	In feature area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Roosting known to occur within area	In feature area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area overfly marine area	In feature area
Chroicocephalus novaehollandiae as Larus novaehollandiae Silver Gull [82326]		Breeding known to occur within area	In feature area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
Eudyptula minor Little Penguin [1085]		Breeding known to occur within area	In buffer area only
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area overfly marine area	In feature area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area overfly marine area	In feature area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area	In feature area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area	In feature area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Roosting known to occur within area overfly marine area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area
Hydroprogne caspia as Sterna caspia Caspian Tern [808]		Breeding known to occur within area	In buffer area only
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat known to occur within area overfly marine area	In feature area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area overfly marine area	In feature area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area	In feature area
Limosa limosa Black-tailed Godwit [845]	Endangered	Roosting known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat may occur within area overfly marine area	In buffer area only
Morus capensis Cape Gannet [59569]		Breeding known to occur within area	In buffer area only
Morus serrator Australasian Gannet [1020]		Breeding known to occur within area	In buffer area only
Motacilla flava Yellow Wagtail [644]		Species or species habitat likely to occur within area overfly marine area	In feature area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area overfly marine area	In feature area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Migration route known to occur within area overfly marine area	In feature area
Neophema chrysostoma Blue-winged Parrot [726]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area overfly marine area	In feature area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area	In feature area
Onychoprion fuscatus as Sterna fuscata Sooty Tern [90682]		Breeding known to occur within area	In feature area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat known to occur within area	In feature area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area	In feature area
Pelagodroma marina White-faced Storm-Petrel [1016]		Breeding known to occur within area	In buffer area only
Phalaropus lobatus Red-necked Phalarope [838]		Roosting known to occur within area	In feature area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area overfly marine area	In buffer area only
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area	In feature area
Pluvialis squatarola Grey Plover [865]	Vulnerable	Roosting known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Pterodroma mollis Soft-plumaged Petrel [1036]	Vulnerable	Species or species habitat may occur within area	In feature area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area overfly marine area	In feature area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area overfly marine area	In feature area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area	In feature area
Stercorarius antarcticus as Catharacta skua Brown Skua [85039]		Species or species habitat may occur within area	In feature area
Sterna striata White-fronted Tern [799]		Foraging, feeding or related behaviour likely to occur within area	In feature area
Sternula albifrons as Sterna albifrons Little Tern [82849]		Species or species habitat may occur within area	In feature area
Sternula nereis as Sterna nereis Fairy Tern [82949]		Breeding known to occur within area	In feature area
Stiltia isabella Australian Pratincole [818]		Roosting known to occur within area overfly marine area	In feature area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche bulleri platei as Thalassarche sp. nov. Northern Buller's Albatross, Pacific Albatross [82273]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area	In feature area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In feature area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour known to occur within area	In feature area
Thalasseus bergii as Sterna bergii Greater Crested Tern [83000]		Breeding known to occur within area	In buffer area only
Thinornis cucullatus as Thinornis rubricollis Hooded Plover, Hooded Dotterel [87735]		Species or species habitat known to occur within area overfly marine area	In feature area
Thinornis cucullatus cucullatus as Thinornis rubricollis rubricollis Eastern Hooded Plover, Eastern Hooded Plover [90381]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Tringa brevipes as Heteroscelus brevipes](#) Grey-tailed Tattler [851]		Roosting known to occur within area	In feature area
[Tringa glareola](#) Wood Sandpiper [829]		Roosting known to occur within area overfly marine area	In buffer area only
[Tringa nebularia](#) Common Greenshank, Greenshank [832]	Endangered	Species or species habitat known to occur within area overfly marine area	In feature area
[Tringa stagnatilis](#) Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area overfly marine area	In feature area
[Xenus cinereus](#) Terek Sandpiper [59300]	Vulnerable	Roosting known to occur within area overfly marine area	In feature area
Fish			
[Heraldia nocturna](#) Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area	In feature area
[Hippocampus abdominalis](#) Big-belly Seahorse, Eastern Potbelly Seahorse, New Zealand Potbelly Seahorse [66233]		Species or species habitat may occur within area	In feature area
[Hippocampus breviceps](#) Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area	In feature area
[Hippocampus minotaur](#) Bullneck Seahorse [66705]		Species or species habitat may occur within area	In feature area
[Histiogamphelus briggsii](#) Crested Pipefish, Briggs' Crested Pipefish, Briggs' Pipefish [66242]		Species or species habitat may occur within area	In feature area
[Histiogamphelus cristatus](#) Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Hypselognathus rostratus Knifesnout Pipefish, Knife-snouted Pipefish [66245]		Species or species habitat may occur within area	In feature area
Kaupus costatus Deepbody Pipefish, Deep-bodied Pipefish [66246]		Species or species habitat may occur within area	In feature area
Leptoichthys fistularius Brushtail Pipefish [66248]		Species or species habitat may occur within area	In feature area
Lissocampus caudalis Australian Smooth Pipefish, Smooth Pipefish [66249]		Species or species habitat may occur within area	In feature area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area	In feature area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area	In feature area
Mitotichthys mollisoni Mollison's Pipefish [66260]		Species or species habitat may occur within area	In feature area
Mitotichthys semistriatus Halfbanded Pipefish [66261]		Species or species habitat may occur within area	In feature area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area	In feature area
Phycodurus eques Leafy Seadragon [66267]		Species or species habitat may occur within area	In feature area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Pugnaso curtirostris Pugnose Pipefish, Pug-nosed Pipefish [66269]		Species or species habitat may occur within area	In feature area
Solegnathus robustus Robust Pipehorse, Robust Spiny Pipehorse [66274]		Species or species habitat may occur within area	In feature area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse [66275]		Species or species habitat may occur within area	In feature area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area	In feature area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area	In feature area
Stipecampus cristatus Ringback Pipefish, Ring-backed Pipefish [66278]		Species or species habitat may occur within area	In feature area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area	In feature area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area	In feature area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area	In feature area
Mammal			
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area	In feature area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal [21]		Species or species habitat may occur within area	In feature area
Reptile			

Scientific Name	Threatened Category	Presence Text	Buffer Status
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat may occur within area	In feature area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area

Whales and Other Cetaceans			[Resource Information]
Current Scientific Name	Status	Type of Presence	Buffer Status
Mammal			
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area	In feature area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area	In feature area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area	In feature area

Current Scientific Name	Status	Type of Presence	Buffer Status
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area	In feature area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area	In feature area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area	In feature area
Megaptera novaeangliae Humpback Whale [38]		Species or species habitat known to occur within area	In feature area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat likely to occur within area	In feature area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area	In feature area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area	In feature area

Extra Information

State and Territory Reserves			[Resource Information]
Protected Area Name	Reserve Type	State	Buffer Status
Barwon Bluff	Marine Sanctuary	VIC	In feature area
Bellarine I109 B.R.	Natural Features Reserve	VIC	In feature area
Bellarine I110 B.R.	Natural Features Reserve	VIC	In feature area
Breamlea F.F.R.	Nature Conservation Reserve	VIC	In feature area
Conewarre K47 SS.R.	Natural Features Reserve	VIC	In feature area
Conewarre K48 SS.R.	Natural Features Reserve	VIC	In feature area

Protected Area Name	Reserve Type	State	Buffer Status
Drakes B.R.	Natural Features Reserve	VIC	In feature area
Lake Connewarre W.R	Natural Features Reserve	VIC	In feature area
Limeburners Lagoon (Hovells Creek) F.F.R	Nature Conservation Reserve	VIC	In buffer area only
Lonsdale Lakes W.R	Nature Conservation Reserve	VIC	In feature area
Point Danger	Marine Sanctuary	VIC	In buffer area only
Point Nepean	National Park	VIC	In buffer area only
Portarlington (Point Richard) F.F.R.	Nature Conservation Reserve	VIC	In feature area
Port Phillip Heads	Marine National Park	VIC	In feature area
Queenscliff N.F.R	Natural Features Reserve	VIC	In feature area
Salt Lagoon, St Leonards W.R	Nature Conservation Reserve	VIC	In feature area
Swan Bay - Edwards Point W.R	Nature Conservation Reserve	VIC	In feature area
The Spit W.R.	Nature Conservation Reserve	VIC	In buffer area only

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included. Please see the associated resource information for specific caveats and use limitations associated with RFA boundary information.

RFA Name	State	Buffer Status
West Victoria RFA	Victoria	In feature area

Nationally Important Wetlands [Resource Information]

Wetland Name	State	Buffer Status
Lake Connewarre State Wildlife Reserve	VIC	In feature area
Mud Islands	VIC	In buffer area only
Swan Bay & Swan Island	VIC	In feature area
Werribee-Avalon Area	VIC	In buffer area only

EPBC Act Referrals [Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Armstrong Creek Aquatic Venue and Multi-sport Community Facility	2023/09553		Completed	In feature area
Australian Centre for Disease Preparedness Part life Refit	2023/09497		Completed	In feature area
Geelong Hydrogen Hub	2022/09288		Referral Decision	In buffer area only
Offshore Tidal Energy Facility and Submarine Cable	2008/4480		Completed	In feature area
Residential Development, Groves Road	2022/09357		Assessment	In feature area
Vopak Victoria Energy Terminal	2023/09507		Assessment	In buffer area only
Controlled action				
Basalt Quarry Extension (Mountainview Quarry)	2004/1329	Controlled Action	Completed	In feature area
City Of Greater Geelong Mosquito Control Program 2021-2030, Vic	2020/8782	Controlled Action	Further Information Request	In feature area
Extension of Mountain View basalt quarry by 490 hectares (Stage 2)	2004/1590	Controlled Action	Post-Approval	In buffer area only
Geelong Salt Fields Urban Renewal Project	2012/6630	Controlled Action	Assessment Approach	In feature area
Lonsdale Golf Club Redevelopment	2003/969	Controlled Action	Post-Approval	In feature area
Mosquito Control	2005/2132	Controlled Action	Post-Approval	In feature area
Motocross Track and Associated Infrastructure	2009/4956	Controlled Action	Completed	In buffer area only
Port Phillip Bay Channel Deepening	2002/576	Controlled Action	Post-Approval	In feature area
Residential and Golf Course Development Project	2003/1144	Controlled Action	Post-Approval	In feature area
Residential Estate, 251-319 Melaluka Rd	2007/3308	Controlled Action	Post-Approval	In feature area
Residential Subdivision and Stormwater Enhancements for land west of Ash Road	2012/6544	Controlled Action	Completed	In feature area
Viva Energy Gas Terminal Project	2020/8838	Controlled Action	Assessment Approach	In buffer area only

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Controlled action				
Warralily - East Precinct Sparrovale Outfall, stormwater bypass channel, Armstrong Creek, Vic	2015/7553	Controlled Action	Post-Approval	In feature area
Wind Turbines	2001/439	Controlled Action	Completed	In feature area
Wyndham Cove marina and residential development	2004/1331	Controlled Action	Post-Approval	In buffer area only
Not controlled action				
Barwon Heads Rd gas pipeline installation	2006/2769	Not Controlled Action	Completed	In feature area
Barwon Heads Stormwater Outfall upgrade, Victoria	2016/7650	Not Controlled Action	Completed	In feature area
Barwon River Parkland Initiative, Taits Point, Stages 1 and 2	2010/5437	Not Controlled Action	Completed	In feature area
Bluff Heights Estate Stages 2 to 4	2003/1047	Not Controlled Action	Completed	In feature area
Construction and operation of Barwon Water biosolids treatment facility	2008/4345	Not Controlled Action	Completed	In feature area
Construction of a Dwelling	2011/6160	Not Controlled Action	Completed	In feature area
Construction of Barwon Heads Bridge	2005/2375	Not Controlled Action	Completed	In feature area
Construction of the Edgars Road Extension, from Childs Road, Lalor to Cooper Street, Epping	2003/1135	Not Controlled Action	Completed	In feature area
Conversion of the North Western Victoria rail system from broad gauge to standar	2002/657	Not Controlled Action	Completed	In buffer area only
Development of Pt Nepean Quarantine Station (former) National Centre for Coasts and Climate	2008/4653	Not Controlled Action	Completed	In buffer area only
Divestment of Norris Barracks	2003/963	Not Controlled Action	Completed	In buffer area only
Expansion and upgrade of Biogas Utilisation Facilities at the Western Treatment	2005/2183	Not Controlled Action	Completed	In buffer area only
Extension of Mountain View basalt quarry by 113 hectares (stage one)	2004/1591	Not Controlled Action	Completed	In feature area

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action				
Geelong Bypass Sections 1 & 2	2005/2097	Not Controlled Action	Completed	In feature area
Golflinks Road Residential Development & Water Storage Facility at Barwon Heads	2004/1793	Not Controlled Action	Completed	In feature area
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
INDIGO Central Submarine Telecommunications Cable	2017/8127	Not Controlled Action	Completed	In feature area
Installation of a 35 metre telecommunications facility at Jirrahlinga Animal San	2003/1151	Not Controlled Action	Completed	In feature area
Maintenance and priority works to heritage buildings at Point Nepean Quarantine	2006/3151	Not Controlled Action	Completed	In buffer area only
Maintenance Dredging South Channel 2012	2011/6198	Not Controlled Action	Completed	In feature area
Maintenance works at Barwon Heads Bridge	2003/1199	Not Controlled Action	Completed	In feature area
Marine and Freshwater Resources Institute (MAFRI) Facility	2000/121	Not Controlled Action	Completed	In feature area
Multi-species Aquaculture Enterprise	2001/404	Not Controlled Action	Completed	In buffer area only
Ocean Grove rising main 2 upgrade	2009/4978	Not Controlled Action	Completed	In feature area
Ocean Grove Rising Main 2 Upgrade (OGRM2) - East Section & River Crossing	2010/5508	Not Controlled Action	Completed	In feature area
Pioneer Road and bridge Duplication	2012/6291	Not Controlled Action	Completed	In buffer area only
Point Nepean Quarantine Station (former)/Restoration of Medical Superintendent's	2006/3149	Not Controlled Action	Completed	In buffer area only
Port Phillip Channel Deepening Project - Trial Dredge Program	2005/2164	Not Controlled Action	Completed	In feature area
Power Station	2001/239	Not Controlled Action	Completed	In buffer area only
Queenscliff Harbour Redevelopment	2004/1352	Not Controlled Action	Completed	In feature area

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action				
Re-alignment of Breakwater Road	2006/2762	Not Controlled Action	Completed	In feature area
Regional Fast Rail Project - Geelong Country Works Package	2002/577	Not Controlled Action	Completed	In buffer area only
Rehabilitation of Lake Connewarre State Game Reserve	2002/708	Not Controlled Action	Completed	In feature area
Remedial Works to the Swan Island Bridge	2003/1129	Not Controlled Action	Completed	In feature area
Replacement of sewer pipelines	2002/623	Not Controlled Action	Completed	In feature area
Residential Development, 409 The Esplanade, St Leonards	2006/2950	Not Controlled Action	Completed	In feature area
Sparrovale Wetland stormwater management, Armstrong Creek and Charlemont, VIC	2018/8375	Not Controlled Action	Completed	In feature area
Torquay Sewerage Strategy - pipe replacement between Torquay and the Black Rock	2004/1704	Not Controlled Action	Completed	In feature area
Transfer of 90ha Point Nepean Quarantine Station from Commonwealth to Victorian	2008/4521	Not Controlled Action	Completed	In buffer area only
Wastewater Treatment System Upgrade	2004/1420	Not Controlled Action	Completed	In feature area
Not controlled action (particular manner)				
Barwon Heads Rising Main No.11 Sewerage Pipe Upgrade	2008/4091	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Barwon Heads Road Settlement Road to Reserve Road Duplication Project	2020/8737	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Construct, operate & maintain Geelong Ring Road, Section 4A	2008/4486	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Construction of bridge across Barwon River	2006/2947	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Controlled Burn, Understorey Clearance and Removal of UXO	2003/1030	Not Controlled Action (Particular Manner)	Post-Approval	In feature area

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action (particular manner)				
Corio Bay Channel Safety Adjustment Program	2011/6208	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
development of retirement village, Bellarine Lakes Golf Course, Bellarine Hwy	2006/3015	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
DIDR01 Wetlands, Barwon Heads Road, Armstrong Creek	2020/8835	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Geelong Bypass Section 3	2005/2099	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
INDIGO Marine Cable Route Survey (INDIGO)	2017/7996	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Maintenance Dredging Program 2012-21 in Port of Melbourne	2012/6332	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Point Wilson Explosives Area Waterside Infrastructure Remediation	2012/6376	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Rail Upgrades at Geelong Port Project	2010/5363	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Regional Fibre Optic Project (RFOP)	2003/913	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Wandana Heights land - residential development	2002/666	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Referral decision				
Alteration Reconstruction Restoration and Repairs to Buildings	2008/4179	Referral Decision	Completed	In buffer area only
Upgrade of Services Infrastructure Point Nepean Quarantine Station	2008/4591	Referral Decision	Completed	In buffer area only

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Referral decision				
Works to the buildings and surrounds at the former Point Nepean Quarantine Stati	2008/4156	Referral Decision	Completed	In buffer area only

Biologically Important Areas

Scientific Name	Behaviour	Presence	Buffer Status
Seabirds			
Ardenna pacifica Wedge-tailed Shearwater [84292]	Foraging	Likely to occur	In feature area
Ardenna tenuirostris Short-tailed Shearwater [82652]	Foraging	Known to occur	In feature area
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Foraging	Known to occur	In buffer area only
Morus serrator Australasian Gannet [1020]	Aggregation	Known to occur	In buffer area only
Morus serrator Australasian Gannet [1020]	Foraging	Known to occur	In feature area
Pelagodroma marina White-faced Storm-petrel [1016]	Breeding	Known to occur	In buffer area only
Pelagodroma marina White-faced Storm-petrel [1016]	Foraging	Known to occur	In feature area
Pelecanoides urinatrix Common Diving-petrel [1018]	Foraging	Known to occur	In feature area
Thalassarche bulleri Bullers Albatross [64460]	Foraging	Known to occur	In buffer area only
Thalassarche cauta cauta Shy Albatross [82345]	Foraging likely	Likely to occur	In feature area
Thalassarche chlororhynchos bassi Indian Yellow-nosed Albatross [85249]	Foraging	Known to occur	In buffer area only
Thalassarche melanophris Black-browed Albatross [66472]	Foraging	Known to occur	In buffer area only

Scientific Name	Behaviour	Presence	Buffer Status
Thalassarche melanophris impavida Campbell Albatross [82449]	Foraging	Known to occur	In buffer area only
Sharks			
Carcharodon carcharias White Shark [64470]	Distribution (low density)	Likely to occur	In buffer area only
Carcharodon carcharias White Shark [64470]	Known distribution	Known to occur	In buffer area only
Whales			
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur	In feature area
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Foraging	Likely to be present	In feature area
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Known Foraging Area	Known to occur	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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Appendix D

Product label details and safety data sheets

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

VectoPrime® FG

BIOLOGICAL LARVACIDE FINE GRANULE

ACTIVE CONSTITUENTS: 400 ITU/mg *Bacillus thuringiensis* subspecies *israelensis*, strain AM 65-52
1.0 g/kg S-METHOPRENE

For control of mosquito larvae in post flood applications

GROUP 7A 11 INSECTICIDE

Net Contents: 100g - 20kg

GENERAL INSTRUCTIONS

Application:
VectoPrime FG can be applied prior to flooding by tides, or at any larval stage after flooding by rain or tides, or in permanent water sites.

For Aerial and Ground Applications
Apply by properly calibrated aircraft or ground application equipment to ensure even coverage of all water bodies containing mosquito larvae.

Apply uniformly by aerial or ground conventional equipment. Avoiding drift at the application site is the responsibility of the applicator. The interaction of many equipment and weather-related factors determine the potential for drift. The applicator and the treatment coordinator are responsible for considering all of these factors when making decisions.

INSECTICIDE RESISTANCE WARNING

GROUP 7A 11 INSECTICIDE

For insecticide resistance management VectoPrime FG is both a Group 7A and 11 insecticide.

Some naturally occurring insect biotypes resistant to VectoPrime FG and other Group 7A and 11 insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if VectoPrime FG and other Group 7A and 11 insecticides are used repeatedly.
The effectiveness of VectoPrime FG on resistance individuals could be significantly reduced. Since occurrence of resistant individuals is difficult to detect prior to use, Valent BioSciences accepts no liability for any losses that may result from the failure of VectoPrime FG to control resistant insects.

VectoPrime FG may be subject to specific resistant management strategies. For further information contact your local supplier, Sumitomo Chemical Australia representative or local agricultural department agronomist.

STORAGE AND DISPOSAL

VectoPrime FG must be kept in its closed, original, properly labelled container, well sealed and stored in a cool, dry and well-ventilated place. Product is stable for 2 years from date of manufacture when stored at 25 ± 3°C.

Shake contents into the applicator. Do not dispose of undiluted chemicals on site. Puncture and deliver empty packaging to an approved waste management facility. If an approved waste management facility is not available, bury the empty packaging 500 mm below the surface in a disposal pit specifically marked and set up for this purpose, clear of waterways, desirable vegetation and tree roots, in compliance with relevant local, state or territory government regulations.
Do not burn empty containers or product.

SAFETY DIRECTIONS

May irritate the eyes. Avoid contact with eyes. Do not inhale. When opening the container and using the product, wear a disposable dust face mask covering mouth and nose, except when using the product by enclosed cabs or aerial application. Wash hands after use.

FIRST AID

If poisoning occurs, contact a doctor or Poisons Information Centre (ph: 13 11 26).

SAFETY DATA SHEET

Additional information is listed in the Safety Data Sheet.

IMPORTANT NOTICE

These goods are to be used only for the purpose and as specified on the label, and are not suitable for any other purpose. To the fullest extent permitted by law, we do not accept or bear any liability on any basis for any loss, damage, cost or expense, arising in any way, directly or indirectly, in connection with the goods.

® VectoPrime FG is a registered Trademark of Valent BioSciences LLC.
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THIS PRODUCT IS NOT CONSIDERED TO BE A DANGEROUS GOOD UNDER THE AUSTRALIAN CODE FOR THE TRANSPORT OF DANGEROUS GOODS BY ROAD OR RAIL	
In a Transport Emergency **Dial 000** **Police or Fire Brigade**	**SPECIALIST ADVICE IN EMERGENCY ONLY** **ALL HOURS - AUSTRALIA WIDE** **1800 024 973**

APVMA Approval No.: 82315/105416

DIRECTIONS FOR USE

RESTRAINTS:

DO NOT USE IN HIGHLY ENVIRONMENTALLY SENSITIVE AREAS, OR IN TIDEWATER OR MARINE HABITATS WHERE THREATENED OR ENDANGERED SPECIES ARE KNOWN TO EXIST.

DO NOT APPLY DIRECTLY TO TREATED, FINISHED DRINKING WATER RESERVOIRS OR DRINKING WATER RECEPTACLES WHEN THE WATER IS INTENDED FOR HUMAN CONSUMPTION.

PRIOR TO APPLYING TO AREA GRAZED BY LIVESTOCK, USERS MUST NOTIFY PRODUCERS OF WITHHOLDING PERIOD.

SITUATION	PESTS	USE	RATE	CRITICAL COMMENTS
Mosquito Habitats such as: Stagnant ponds and ditches; Freshwater swamps and marshes; Salt and freshwater lagoons; Salt marshes; Mangrove swamps; Estuarine areas; Woodland pools; Any natural water holding feature. For use in open water or where water is obscured by vegetation	Mosquito larvae (e.g. *Aedes, Anopheles, Culex* and *Ochlerotatus* spp.)	Post-flood Applications	1.4 - 11.2 kg/ha	Use 1.4 – 4.0 kg/ha against 1st – 4th instar mosquito larvae. Use 4.0 – 11.2 kg/ha when water is heavily polluted (e.g. sewage lagoons, animal waste lagoons), algae are abundant, and/or local conditions support mosquito development. Re-treat as needed based on local conditions.
		Applications prior to flooding by tides	10 - 20 kg/ha	VectoPrime FG can be applied prior to flooding by tides of mosquito larval habitats. Dry-down/re-flood capacity of VectoPrime FG depends on local conditions. Retreat as needed. Lower rates should be used when flooding will result in water <30cm deep, where water is clean and mosquito larva counts are low (<10/dip). Use 16 kg/ha when flooding will result in water >30cm deep, where vegetation and/or pollution are present and/or where mosquito larval counts are high (>10/dip). Higher rates may be required where water is likely to be heavily contaminated. Only use 20 kg/ha when the major target species is *Culex sitiens*.

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION.

OTHER LIMITATIONS: Users in NSW must comply with the 'Protection of the Environment Operations Act, 1997' and its subsequent amendments.

WITHHOLDING PERIODS:
NOT REQUIRED WHEN USED AS DIRECTED FOR LIVESTOCK DRINKING WATER TREATED WITH THE PRODUCT
IF THE PRODUCT IS APPLIED TO DRY SITES (PRIOR TO FLOODING OR RAINFALL) THEN THE FOLLOWING WITHHOLDING PERIOD MUST BE OBSERVED:
LIVESTOCK THAT GRAZE VEGETATION OR SOIL WITHIN 14 DAYS OF APPLICATION MUST BE PLACED ON CLEAN FEED FOR A PERIOD OF 21 DAYS PRIOR TO SLAUGHTER.

SUMITOMO CHEMICAL

SAFETY DATA SHEET
VectoPrime FG Biological Larvicide Fine Granule

According to Preparation of Safety Data Sheets for Hazardous Chemicals Code of Practice, February 2016

SECTION 1: Identification: Product identifier and chemical identity

Product identifier

Product name VectoPrime FG Biological Larvicide Fine Granule

Relevant identified uses of the substance or mixture and uses advised against

Application Insecticide

Uses advised against -

Details of the supplier of the safety data sheet

Supplier

www.sumitomo-chem.com.au
Sumitomo Chemical Australia Pty Ltd
Level 5, 51 Rawson Street,
EPPING, NSW 2121
(02) 8752 9000
(02) 8752 9099
Reception@sumitomo-chem.com.au

Emergency telephone number

Emergency telephone 1800 024 973 (Australia) 0800 243 6225 (New Zealand)

SECTION 2: Hazard(s) identification

Classification of the substance or mixture

Physical hazards Not Classified

Health hazards Not Classified

Environmental hazards Not Classified

Label elements

Hazard statements NC Not Classified

Other hazards

This product does not contain any substances classified as PBT or vPvB.

SECTION 3: Composition and information on ingredients

Substances

Bacillus thuringiensis subsp. israelensis strain AM65-32 CAS number: —	**5-10%**
s-methoprene CAS number: 65733-16-6	**<1%**

VectoPrime FG Biological Larvicide Fine Granule

Product name VectoPrime FG Biological Larvicide Fine Granule

SECTION 4: First aid measures

Description of first aid measures

General information If poisoning occurs, contact a doctor or Poisons Information Centre (Phone Australia 131126; New Zealand 0800 764 766), and follow the advice given. Show this Safety Data Sheet to a doctor.

Inhalation No specific recommendations. If throat irritation or coughing persists, proceed as follows. Move affected person to fresh air and keep warm and at rest in a position comfortable for breathing. Loosen tight clothing such as collar, tie or belt. Get medical attention if any discomfort continues.

Ingestion No specific recommendations. If throat irritation or coughing persists, proceed as follows. Rinse mouth. Get medical attention if any discomfort continues.

Skin Contact No specific recommendations. Rinse with water. Get medical attention if any discomfort continues.

Eye contact Remove any contact lenses and open eyelids wide apart. Rinse with water. Get medical attention if any discomfort continues.

Protection of first aiders Use protective equipment appropriate for surrounding materials.

Most important symptoms and effects, both acute and delayed

General information The severity of the symptoms described will vary dependent on the concentration and the length of exposure.

Inhalation No specific symptoms known.

Ingestion No specific symptoms known. May cause discomfort if swallowed.

Skin contact Prolonged contact may cause dryness of the skin.

Eye contact No specific symptoms known. May be slightly irritating to eyes.

Indication of any immediate medical attention and special treatment needed

Notes for the doctor Treat symptomatically.

Specific treatments No special treatment required.

SECTION 5: Firefighting measures

Extinguishing media

Suitable extinguishing media The product is not flammable. Extinguish with alcohol-resistant foam, carbon dioxide, dry powder or water fog. Use fire-extinguishing media suitable for the surrounding fire.

Unsuitable extinguishing media Do not use water jet as an extinguisher, as this will spread the fire.

Special hazards arising from the substance or mixture

Specific hazards None known.

Hazardous combustion products Thermal decomposition or combustion products may include the following substances: Harmful gases or vapours.

Advice for firefighters

Protective actions during firefighting Avoid breathing fire gases or vapours. Evacuate area. Cool containers exposed to heat with water spray and remove them from the fire area if it can be done without risk. Cool containers exposed to flames with water until well after the fire is out.

VectoPrime FG Biological Larvicide Fine Granule

Special protective equipment for firefighters	Wear positive-pressure self-contained breathing apparatus (SCBA) and appropriate protective clothing. Firefighter's clothing conforming to Australia/New Zealand Standards AS/NZS 4967 (for clothing) AS/NZS 1801 (for helmets), AS/NZS 4821 (for protective boots), AS/NZS 1801 (for protective gloves) will provide a basic level of protection for chemical incidents.

SECTION 6: Accidental release measures

Personal precautions, protective equipment and emergency procedures

Personal precautions	No specific recommendations. For personal protection, see Section 8.

Environmental precautions

Environmental precautions	Avoid discharge into drains or watercourses or onto the ground.

Methods and material for containment and cleaning up

Methods for cleaning up	Reuse or recycle products wherever possible. Collect spillage with a shovel and broom, or similar and reuse, if possible. Collect and place in suitable waste disposal containers and seal securely. Flush contaminated area with plenty of water. Wash thoroughly after dealing with a spillage. Dispose of contents/container in accordance with national regulations.

Reference to other sections

Reference to other sections	For personal protection, see Section 8. For waste disposal, see Section 13.

SECTION 7: Handling and storage, including how the chemical may be safely used

Precautions for safe handling

Usage precautions	Wear protective clothing as described in Section 8 of this safety data sheet. Keep away from food, drink and animal feeding stuffs. Keep container tightly sealed when not in use.
Advice on general occupational hygiene	Wash promptly if skin becomes contaminated. Take off contaminated clothing and wash before reuse. Wash contaminated clothing before reuse.

Conditions for safe storage, including any incompatibilities

Storage precautions	Store away from incompatible materials (see Section 10). No specific recommendations.
Storage class	Unspecified storage.

Specific end use(s)

Specific end use(s)	The identified uses for this product are detailed in Section 1.

SECTION 8: Exposure controls and personal protection

Control parameters

Occupational exposure limits

No value assigned for this specific material by Safe Work Australia

Exposure controls

Appropriate engineering controls	No specific ventilation requirements.
Eye/face protection	No specific eye protection required during normal use. Large Spillages: Eyewear complying with an approved standard should be worn if a risk assessment indicates eye contact is possible.
Hand protection	No specific hand protection recommended. Large Spillages: Wear protective gloves.
Hygiene measures	Wash after use and before eating, smoking and using the toilet. Do not eat, drink or smoke when using this product.

VectoPrime FG Biological Larvicide Fine Granule

Respiratory protection	No specific recommendations. Provide adequate ventilation. Large Spillages: If ventilation is inadequate, suitable respiratory protection must be worn.
Environmental exposure controls	Not regarded as dangerous for the environment.

SECTION 9: Physical and chemical properties

Information on basic physical and chemical properties

Appearance	Brown, granular
Odour	Very little odour
pH	5.0 (1% w/v)

SECTION 10: Stability and reactivity

Reactivity	See the other subsections of this section for further details.
Stability	Stable at normal ambient temperatures and when used as recommended. Stable under the prescribed storage conditions.
Possibility of hazardous reactions	No potentially hazardous reactions known.
Conditions to avoid	There are no known conditions that are likely to result in a hazardous situation.
Materials to avoid	No specific material or group of materials is likely to react with the product to produce a hazardous situation.
Hazardous decomposition products	Does not decompose when used and stored as recommended. Thermal decomposition or combustion products may include the following substances: Harmful gases or vapours.

SECTION 11: Toxicological information

Information on toxicological effects

Toxicological effects Not regarded as a health hazard under current legislation.

Acute toxicity - oral

Notes (oral LD_{50}) Based on available data the classification criteria are not met.

Acute toxicity - dermal

Notes (dermal LD_{50}) Based on available data the classification criteria are not met.

Acute toxicity - inhalation

Notes (inhalation LC_{50}) Based on available data the classification criteria are not met.

Skin corrosion/irritation

Animal data Based on available data the classification criteria are not met.

Serious eye damage/irritation

Serious eye damage/irritation Based on available data the classification criteria are not met.

Respiratory sensitisation

Respiratory sensitisation Based on available data the classification criteria are not met.

Skin sensitisation

Skin sensitisation Based on available data the classification criteria are not met.

VectoPrime FG Biological Larvicide Fine Granule

Germ cell mutagenicity

Genotoxicity - in vitro Based on available data the classification criteria are not met.

Carcinogenicity

Carcinogenicity Based on available data the classification criteria are not met.

IARC carcinogenicity None of the ingredients are listed or exempt.

Reproductive toxicity

Reproductive toxicity - fertility Based on available data the classification criteria are not met.

Reproductive toxicity - development Based on available data the classification criteria are not met.

Specific target organ toxicity - single exposure

STOT - single exposure Not classified as a specific target organ toxicant after a single exposure.

Specific target organ toxicity - repeated exposure

STOT - repeated exposure Not classified as a specific target organ toxicant after repeated exposure.

Aspiration hazard

Aspiration hazard Not relevant. Solid.

General information No specific health hazards known. The severity of the symptoms described will vary dependent on the concentration and the length of exposure.

Inhalation No specific symptoms known.

Ingestion No specific symptoms known. May cause discomfort if swallowed.

Skin Contact Prolonged contact may cause dryness of the skin.

Eye contact No specific symptoms known. May be slightly irritating to eyes.

Route of entry Ingestion Inhalation Skin and/or eye contact

Target Organs No specific target organs known.

SECTION 12: Ecological Information

Ecotoxicity Not regarded as dangerous for the environment. However, large or frequent spills may have hazardous effects on the environment.

Toxicity Based on available data the classification criteria are not met.

Persistence and degradability

Persistence and degradability The degradability of the product is not known.

Bioaccumulative potential

Bioaccumulative Potential No data available on bioaccumulation.

Mobility in soil

Mobility No data available.

Other adverse effects

Other adverse effects None known.

SECTION 13: Disposal considerations

Waste treatment methods

VectoPrime FG Biological Larvicide Fine Granule

General information The generation of waste should be minimised or avoided wherever possible. This material and its container must be disposed of as hazardous waste.

Disposal methods Shake contents into the applicator. Do not dispose of undiluted chemicals on site. Puncture and deliver empty packaging to an approved waste management facility. If an approved waste management facility is not available, bury the empty packaging 500 mm below the surface in a disposal pit specifically marked and set up for this purpose, clear of waterways, desirable vegetation and tree roots, in compliance with relevant local, state or territory government regulations.
Do not burn empty containers or product.

SECTION 14: Transport information

General Not a dangerous good according to ADG code 7

SECTION 15: Regulatory information

Inventories

Australia - AICS

None of the ingredients are listed or exempt.
Not applicable

SECTION 16: Any other relevant information

Training advice Only trained personnel should use this material.

Revision date 29/06/2018

Revision 1

SDS No. 4821

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process. Such information is, to the best of the company's knowledge and belief, accurate and reliable as of the date indicated. However, no warranty, guarantee or representation is made to its accuracy, reliability or completeness. It is the user's responsibility to satisfy himself as to the suitability of such information for his own particular use.

Wellmark Logo

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

ProLink™ XR BRIQUETS
MOSQUITO GROWTH REGULATOR

ACTIVE CONSTITUENT: 18 g/kg (S)-METHOPRENE (dry weight basis)

(This product contains water, therefore the weight of the briquet and percent by weight of active constituent will vary with hydration.)

GROUP	7A	INSECTICIDE

A SUSTAINED RELEASE PRODUCT TO PREVENT ADULT MOSQUITO EMERGENCE

BATCH NUMBER:
EXPIRY DATE:
D.O.M.
MADE IN USA

Distributed by:
Pacific Biologics Pty Ltd
35 Beach Street
Kippa Ring QLD 4021
(07) 3283 5077
(8:30 am to 5:30 pm E.S.T. Monday to Friday
www.pacificbiologics.com.au

Net Contents: 8 kg dry weight basis
contains 220 briquets

DIRECTIONS FOR USE: Restraint: DO NOT use in areas grazed by livestock.

Site	Pest	Rate	Critical Comments
Dams, storm drains, catch basins, roadside ditches, ornamental ponds and pools, cesspools and septic tanks, sewage treatment settling ponds, abandoned swimming pools, construction and other man-made depressions, ponds and pools in freshwater swamps and marshes, salt marshes, mangrove swamps, woodland pools and flood plains.	***Ochlerotatus vigilax***	1 briquet per 20 m^2	Use this rate when water is shallow (<30 cm), clean and where larval mosquito counts are low (<10 per dip).
		1 briquet per 10 m^2	Use this rate where water is deep (>30 cm) or is rich in organic matter or sediment, or where larval mosquito counts are high (>10 per dip).
	All other mosquito species	1 briquet per 10 m^2	Use 1 briquet per 10 m^2 for all other mosquito species.
Rain water tanks (including those containing potable water)	All mosquito larvae	1 briquet per 5,000L water	Retreat rainwater tanks at 6 monthly to yearly intervals.

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION

Users in NSW must comply with the Protection of the Environment Operations Act, 1997 and its subsequent amendments.

GENERAL INSTRUCTIONS

ProLink™ XR BRIQUETS provide extended mosquito control in chronic, long-term breeding sites by preventing the emergence of adult mosquitoes, including common ***Aedes, Anopheles, Culex*** *and* ***Ochlerotatus*** **spp.** Treated larvae continue to develop normally to the pupal stage after which they fail to emerge. **(S)-methoprene has no effect on mosquitoes which have reached the pupal or adult stage of development at time of treatment.**

Application:

ProLink XR BRIQUETS are designed to release (S)-methoprene over a period up to 150 days in submerged mosquito breeding sites. Soft mud and loose sediment can cover the briquets and inhibit normal dispersion of the active ingredient. In such sites briquets may be placed in mesh bags, tied to stakes, to prevent the briquet sinking into th substrate. This also enables easy monitoring of the rate of breakdown on the briquets. Similarly a briquet suspended in a mesh bag in a water tank can be checked at intervals.

ProLink XR BRIQUETS may not be effective in those situations where the briquets can be removed from the site by flushing action. Briquets should be anchored as described above.

ProLink XR BRIQUETS should be applied before or at the beginning of the mosquito control season. The briquets can be applied prior to flooding or rainfall when sites are dry. Briquets should be placed in the lowest areas of mosquito breeding sites to maintain continuous control as the site alternately floods and dries up. Under normal conditions, one application should last the entire mosquito control season, or at least 150 days, whichever is shorter. Alternate wetting and drying will not reduce the effectiveness of **ProLink XR BRIQUETS**.

Aerial application rates should be frequently checked by comparing amount of product used against area flown during application.

Insecticide Resistance Warning

GROUP	7A	INSECTICIDE

For insecticide resistance management, **ProLink** is a Group 7A insecticide. Some naturally occurring insect biotypes resistant to **ProLink** and other Group 7A insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if **ProLink** or other Group 7A insecticides are used repeatedly. The effectiveness of **ProLink** on resistant individuals could be significantly reduced. Since occurrence of resistant individuals is difficult to detect prior to use, Wellmark International accepts no liability for any losses that may result from the failure of **ProLink** to control resistant insects.

STORAGE AND DISPOSAL

Keep out of reach of children. Store in the closed, original container in a dry, cool, well-ventilated area out of direct sunlight.
Triple or preferably pressure rinse container into the treated water. Do not dispose of undiluted chemicals on-site. Break, crush or puncture and bury empty containers in a local authority landfill. If no landfill is available, bury the containers below 500 mm in a disposal pit specifically marked and set up for this purpose clear of waterways, vegetation and tree roots. Empty containers and product should not be burnt.

SAFETY DIRECTIONS

Will irritate the eyes and skin. Avoid contact with eyes and skin. When using the product, wear elbow-length PVC gloves. If dust is present wear faceshield or goggles and disposable dust mask. If product in eyes, wash it out immediately with water. Wash hands after use. After each day's use, wash gloves and faceshield or goggles.

FIRST AID

If poisoning occurs, contact a doctor or Poisons Information Centre (Phone: 131126)

Material Safety Data Sheet

If additional hazard information is required refer to the Material Safety Data Sheet. For a copy phone your distributor.

WARRANTY AND EXCLUSION OF LIABILITY
This product is warranted fit for the purposes specifically recommended by Wellmark International when used strictly as directed on this label. All other warranties and obligations for liabilities, whether expressed or implied by statute or otherwise, are excluded to the full extent that exclusion is permitted by law.

APVMA Approval No. 58061/220/0505

PROLINK is a trademark of Wellmark International in New Zealand and other countries.
Made in USA

Wellmark Logo

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

ProLink® PELLETS
MOSQUITO GROWTH REGULATOR

ACTIVE CONSTITUENT: 40 g/kg (S)-METHOPRENE

GROUP	7A	INSECTICIDE

A SUSTAINED RELEASE PRODUCT TO PREVENT ADULT MOSQUITO EMERGENCE

NET CONTENTS: 10 kg

DIRECTIONS FOR USE:

Restraint: DO NOT use in areas grazed by livestock.

Site	Pest	Rate (kg/ha)	Critical Comments
Temporary water sites: Freshwater swamps and marshes, salt and freshwater lagoons, salt marshes, mangrove swamps, estuarine areas, woodland pools, any natural water holding features.	***Aedes*, *Anopheles*, *Culex*** and **Ochlerotatus spp.**	3	Use this rate when water is shallow (<30 cm), clean, and where larval mosquito counts are low (<10 per dip).
Permanent water sites: Ornamental ponds, pools, birdbaths, plant pot holders, water troughs, gutters and any other artificial water holding containers, construction and other manmade depressions, tree holes, cesspools, septic tanks, sewage treatment settling ponds.		4	Use this rate when water is deep (>30 cm), or is rich in organic matter and/or sediment, or where larval mosquito counts are high (>10 per dip).
(For treatment by hand of small areas or containers with ProLink® Pellets, refer to the Application section in the General Instructions)			4 kg/ha should be used when the major target is ***Culex sitiens***.

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION
Users in NSW must comply with the Protection of the Environment Operations Act, 1997, and its subsequent amendments.

GENERAL INSTRUCTIONS
Always keep unused product as dry as possible

ProLink PELLETS, when submerged in water, release (S)-methoprene for at least 30 days, preventing the emergence of adult mosquitoes including common ***Aedes*, *Anopheles, Culex*** and **Ochlerotatus spp.** from treated sites. Treated larvae continue to develop normally to the pupal stage after which they fail to emerge. **(S)-methoprene has no effect on mosquitoes which have reached the pupal or adult stage prior to treatment.**

Application: ProLink PELLETS can be applied prior to flooding, or at any stage of larval development after flooding or in permanent water sites.

Aerial: Apply at rates from 3-4 kg/ha by fixed-wing aircraft or helicopters equipped with granular spreaders. Aerial application rates should be frequently checked by comparing amount of product used against area flown during application.

Ground: Apply using ground equipment which will achieve good, even coverage at the above rates.

ProLink PELLETS may be used in artificial containers which breed mosquitoes, such as water tanks, plant pot holders, tyres, gutters and catch basins, and in ornamental plants such as Bromeliads. For residual treatment of water in small containers or wet areas, the following is recommended: 1 pellet/L or m^2 for control up to 3 months; 3 pellets/L or m^2 for control up to 6 months.

Insecticide Resistance Warning

GROUP	7A	INSECTICIDE

For insecticide resistance management, ProLink is a Group 7A insecticide. Some naturally occurring insect biotypes resistant to ProLink and other Group 7A insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if ProLink or other Group 7A insecticides are used repeatedly. The effectiveness of ProLink on resistant individuals could be significantly reduced. Since occurrence of resistant individuals is difficult to detect prior to use, Wellmark International accepts no liability for any losses that may result from the failure of ProLink to control resistant insects.

Protection of Crops, Native and Other Non-Target Plants

DO NOT apply when weather conditions favour drift from treated areas.

STORAGE AND DISPOSAL: Keep out of reach of children. Store in the closed, original container in a dry, cool, well-ventilated area out of direct sunlight. Triple or preferably pressure rinse container into the treated water. Do not dispose of undiluted chemicals on-site. If recycling, replace cap and return clean containers to recycler or designated collection point. If not recycling, break, crush or puncture and bury empty containers in a local authority landfill. If no landfill is available bury the containers below 500 mm in a disposal pit specifically marked and set up for this purpose clear of waterways, vegetation and roots. Empty containers and product should not be burnt.

SAFETY DIRECTIONS: Will irritate the eyes. Avoid contact with eyes. When preparing product for use, wear elbow-length PVC gloves and face shield or goggles. If applying by hand, wear elbow-length PVC gloves. If dust is present, wear disposable dust mask. If product in eyes, wash it out immediately with water. Wash hands after use. After each day's use, wash gloves and face shield or goggles.

FIRST AID: If poisoning occurs, contact a doctor or Poisons Information Centre (Phone: 131126)

Material Safety Data Sheet: If additional hazard information is required refer to the Material Safety Data Sheet. For a copy phone your distributor.

WARRANTY AND EXCLUSION OF LIABILITY: This product is warranted fit for the purposes specifically recommended by Wellmark International when used strictly as directed on this label. All other warranties and obligations for liability, whether expressed or implied by statute or otherwise, are excluded to the full extent that exclusion is permitted by law.

APVMA Approval No. 58064/1/0705

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Distributed by: Pacific BioLogics
35 Beach Street
Kippa Ring QLD 4021
(07) 3283 5077
www.pacificbiologics.com.au

Batch Number:
Date of Manufacture:
Expiry Date:
Made in USA

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

ProLink® ProSand™
MOSQUITO GROWTH REGULATOR

ACTIVE CONSTITUENT: 4 g/kg (S)-METHOPRENE

FOR THE PREVENTION OF ADULT MOSQUITO EMERGENCE

GROUP	7A	INSECTICIDE

Distributed by:
Pacific Biologics
PO Box 58
Scarborough QLD 4020
Phone (07) 3283 5077
www.pacificbiologics.com.au

Net Contents: 20 kg

DIRECTION FOR USE

RESTRAINTS:
This product should be used within 6 weeks of the date of manufacture.
Prior to treating areas grazed by livestock, users must notify livestock producers of the withholding period.

Site	Pest	Rate (kg/ha)	Critical Comments
Freshwater swamps and marshes, salt and freshwater lagoons, salt marshes, mangrove swamps, estuarine areas, woodland pools, any natural water-holding features. For use in open water or where water is obscured by vegetation.	*Aedes,* *Anopheles*, *Culex* and *Ochlerotatus* spp.	3	Use this rate when water is shallow (<30 cm), clean and mosquito larval numbers are low (<10 per dip).
		4	Use this rate when water is deep (> 30 cm), vegetation and/or pollution are present, and or mosquito larval numbers are high (> 10 per dip).
		5	This rate should only be used when the major target mosquito species is *Culex sitiens*.

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION

Users in NSW must comply with the Protection of the Environment Operations Act, 1997 and its subsequent amendments.

WITHHOLDING PERIODS

NO WITHHOLDING PERIOD IS REQUIRED FOR LIVESTOCK CONSUMING THE TREATED WATER IF THE PRODUCT IS APPLIED DIRECTLY ONTO WATER.

IF THE PRODUCT IS APPLIED TO DRY SITES (PRIOR TO FLOODING OR RAINFALL) THEN THE FOLLOWING WITHHOLDING PERIOD MUST BE OBSERVED:
LIVESTOCK THAT GRAZE VEGETATION OR SOIL WITHIN 14 DAYS OF APPLICATION MUST BE PLACED ON CLEAN FEED FOR A PERIOD OF 21 DAYS PRIOR TO SLAUGHTER.

GENERAL INSTRUCTIONS

Always keep unused product as dry as possible.

ProLink ProSand prevents the emergence of adult mosquitoes, includijng common *Aedes, Anopheles*, *Culex* and *Ochlerotatus* spp. from treated sites. Treated larvae continue to develop normally to the pupal stage after which they fail to emerge. ProLink ProSand has sufficient activity to be effective against existing broods when applied to any larval stage at recommended rates. Third and fourth larval stages are more suspectible to the effects of (S)-methoprene than early stages. (S)-methoprene has no effect on mosquitoes which have reached the pupal or adult stage of development at time of treatment.

Insecticide Resistance Warning

GROUP	7A	INSECTICIDE

For insecticide resistance management, ProSand is a Group 7A insecticide. Some naturally occurring insect biotypes resistant to ProSand and other Group 7A insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if ProSand or other Group 7A insecticides are used repeatedly. The effectiveness of ProSand on resistant individuals could be significantly reduced. Since occurrence of resistant individuals is difficult to detect prior to use, Wellmark International accepts no liability for any losses that may result from the failure of ProSand to control resistant insects.

Application

ProLink ProSand can be applied prior to flooding by tides, or at any larval stage after flooding by rain or tide, or in permanent water sites.

Aerial: Apply by fixed wing aircraft or helicopters equipped with granular spreaders capable of applying rates from 2-5 kg/ha.

Ground: Apply by hand or by using ground equipment capable of achieving good, even coverage. A guide to the weight or volume of ProLink ProSand at rates typically used to treat small areas is given in the following table:

Area to be Treated	3 kg/ha RATE		4 kg/ha RATE	
	by weight, g	by volume, mL	by weight, g	by volume, mL
$10m^2$	3 g	2 mL	4 g	2.5 mL
$100m^2$	30 g	20 mL	40 g	25 mL

PROTECTION OF CROPS, NATIVE AND OTHER NON-TARGET PLANTS

DO NOT apply when weather conditions favour drift from treated areas.

STORAGE AND DISPOSAL

Keep out of reach of children

Sore in closed, original container in a dry, cool, well ventilated area out of direct sunlight.

Shake contents of product container into the applicator. Do not dispose of undiluted chemicals on site. Break, crush or puncture and bury empty containers in a local authority landfill. If no landfill is available, bury the containers below 500 mm in a disposal pit specially marked and set up for this purpose clear of waterways, vegetation and tree roots. Empty containers and product should not be burnt.

SAFETY DIRECTIONS

May irritate the eyes. Repeated exposure may cause allergic disorders. Avoid contact with eyes. When preparing product for use wear elbow-length PVC gloves. If applying by hand wear elbow-length PVC gloves. Wash hands after use. After each day's use, wash gloves.

FIRST AID

If poisoning occurs contact a doctor, or Poisons Information Centre (Phone Australia 13 11 26)

Material Safety Data Sheet

If additional information is required refer to the Material Safety Data Sheet. For a copy contact the distributor.

MANUFACTURER'S WARRANTY AND EXCLUSION OF LIABILITY

This product is warranted fit for the purposes specifically recommended by Wellmark International when used strictly as directed on the label. All other warranties and obligations for liabilities, whether expressed or implied by statute or otherwise, are excluded to the full extent that exclusion is permitted by law.

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Distributed by:
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PO Box 58
Scarborough QLD 4020
(07) 3283 5077 (8.30 am to 5.30 pm EST Monday to Friday)
APVMA Approval No. 59598/1/0705

Batch Number: D.O.M. Expiry Date:

Section 1 - Identification of The Material and Supplier

Pacific BioLogics Pty Ltd **Phone: 07 3283 5077 (office hours)**
35 Beach Road, Kippa Ring **Fax: 07 3283 5088**
Qld 4021

Chemical nature: S-Methoprene plus carrier and other ingredients.
Trade Name: **ProLink Pellets Mosquito Growth Regulator**
APVMA Code: 58064
Product Use: Mosquito Growth Regulator for use as described on the product label.
Creation Date: **April, 2011**
This version issued: **April, 2016** and is valid for 5 years from this date.
Poisons Information Centre: Phone 13 1126 from anywhere in Australia

Section 2 - Hazards Identification

Statement of Hazardous Nature

This product is classified as: Not classified as hazardous according to the criteria of SWA.

Not a Dangerous Good according to Australian Dangerous Goods (ADG) Code, IATA and IMDG/IMSBC criteria.

SUSMP Classification: None allocated.
ADG Classification: None allocated. Not a Dangerous Good under the ADG Code.
UN Number: None allocated

GHS Signal word: NONE. Not hazardous.

PREVENTION

P102: Keep out of reach of children.
P262: Do not get in eyes, on skin, or on clothing.
P273: Avoid release to the environment.
P281: Use personal protective equipment as required.

RESPONSE

P337: If eye irritation persists: seek medical attention.
P353: Rinse skin or shower with water.
P301+P330+P331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P370+P378: Not combustible. Use extinguishing media suited to burning materials.

STORAGE

P402+P404: Store in a dry place. Store in a closed container.

DISPOSAL

P501: Dispose of contents and containers as specified on the registered label.

Emergency Overview

Physical Description & Colour: Grey to black solid pellets.
Odour: Slight hydrocarbon odour.
Major Health Hazards: no significant risk factors have been found for this product.

Section 3 - Composition/Information on Ingredients

Ingredients	CAS No	Conc,%	TWA (mg/m^3)	STEL (mg/m^3)
(S)-Methoprene	65733-16-6	40g/kg	not set	not set
Other non hazardous ingredients	secret	to 100	not set	not set

This is a commercial product whose exact ratio of components may vary slightly. Minor quantities of other non hazardous ingredients are also possible.

The SWA TWA exposure value is the average airborne concentration of a particular substance when calculated over a normal 8 hour working day for a 5 day working week. The STEL (Short Term Exposure Limit) is an exposure value that may be equalled (but should not be exceeded) for no

longer than 15 minutes and should not be repeated more than 4 times per day. There should be at least 60 minutes between successive exposures at the STEL. The term "peak "is used when the TWA limit, because of the rapid action of the substance, should never be exceeded, even briefly.

Section 4 - First Aid Measures

General Information:

You should call The Poisons Information Centre if you feel that you may have been poisoned, burned or irritated by this product. The number is 13 1126 from anywhere in Australia (0800 764 766 in New Zealand) and is available at all times. Have this SDS with you when you call.

Inhalation: First aid is not generally required. If in doubt, contact a Poisons Information Centre or a doctor.
Skin Contact: Gently brush away excess particles. Irritation is unlikely. However, if irritation does occur, flush with lukewarm, gently flowing water for 5 minutes or until chemical is removed.
Eye Contact: Quickly and gently brush particles from eyes. No effects expected. If irritation does occur, flush contaminated eye(s) with lukewarm, gently flowing water for 5 minutes or until the product is removed. Obtain medical advice if irritation becomes painful or lasts more than a few minutes. Take special care if exposed person is wearing contact lenses.
Ingestion: If product is swallowed or gets in mouth, do NOT induce vomiting; wash mouth with water and give some water to drink. If symptoms develop, or if in doubt contact a Poisons Information Centre or a doctor.

Section 5 - Fire Fighting Measures

Fire and Explosion Hazards: The major hazard in fires is usually inhalation of heated and toxic or oxygen deficient (or both), fire gases. There is no risk of an explosion from this product under normal circumstances if it is involved in a fire.
Fire decomposition products from this product may be toxic if inhaled. Take appropriate protective measures.
Extinguishing Media: Suitable extinguishing media are carbon dioxide, dry chemical, foam, water fog.
Fire Fighting: If a significant quantity of this product is involved in a fire, call the fire brigade.

Flash point:	No data
Upper Flammability Limit:	No data.
Lower Flammability Limit:	No data.
Autoignition temperature:	No data.
Flammability Class:	No data.

Section 6 - Accidental Release Measures

Accidental release: Minor spills do not normally need any special cleanup measures. In the event of a major spill, prevent spillage from entering drains or water courses. As a minimum, wear overalls, goggles and gloves. Suitable materials for protective clothing include PVC, Viton, Nitrile. Eye/face protective equipment should comprise as a minimum, protective glasses and, preferably, goggles. If there is a significant chance that dusts are likely to build up in cleanup area, we recommend that you use a suitable Dust Mask.
Stop leak if safe to do so, and contain spill. Sweep up and shovel or collect recoverable product into labelled containers for recycling or salvage, and dispose of promptly. Consider vacuuming if appropriate. Recycle containers wherever possible after careful cleaning. Refer to product label for specific instructions. After spills, wash area preventing runoff from entering drains. If a significant quantity of material enters drains, advise emergency services. Full details regarding disposal of used containers, spillage and unused material may be found on the label. If there is any conflict between this SDS and the label, instructions on the label prevail. Ensure legality of disposal by consulting regulations prior to disposal. Thoroughly launder protective clothing before storage or re-use. Advise laundry of nature of contamination when sending contaminated clothing to laundry.

Section 7 - Handling and Storage

Handling: Keep exposure to this product to a minimum, and minimise the quantities kept in work areas. Check Section 8 of this SDS for details of personal protective measures, and make sure that those measures are followed. The measures detailed below under "Storage" should be followed during handling in order to minimise risks to persons using the product in the workplace. Also, avoid contact or contamination of product with incompatible materials listed in Section 10.
Storage: Store packages of this product in a cool place. Make sure that containers of this product are kept tightly closed. Keep containers of this product in a well ventilated area. Protect this product from light. Make sure that the product does not come into contact with substances listed under "Incompatibilities" in Section 10. Check packaging - there may be further storage instructions on the label.

Section 8 - Exposure Controls and Personal Protection

The following Australian Standards will provide general advice regarding safety clothing and equipment:

Respiratory equipment: **AS/NZS 1715**, Protective Gloves: **AS 2161**, Occupational Protective Clothing: AS/NZS 4501 set 2008, Industrial Eye Protection: **AS1336** and **AS/NZS 1337**, Occupational Protective Footwear: **AS/NZS2210**.

SWA Exposure Limits **TWA (mg/m^3)** **STEL (mg/m^3)**

Exposure limits have not been established by SWA for any of the significant ingredients in this product.

No special equipment is usually needed when occasionally handling small quantities. The following instructions are for bulk handling or where regular exposure in an occupational setting occurs without proper containment systems.

Ventilation: This product should only be used in a well ventilated area. If natural ventilation is inadequate, use of a fan is suggested.

Eye Protection: Eye protection such as protective glasses or goggles is recommended when product is being used.

Skin Protection: The information at hand indicates that this product is not harmful and that normally no special skin protection is necessary. However, we suggest that you routinely avoid contact with all chemical products and that you wear suitable gloves (preferably elbow-length) when skin contact is likely.

Protective Material Types: We suggest that protective clothing be made from the following: PVC, Viton, nitrile.

Respirator: If there is a significant chance that dusts are likely to build up in the area where this product is being used, we recommend that you use a suitable Dust Mask.

Section 9 - Physical and Chemical Properties:

Physical Description & colour:	Grey to black solid pellets.
Odour:	Slight hydrocarbon odour.
Boiling Point:	Not available.
Freezing/Melting Point:	No specific data. Solid at normal temperatures.
Volatiles:	No data.
Vapour Pressure:	No data.
Vapour Density:	Not applicable.
Specific Gravity:	1.04
Water Solubility:	1ppm
pH:	No data.
Volatility:	No data.
Odour Threshold:	No data.
Evaporation Rate:	Not applicable.
Coeff Oil/water Distribution:	No data
Viscosity:	Not applicable.
Autoignition temp:	No data.

Section 10 - Stability and Reactivity

Reactivity: This product is unlikely to react or decompose under normal storage conditions. However, if you have any doubts, contact the supplier for advice on shelf life properties.

Conditions to Avoid: This product should be kept in a cool place, preferably below 30°C. Keep containers tightly closed. Keep containers and surrounding areas well ventilated. Protect this product from light.

Incompatibilities: No particular Incompatibilities.

Fire Decomposition: Combustion forms carbon dioxide, and if incomplete, carbon monoxide and smoke. Water is also formed. Carbon monoxide poisoning produces headache, weakness, nausea, dizziness, confusion, dimness of vision, disturbance of judgment, and unconsciousness followed by coma and death.

Polymerisation: This product will not undergo polymerisation reactions.

Section 11 - Toxicological Information

Local Effects:

Target Organs: There is no data to hand indicating any particular target organs.

This product has low toxicity by the dermal route. Acute Dermal LD_{50} (rabbit) > 2000 mg/kg.
No data available on this formulation. In studies with laboratory animals, S-methoprene did not cause teratogenicity, reproductive toxicity or carcinogenicity.

Classification of Hazardous Ingredients

Ingredient	Risk Phrases

No ingredient mentioned in the HSIS Database is present in this product at hazardous concentrations.

Potential Health Effects

Inhalation:
Short Term Exposure: Available data indicates that this product is not harmful. In addition product is unlikely to cause any discomfort or irritation.
Long Term Exposure: No data for health effects associated with long term inhalation.

Skin Contact:
Short Term Exposure: Available data indicates that this product is not harmful. It should present no hazards in normal use. In addition product is unlikely to cause any discomfort in normal use.
Long Term Exposure: No data for health effects associated with long term skin exposure.

Eye Contact:
Short Term Exposure: This product may be irritating to eyes, but is unlikely to cause anything more than mild transient discomfort.
Long Term Exposure: No data for health effects associated with long term eye exposure.

Ingestion:
Short Term Exposure: Significant oral exposure is considered to be unlikely. However, this product may be irritating to mucous membranes but is unlikely to cause anything more than transient discomfort.
Long Term Exposure: No data for health effects associated with long term ingestion.

Carcinogen Status:
SWA: No significant ingredient is classified as carcinogenic by SWA.
NTP: No significant ingredient is classified as carcinogenic by NTP.
IARC: No significant ingredient is classified as carcinogenic by IARC.

Section 12 - Ecological Information

Insufficient data to be sure of status.

Environmental Properties: No data is available on this product. Toxicity data is on the active constituent, (S)-Methoprene, has a half-life in soil of approximately 10 days which varies with soil type.
The hydrolysis half-life > 4 weeks. Photolysis half-life is < 10 hours. Water solubility is < 2 mg/L.
Environmental Toxicology: With fish LC_{50} values of > 370 mg/L to 760 mg/L, (S)- methoprene is considered moderately toxic to fish. [Note: Acute fish toxicity would not be expected during control programmes as the concentration of methoprene in water at any one time is unlikely to exceed 0.002 mg/L.] (S)-methoprene has low toxicity to birds and is practically non-toxic to adult bees, but bee larvae are sensitive.

Section 13 - Disposal Considerations

Disposal: Special help is available for the disposal of Agricultural Chemicals. The product label will give general advice regarding disposal of small quantities, and how to cleanse containers. However, for help with the collection of unwanted rural chemicals, contact ChemClear 1800 008 182 http://www.chemclear.com.au/ and for help with the disposal of empty drums, contact DrumMuster http://www.drummuster.com.au/ where you will find contact details for your area.

Section 14 - Transport Information

UN Number: This product is not classified as a Dangerous Good by ADG, IATA or IMDG/IMSBC criteria. No special transport conditions are necessary unless required by other regulations.

Section 15 - Regulatory Information

AICS: All of the significant ingredients in this formulation are compliant with NICNAS regulations.

Section 16 - Other Information

This SDS contains only safety-related information. For other data see product literature.

Acronyms:

ADG Code	Australian Code for the Transport of Dangerous Goods by Road and Rail (7th edition)
AICS	Australian Inventory of Chemical Substances

SWA	Safe Work Australia, formerly ASCC and NOHSC
CAS number	Chemical Abstracts Service Registry Number
Hazchem Code	Emergency action code of numbers and letters that provide information to emergency services especially firefighters
IARC	International Agency for Research on Cancer
NTP	National Toxicology Program (USA)
R-Phrase	Risk Phrase
SUSMP	Standard for the Uniform Scheduling of Medicines & Poisons
UN Number	United Nations Number

THIS SDS SUMMARISES OUR BEST KNOWLEDGE OF THE HEALTH AND SAFETY HAZARD INFORMATION OF THE PRODUCT AND HOW TO SAFELY HANDLE AND USE THE PRODUCT IN THE WORKPLACE. EACH USER MUST REVIEW THIS SDS IN THE CONTEXT OF HOW THE PRODUCT WILL BE HANDLED AND USED IN THE WORKPLACE.

IF CLARIFICATION OR FURTHER INFORMATION IS NEEDED TO ENSURE THAT AN APPROPRIATE RISK ASSESSMENT CAN BE MADE, THE USER SHOULD CONTACT THIS COMPANY SO WE CAN ATTEMPT TO OBTAIN ADDITIONAL INFORMATION FROM OUR SUPPLIERS

OUR RESPONSIBILITY FOR PRODUCTS SOLD IS SUBJECT TO OUR STANDARD TERMS AND CONDITIONS, A COPY OF WHICH IS SENT TO OUR CUSTOMERS AND IS ALSO AVAILABLE ON REQUEST.

Please read all labels carefully before using product.

This SDS is prepared in accord with the SWA document “Preparation of Safety Data Sheets for Hazardous Chemicals - Code of Practice” (December 2011)

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http://www.kilford.com.au/ Phone (02)9251 4532

Section 1 - Identification of The Material and Supplier

Pacific BioLogics Pty Ltd **Phone: 07 3283 5077 (office hours)**
35 Beach Road, Kippa Ring **Fax: 07 3283 5088**
Qld 4021

Chemical nature: (S)-Methoprene on a sand base.
Trade Name: **ProLink ProSand Mosquito Growth Regulator**
APVMA Code: 58061
Product Use: Mosquito Growth Regulator for use as described on the product label.
Creation Date: **April, 2011**
This version issued: **April, 2016** and is valid for 5 years from this date.
Poisons Information Centre: Phone 13 1126 from anywhere in Australia

Section 2 - Hazards Identification

Statement of Hazardous Nature

This product is classified as: Not classified as hazardous according to the criteria of SWA.

Not a Dangerous Good according to Australian Dangerous Goods (ADG) Code, IATA and IMDG/IMSBC criteria.

SUSMP Classification: None allocated.
ADG Classification: None allocated. Not a Dangerous Good under the ADG Code.
UN Number: None allocated

GHS Signal word: NONE. Not hazardous.

PREVENTION

P102: Keep out of reach of children.
P273: Avoid release to the environment.
P281: Use personal protective equipment as required.

RESPONSE

P337: If eye irritation persists: seek medical attention.
P353: Rinse skin or shower with water.
P301+P330+P331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P370+P378: Not combustible. Use extinguishing media suited to burning materials.

STORAGE

P402+P404: Store in a dry place. Store in a closed container.

DISPOSAL

P501: Dispose of contents and containers as specified on the registered label.

Emergency Overview

Physical Description & Colour: Grey sand based granule.
Odour: Slight odour.
Major Health Hazards: no significant risk factors have been found for this product.

Section 3 - Composition/Information on Ingredients

Ingredients	CAS No	Conc,%	TWA (mg/m^3)	STEL (mg/m^3)
(S)-Methoprene	65733-16-6	4g/kg	not set	not set
Other non hazardous ingredients	secret	to 100	not set	not set

This is a commercial product whose exact ratio of components may vary slightly. Minor quantities of other non hazardous ingredients are also possible.

The SWA TWA exposure value is the average airborne concentration of a particular substance when calculated over a normal 8 hour working day for a 5 day working week. The STEL (Short Term Exposure Limit) is an exposure value that may be equalled (but should not be exceeded) for no longer than 15 minutes and should not be repeated more than 4 times per day. There should be at least 60 minutes between successive exposures at the STEL. The term "peak "is used when the TWA limit, because of the rapid action of the substance, should never be exceeded, even briefly.

Section 4 - First Aid Measures

General Information:

You should call The Poisons Information Centre if you feel that you may have been poisoned, burned or irritated by this product. The number is 13 1126 from anywhere in Australia (0800 764 766 in New Zealand) and is available at all times. Have this SDS with you when you call.

Inhalation: First aid is not generally required. If in doubt, contact a Poisons Information Centre or a doctor.
Skin Contact: Gently brush away excess particles. Irritation is unlikely. However, if irritation does occur, flush with lukewarm, gently flowing water for 5 minutes or until chemical is removed.
Eye Contact: Quickly and gently brush particles from eyes. Immediately flush the contaminated eye(s) with lukewarm, gently flowing water until the particles are removed, while holding the eyelid(s) open. Obtain medical attention if irritation persists, or if particles are lodged in surface of the eye(s). Take special care if exposed person is wearing contact lenses.
Ingestion: If product is swallowed or gets in mouth, do NOT induce vomiting; wash mouth with water and give some water to drink. If symptoms develop, or if in doubt contact a Poisons Information Centre or a doctor.

Section 5 - Fire Fighting Measures

Fire and Explosion Hazards: There is no risk of an explosion from this product under normal circumstances if it is involved in a fire.
Only small quantities of decomposition products are expected from this product at temperatures normally achieved in a fire.
Fire decomposition products from this product are not expected to be hazardous or harmful.
Extinguishing Media: Not Combustible. Use extinguishing media suited to burning materials.
Fire Fighting: If a significant quantity of this product is involved in a fire, call the fire brigade.

Flash point:	Does not burn.
Upper Flammability Limit:	Does not burn.
Lower Flammability Limit:	Does not burn.
Autoignition temperature:	Not applicable - does not burn.
Flammability Class:	Does not burn.

Section 6 - Accidental Release Measures

Accidental release: This product is sold in small packages, and the accidental release from one of these is not usually a cause for concern. For minor spills, clean up, rinsing to sewer and put empty container in garbage. Although no special protective clothing is normally necessary because of occasional minor contact with this product, it is good practice to wear impermeable gloves when handling chemical products. In the event of a major spill, prevent spillage from entering drains or water courses and call emergency services.

Section 7 - Handling and Storage

Handling: Keep exposure to this product to a minimum, and minimise the quantities kept in work areas. Check Section 8 of this SDS for details of personal protective measures, and make sure that those measures are followed. The measures detailed below under "Storage" should be followed during handling in order to minimise risks to persons using the product in the workplace. Also, avoid contact or contamination of product with incompatible materials listed in Section 10.
Storage: Store packages of this product in a cool place. Make sure that containers of this product are kept tightly closed. Keep containers dry and away from water. Make sure that the product does not come into contact with substances listed under "Incompatibilities" in Section 10. Check packaging - there may be further storage instructions on the label.

Section 8 - Exposure Controls and Personal Protection

The following Australian Standards will provide general advice regarding safety clothing and equipment:

Respiratory equipment: **AS/NZS 1715**, Protective Gloves: **AS 2161**, Occupational Protective Clothing: AS/NZS 4501 set 2008, Industrial Eye Protection: **AS1336** and **AS/NZS 1337**, Occupational Protective Footwear: **AS/NZS2210**.

SWA Exposure Limits	**TWA (mg/m^3)**	**STEL (mg/m^3)**

Exposure limits have not been established by SWA for any of the significant ingredients in this product.

No special equipment is usually needed when occasionally handling small quantities. The following instructions are for bulk handling or where regular exposure in an occupational setting occurs without proper containment systems.
Ventilation: No special ventilation requirements are normally necessary for this product. However make sure that the work environment remains clean and that dusts are minimised.

Eye Protection: Eye protection is not normally necessary when this product is being used. However, if in doubt, wear suitable protective glasses or goggles.
Skin Protection: The information at hand indicates that this product is not harmful and that normally no special skin protection is necessary. However, we suggest that you routinely avoid contact with all chemical products and that you wear suitable gloves (preferably elbow-length) when skin contact is likely.
Protective Material Types: There is no specific recommendation for any particular protective material type.
Respirator: If there is a significant chance that dusts are likely to build up in the area where this product is being used, we recommend that you use a suitable Dust Mask.

Section 9 - Physical and Chemical Properties:

Physical Description & colour:	Grey sand based granule.
Odour:	Slight odour.
Boiling Point:	Not available.
Freezing/Melting Point:	No specific data. Solid at normal temperatures.
Volatiles:	No specific data. Expected to be low at 100°C.
Vapour Pressure:	Nil at normal ambient temperatures.
Vapour Density:	Not applicable.
Specific Gravity:	No data. Bulk density 1.56
Water Solubility:	Active concentrate coated on sand granule, disperses in water.
pH:	No data.
Volatility:	Nil at normal ambient temperatures.
Odour Threshold:	No data.
Evaporation Rate:	Not applicable.
Coeff Oil/water Distribution:	No data
Viscosity:	Not applicable.
Autoignition temp:	Not applicable - does not burn.

Section 10 - Stability and Reactivity

Reactivity: This product is unlikely to react or decompose under normal storage conditions. However, if you have any doubts, contact the supplier for advice on shelf life properties.
Conditions to Avoid: This product should be kept in a cool place, preferably below 30°C. Keep containers tightly closed. Containers should be kept dry.
Incompatibilities: strong acids, strong bases, strong oxidising agents.
Fire Decomposition: Only small quantities of decomposition products are expected from this product at temperatures normally achieved in a fire. Combustion forms carbon dioxide, and if incomplete, carbon monoxide. Water is also formed. Carbon monoxide poisoning produces headache, weakness, nausea, dizziness, confusion, dimness of vision, disturbance of judgment, and unconsciousness followed by coma and death.
Polymerisation: This product will not undergo polymerisation reactions.

Section 11 - Toxicological Information

Local Effects:
Target Organs: There is no data to hand indicating any particular target organs.

This product has low toxicity by the dermal route. Acute Dermal LD_{50} (rabbit) > 2000 mg/kg (calculated from S-Methoprene). Other ingredients in the formulation may cause an allergic disorder with repeated exposure.
No data available on this formulation. In studies with laboratory animals, S-methoprene Technical did not cause teratogenicity, reproductive toxicity or carcinogenicity.

Classification of Hazardous Ingredients

Ingredient Risk Phrases

No ingredient mentioned in the HSIS Database is present in this product at hazardous concentrations.

Potential Health Effects

Inhalation:
Short Term Exposure: Available data indicates that this product is not harmful. In addition product is unlikely to cause any discomfort or irritation.
Long Term Exposure: No data for health effects associated with long term inhalation.

Skin Contact:

Short Term Exposure: Available data indicates that this product is not harmful. It should present no hazards in normal use. However product may be mildly irritating, but is unlikely to cause anything more than mild discomfort which should disappear once contact ceases.

Long Term Exposure: No data for health effects associated with long term skin exposure.

Eye Contact:

Short Term Exposure: This product is likely to be mechanically irritating. If exposure is minor or brief, no long term effects should result. However, if material is not removed promptly, scratches to surface of the eye may result with long term consequences.

Long Term Exposure: No data for health effects associated with long term eye exposure.

Ingestion:

Short Term Exposure: Significant oral exposure is considered to be unlikely. However, this product may be mildly irritating to mucous membranes but is unlikely to cause anything more than mild transient discomfort.

Long Term Exposure: No data for health effects associated with long term ingestion.

Carcinogen Status:

SWA: No significant ingredient is classified as carcinogenic by SWA.

NTP: No significant ingredient is classified as carcinogenic by NTP.

IARC: No significant ingredient is classified as carcinogenic by IARC.

Section 12 - Ecological Information

Insufficient data to be sure of status.

Environmental Properties: No data is available on this product. Toxicity data is on the active constituent, (S)-Methoprene, has a half-life in soil of approximately 10 days which varies with soil type.
The hydrolysis half-life > 4 weeks. Photolysis half-life is < 10 hours. Water solubility is < 2 mg/L.

Environmental Toxicology: With LC_{50} values of > 370 mg/L to 760 µg/L, (S)-methoprene is considered toxic to fish. [Note: Acute fish toxicity would not be expected during control programmes as the concentration of methoprene in water at any one time is unlikely to exceed 0.002 mg/L.]. (S)-methoprene has low toxicity to birds and is practically non-toxic to adult bees, but bee larvae are sensitive.

Section 13 - Disposal Considerations

Disposal: Special help is available for the disposal of Agricultural Chemicals. The product label will give general advice regarding disposal of small quantities, and how to cleanse containers. However, for help with the collection of unwanted rural chemicals, contact ChemClear 1800 008 182 http://www.chemclear.com.au/ and for help with the disposal of empty drums, contact DrumMuster http://www.drummuster.com.au/ where you will find contact details for your area.

Section 14 - Transport Information

UN Number: This product is not classified as a Dangerous Good by ADG, IATA or IMDG/IMSBC criteria. No special transport conditions are necessary unless required by other regulations.

Section 15 - Regulatory Information

AICS: All of the significant ingredients in this formulation are compliant with NICNAS regulations.

Section 16 - Other Information

This SDS contains only safety-related information. For other data see product literature.

Acronyms:

ADG Code	Australian Code for the Transport of Dangerous Goods by Road and Rail (7th edition)
AICS	Australian Inventory of Chemical Substances
SWA	Safe Work Australia, formerly ASCC and NOHSC
CAS number	Chemical Abstracts Service Registry Number
Hazchem Code	Emergency action code of numbers and letters that provide information to emergency services especially firefighters
IARC	International Agency for Research on Cancer
NOS	Not otherwise specified
NTP	National Toxicology Program (USA)
R-Phrase	Risk Phrase
SUSMP	Standard for the Uniform Scheduling of Medicines & Poisons

UN Number United Nations Number

THIS SDS SUMMARISES OUR BEST KNOWLEDGE OF THE HEALTH AND SAFETY HAZARD INFORMATION OF THE PRODUCT AND HOW TO SAFELY HANDLE AND USE THE PRODUCT IN THE WORKPLACE. EACH USER MUST REVIEW THIS SDS IN THE CONTEXT OF HOW THE PRODUCT WILL BE HANDLED AND USED IN THE WORKPLACE.

IF CLARIFICATION OR FURTHER INFORMATION IS NEEDED TO ENSURE THAT AN APPROPRIATE RISK ASSESSMENT CAN BE MADE, THE USER SHOULD CONTACT THIS COMPANY SO WE CAN ATTEMPT TO OBTAIN ADDITIONAL INFORMATION FROM OUR SUPPLIERS

OUR RESPONSIBILITY FOR PRODUCTS SOLD IS SUBJECT TO OUR STANDARD TERMS AND CONDITIONS, A COPY OF WHICH IS SENT TO OUR CUSTOMERS AND IS ALSO AVAILABLE ON REQUEST.

Please read all labels carefully before using product.

This SDS is prepared in accord with the SWA document “Preparation of Safety Data Sheets for Hazardous Chemicals - Code of Practice” (December 2011)

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Section 1 - Identification of The Material and Supplier

Pacific BioLogics Pty Ltd
35 Beach Road, Kippa Ring
Qld 4021
Phone: 07 3283 5077 (office hours)
Fax: 07 3283 5088

Chemical nature: (S)-Methoprene on a suitable carrier.
Trade Name: **ProLink XR Briquets Mosquito Growth Regulator**
APMA Code: 58061
Product Use: Mosquito Growth Regulator for use as described on the product label.
Creation Date: **April, 2011**
This version issued: **April, 2016** and is valid for 5 years from this date.
Poisons Information Centre: Phone 13 1126 from anywhere in Australia

Section 2 - Hazards Identification

Statement of Hazardous Nature

This product is classified as: Not classified as hazardous according to the criteria of SWA.

Not a Dangerous Good according to Australian Dangerous Goods (ADG) Code, IATA and IMDG/IMSBC criteria.

SUSMP Classification: None allocated.
ADG Classification: None allocated. Not a Dangerous Good under the ADG Code.
UN Number: None allocated

GHS Signal word: NONE. Not hazardous.

PREVENTION

P102: Keep out of reach of children.
P273: Avoid release to the environment.
P281: Use personal protective equipment as required.

RESPONSE

P337: If eye irritation persists: seek medical attention.
P353: Rinse skin or shower with water.
P301+P330+P331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P370+P378: Not combustible. Use extinguishing media suited to burning materials.

STORAGE

P402+P404: Store in a dry place. Store in a closed container.

DISPOSAL

P501: Dispose of contents and containers as specified on the registered label.

Emergency Overview

Physical Description & Colour: Grey to black solid briquettes.
Odour: Slight hydrocarbon odour.
Major Health Hazards: no significant risk factors have been found for this product.

Section 3 - Composition/Information on Ingredients

Ingredients	CAS No	Conc,%	TWA (mg/m^3)	STEL (mg/m^3)
(S)-Methoprene	65733-16-6	18g/kg	not set	not set
Other non hazardous ingredients	secret	to 100	not set	not set

This is a commercial product whose exact ratio of components may vary slightly. Minor quantities of other non hazardous ingredients are also possible.

The SWA TWA exposure value is the average airborne concentration of a particular substance when calculated over a normal 8 hour working day for a 5 day working week. The STEL (Short Term Exposure Limit) is an exposure value that may be equalled (but should not be exceeded) for no longer than 15 minutes and should not be repeated more than 4 times per day. There should be at least 60 minutes between successive exposures at the STEL. The term "peak "is used when the TWA limit, because of the rapid action of the substance, should never be exceeded, even briefly.

Section 4 - First Aid Measures

General Information:

You should call The Poisons Information Centre if you feel that you may have been poisoned, burned or irritated by this product. The number is 13 1126 from anywhere in Australia (0800 764 766 in New Zealand) and is available at all times. Have this SDS with you when you call.

Inhalation: First aid is not generally required. If in doubt, contact a Poisons Information Centre or a doctor.
Skin Contact: Gently brush away excess particles. Irritation is unlikely. However, if irritation does occur, flush with lukewarm, gently flowing water for 5 minutes or until chemical is removed.
Eye Contact: Quickly and gently brush particles from eyes. No effects expected. If irritation does occur, flush contaminated eye(s) with lukewarm, gently flowing water for 5 minutes or until the product is removed. Obtain medical advice if irritation becomes painful or lasts more than a few minutes. Take special care if exposed person is wearing contact lenses.
Ingestion: If product is swallowed or gets in mouth, do NOT induce vomiting; wash mouth with water and give some water to drink. If symptoms develop, or if in doubt contact a Poisons Information Centre or a doctor.

Section 5 - Fire Fighting Measures

Fire and Explosion Hazards: The major hazard in fires is usually inhalation of heated and toxic or oxygen deficient (or both), fire gases. There is no risk of an explosion from this product under normal circumstances if it is involved in a fire.
Fire decomposition products from this product may be toxic if inhaled. Take appropriate protective measures.
Extinguishing Media: Suitable extinguishing media are carbon dioxide, dry chemical, foam, water fog.
Fire Fighting: If a significant quantity of this product is involved in a fire, call the fire brigade.

Flash point:	No data
Upper Flammability Limit:	No data.
Lower Flammability Limit:	No data.
Autoignition temperature:	No data.
Flammability Class:	No data.

Section 6 - Accidental Release Measures

Accidental release: Minor spills do not normally need any special cleanup measures. In the event of a major spill, prevent spillage from entering drains or water courses. As a minimum, wear overalls, goggles and gloves. Suitable materials for protective clothing include cotton, rubber, PVC. Eye/face protective equipment should comprise as a minimum, protective glasses and, preferably, goggles. If there is a significant chance that dusts are likely to build up in cleanup area, we recommend that you use a suitable Dust Mask.
Stop leak if safe to do so, and contain spill. Sweep up and shovel or collect recoverable product into labelled containers for recycling or salvage, and dispose of promptly. Consider vacuuming if appropriate. Recycle containers wherever possible after careful cleaning. Refer to product label for specific instructions. After spills, wash area preventing runoff from entering drains. If a significant quantity of material enters drains, advise emergency services. Full details regarding disposal of used containers, spillage and unused material may be found on the label. If there is any conflict between this SDS and the label, instructions on the label prevail. Ensure legality of disposal by consulting regulations prior to disposal. Thoroughly launder protective clothing before storage or re-use. Advise laundry of nature of contamination when sending contaminated clothing to laundry.

Section 7 - Handling and Storage

Handling: Keep exposure to this product to a minimum, and minimise the quantities kept in work areas. Check Section 8 of this SDS for details of personal protective measures, and make sure that those measures are followed. The measures detailed below under "Storage" should be followed during handling in order to minimise risks to persons using the product in the workplace. Also, avoid contact or contamination of product with incompatible materials listed in Section 10.
Storage: Protect this product from light. Store in the closed original container in a dry, cool, well-ventilated area out of direct sunlight. Make sure that the product does not come into contact with substances listed under "Incompatibilities" in Section 10. Check packaging - there may be further storage instructions on the label.

Section 8 - Exposure Controls and Personal Protection

The following Australian Standards will provide general advice regarding safety clothing and equipment:

Respiratory equipment: **AS/NZS 1715**, Protective Gloves: **AS 2161**, Occupational Protective Clothing: AS/NZS 4501 set 2008, Industrial Eye Protection: **AS1336** and **AS/NZS 1337**, Occupational Protective Footwear: **AS/NZS2210**.

SWA Exposure Limits **TWA (mg/m^3)** **STEL (mg/m^3)**

Exposure limits have not been established by SWA for any of the significant ingredients in this product.

No special equipment is usually needed when occasionally handling small quantities. The following instructions are for bulk handling or where regular exposure in an occupational setting occurs without proper containment systems.

Ventilation: This product should only be used in a well ventilated area. If natural ventilation is inadequate, use of a fan is suggested.

Eye Protection: Eye protection such as protective glasses or goggles is recommended when this product is being used.

Skin Protection: The information at hand indicates that this product is not harmful and that normally no special skin protection is necessary. However, we suggest that you routinely avoid contact with all chemical products and that you wear suitable gloves (preferably elbow-length) when skin contact is likely.

Protective Material Types: We suggest that protective clothing be made from the following materials: cotton, rubber, PVC.

Respirator: If there is a significant chance that dusts are likely to build up in the area where this product is being used, we recommend that you use a suitable Dust Mask.

Section 9 - Physical and Chemical Properties:

Physical Description & colour:	Grey to black solid briquettes.
Odour:	Slight hydrocarbon odour.
Boiling Point:	Not available.
Freezing/Melting Point:	No specific data. Solid at normal temperatures.
Volatiles:	No specific data. Expected to be low at 100°C.
Vapour Pressure:	Negligible at normal ambient temperatures.
Vapour Density:	Not applicable.
Specific Gravity:	1.85
Water Solubility:	Negligible.
pH:	No data.
Volatility:	Negligible at normal ambient temperatures.
Odour Threshold:	No data.
Evaporation Rate:	Not applicable.
Coeff Oil/water Distribution:	No data
Viscosity:	Not applicable.
Autoignition temp:	No data.

Section 10 - Stability and Reactivity

Reactivity: This product is unlikely to react or decompose under normal storage conditions. However, if you have any doubts, contact the supplier for advice on shelf life properties.

Conditions to Avoid: Protect this product from light. Store in the closed original container in a dry, cool, well-ventilated area out of direct sunlight.

Incompatibilities: strong acids, strong bases, strong oxidising agents.

Fire Decomposition: Combustion forms carbon dioxide, and if incomplete, carbon monoxide and smoke. Water is also formed. Carbon monoxide poisoning produces headache, weakness, nausea, dizziness, confusion, dimness of vision, disturbance of judgment, and unconsciousness followed by coma and death.

Polymerisation: This product will not undergo polymerisation reactions.

Section 11 - Toxicological Information

Local Effects:

Target Organs: There is no data to hand indicating any particular target organs.

This product has low toxicity by the dermal route.

Acute Dermal LD_{50} (rabbit) > 2000 mg/kg (calculated from S-Methoprene). Other ingredients in the formulation may cause an allergic disorder with repeated exposure.

No data available on this formulation. In studies with laboratory animals, S-methoprene Technical did not cause teratogenicity, reproductive toxicity or carcinogenicity.

Classification of Hazardous Ingredients

Ingredient Risk Phrases

No ingredient mentioned in the HSIS Database is present in this product at hazardous concentrations.

Potential Health Effects

Inhalation:
Short Term Exposure: Available data indicates that this product is not harmful. In addition product is unlikely to cause any discomfort or irritation.
Long Term Exposure: No data for health effects associated with long term inhalation.

Skin Contact:
Short Term Exposure: Available data indicates that this product is not harmful. It should present no hazards in normal use. However product may be mildly irritating, but is unlikely to cause anything more than mild discomfort which should disappear once contact ceases.
Long Term Exposure: No data for health effects associated with long term skin exposure.

Eye Contact:
Short Term Exposure: This product may be irritating to eyes, but is unlikely to cause anything more than mild transient discomfort.
Long Term Exposure: No data for health effects associated with long term eye exposure.

Ingestion:
Short Term Exposure: Significant oral exposure is considered to be unlikely. However, this product may be irritating to mucous membranes but is unlikely to cause anything more than transient discomfort.
Long Term Exposure: No data for health effects associated with long term ingestion.

Carcinogen Status:
SWA: No significant ingredient is classified as carcinogenic by SWA.
NTP: No significant ingredient is classified as carcinogenic by NTP.
IARC: No significant ingredient is classified as carcinogenic by IARC.

Section 12 - Ecological Information

Insufficient data to be sure of status.

Environmental Properties: No data is available on this product. Toxicity data is on the active constituent, (S)-Methoprene, has a half-life in soil of approximately 10 days which varies with soil type.
The hydrolysis half-life > 4 weeks. Photolysis half-life is < 10 hours. Water solubility is < 2 mg/L.
Environmental Toxicology: With LC_{50} values of > 370 mg/L to 760 µg/L, (S)-methoprene is considered toxic to fish. [Note: Acute fish toxicity would not be expected during control programmes as the concentration of methoprene in water at any one time is unlikely to exceed 0.002 mg/L.]. (S)-methoprene has low toxicity to birds and is practically non-toxic to adult bees, but bee larvae are sensitive.

Section 13 - Disposal Considerations

Disposal: Special help is available for the disposal of Agricultural Chemicals. The product label will give general advice regarding disposal of small quantities, and how to cleanse containers. However, for help with the collection of unwanted rural chemicals, contact ChemClear 1800 008 182 http://www.chemclear.com.au/ and for help with the disposal of empty drums, contact DrumMuster http://www.drummuster.com.au/ where you will find contact details for your area.

Section 14 - Transport Information

UN Number: This product is not classified as a Dangerous Good by ADG, IATA or IMDG/IMSBC criteria. No special transport conditions are necessary unless required by other regulations.

Section 15 - Regulatory Information

AICS: All of the significant ingredients in this formulation are compliant with NICNAS regulations.

Section 16 - Other Information

This SDS contains only safety-related information. For other data see product literature.

Acronyms:

ADG Code	Australian Code for the Transport of Dangerous Goods by Road and Rail (7th edition)
AICS	Australian Inventory of Chemical Substances
SWA	Safe Work Australia, formerly ASCC and NOHSC
CAS number	Chemical Abstracts Service Registry Number
Hazchem Code	Emergency action code of numbers and letters that provide information to emergency services especially firefighters

IARC	International Agency for Research on Cancer
NOS	Not otherwise specified
NTP	National Toxicology Program (USA)
R-Phrase	Risk Phrase
SUSMP	Standard for the Uniform Scheduling of Medicines & Poisons
UN Number	United Nations Number

THIS SDS SUMMARISES OUR BEST KNOWLEDGE OF THE HEALTH AND SAFETY HAZARD INFORMATION OF THE PRODUCT AND HOW TO SAFELY HANDLE AND USE THE PRODUCT IN THE WORKPLACE. EACH USER MUST REVIEW THIS SDS IN THE CONTEXT OF HOW THE PRODUCT WILL BE HANDLED AND USED IN THE WORKPLACE.

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OUR RESPONSIBILITY FOR PRODUCTS SOLD IS SUBJECT TO OUR STANDARD TERMS AND CONDITIONS, A COPY OF WHICH IS SENT TO OUR CUSTOMERS AND IS ALSO AVAILABLE ON REQUEST.

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This SDS is prepared in accord with the SWA document “Preparation of Safety Data Sheets for Hazardous Chemicals - Code of Practice” (December 2011)

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http://www.kilford.com.au/ Phone (02)9251 4532

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

VectoBac® G

BIOLOGICAL LARVICIDE

ACTIVE CONSTITUENT: *Bacillus thuringiensis*, subsp *israelensis*, Strain H-14 (mfg, by Abbott Laboratories in North Chicago) active solids and solubles

GROUP **11B** INSECTICIDE

A Granule for the Control of Saltmarsh Mosquito Larvae as per Directions for Use table.

VectoBac G contains spores and endotoxins of a naturally occurring bacterium. The spores and endotoxins are concentrated by filter feeding mosquito larvae. Fourth instar larvae and pupae will not be controlled by VectoBac G.

VectoBac G is toxic only to the larvae of certain diptera. It does not harm other aquatic, marine or terrestrial fauna.

GENERAL INSTRUCTIONS:
INSECTICIDE RESISTANCE WARNING

GROUP **11B** INSECTICIDE

For insecticide resistance management VectoBac G is a Group 11B insecticide.

Some naturally occurring insect biotypes resistant to VectoBac G and other Group 11B insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if VectoBac G or other Group 11B insecticides are used repeatedly. The effectiveness of VectoBac G on resistant individuals could be significantly reduced.

Since occurrence of resistant individuals is difficult to detect prior to use, Valent BioSciences and Sumitomo Chemical Australia accepts no liability for any losses that may result from the failure of VectoBac G to control resistant insects.

VectoBac G may be subject to specific resistant management strategies. For further information contact your local supplier, Sumitomo representative or local agricultural department agronomist.

APPLICATION:
Apply to properly calibrated aircraft or ground application equipment to ensure even coverage of all pools containing mosquito larvae. The large size of the granules assists in determining the coverage achieved.

PROTECTION OF CROPS, NATIVE AND OTHER NON-TARGET PLANTS:
The empty containers must not be re-used for any other purpose.

STORAGE AND DISPOSAL:
Keep out of reach of children. Store in the original container, tightly closed in a safe well-ventilated area as cool as possible. DO NOT expose to extremes of temperature or to direct sunlight.

Single rinse before disposal. Add rinsings to spray tanks. DO NOT dispose of undiluted chemicals on site. Puncture and bury empty containers in a local authority landfill. If no landfill is available, bury the containers below 500 mm in a disposal pit specifically marked and set up for this purpose clear of waterways, desirable vegetation and tree roots. Empty containers and product should not be burnt.

SAFETY DIRECTIONS:
DO NOT touch or rub eyes, nose or mouth with hand when handling granules. May irritate the eyes. Avoid contact with eyes, skin and open wounds. Avoid inhaling dust. After use and before eating, drinking or smoking, wash hands, arms and face thoroughly with soap and water.

FIRST AID:
If poisoning occurs, contact a doctor or Poisons Information Centre (phone: 13 11 26).

MATERIAL SAFETY DATA SHEET:
Additional information is listed in the Material Safety Data Sheet.

EXCLUSION OF LIABILITY
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DIRECTIONS FOR USE

Not for use in water used for aquaculture

SITUATION	PESTS	STATE	RATE	CRITICAL COMMENT
Salt marshes and tidal waters	Salt marsh mosquito larvae *Aedes vigilax*	All states	7.0 kg/ha	Use on third instar or younger larvae only.

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION

Appendix E

Risk assessment framework



GUIDELINES FOR MOSQUITO RISK ASSESSMENT AND MANAGEMENT IN CONSTRUCTED WETLANDS

A Risk Assessment Tool and Management Guidelines for Councils in the Sydney West Region of NSW

November 2012

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Abbreviations

ABS	Australian Bureau of Statistics
BFV	Barmah Forest virus
EVS	Encephalitis Virus Surveillance
HOIST	Health Outcomes Information Statistical Toolkit
LGA	Local Government Area
NDD	Notifiable Diseases Database
NSW	New South Wales
PHU	Public Health Unit
RRV	Ross River virus
SWAHS	Sydney West Area Health Service

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1. Introduction

Mosquitoes and mosquito-borne disease are a concern for local authorities in Australia and are well known to cause considerable nuisance to the community, affecting both lifestyle and amenity. Most importantly, mosquitoes have the potential to spread disease-causing pathogens such as Ross River virus (RRV) and Barmah Forest virus (BFV). The human illness caused by these viruses causes pain, annoyance and economic loss to the community.

Mosquitoes are found in a wide range of habitats. There are over 60 different species found in Western Sydney with each species exhibiting a close association with a specific habitats. Of greatest concern are those that are found inhabiting permanent and/or semi-permanent bodies of water, whether they are formed naturally or artificially created. An increasingly common habitat where mosquitoes may be found are constructed wetlands.

Constructed wetlands are of concern as they are increasingly being incorporated into urban development designs for the management of stormwater, wastewater, water storage, wildlife habitat and for public amenity. Exposure to wildlife is important as mosquitoes generally only become infected with viruses after biting an infected animal, typically native animals such as macropods, birds or bats. Being located within urban environments, there are greater opportunities for encounters between humans, mosquitoes and local wildlife to occur around constructed wetlands. In addition, the expected increase in the population in Western Sydney will see urban environments encroach on existing mosquito breeding sites and an influx of people who have naïve immunity to the mosquito-borne viruses.

Mosquitoes are a natural part of aquatic ecosystems and it should be expected that at least some mosquito activity will be experienced during the warmer months of the year. However, if poorly designed and/or neglected, constructed wetlands and the mosquitoes they produce may impact on the lifestyles and health of nearby residents. It is therefore important that constructed wetlands are assessed and monitored to ensure that they do not contribute to increased populations of mosquitoes. Proper assessment and monitoring can be conducted by performing risk assessments to identify factors that promote the growth of mosquito populations and that facilitate encounters between humans and mosquitoes.

Purpose of risk assessment framework

The purpose of this document is to provide assistance to local governments with assessing whether a constructed wetland has the potential for increasing local mosquito populations, endangering the health and enjoyment of local residents by increasing public health risks, and the appropriate actions for minimising mosquito risk associated with constructed wetlands.

Applying the framework will help Councils identify the risks for mosquito population growth and implement measures for the control of nuisance biting to minimise the impact on the community from mosquitoes.

Although these guidelines were prepared for risk assessment of artificial or constructed wetlands, they could also apply for rehabilitation projects for natural and/or degraded wetlands that pose potential risks for local residents and visitors.

2. Background

2.1 Mosquito biology

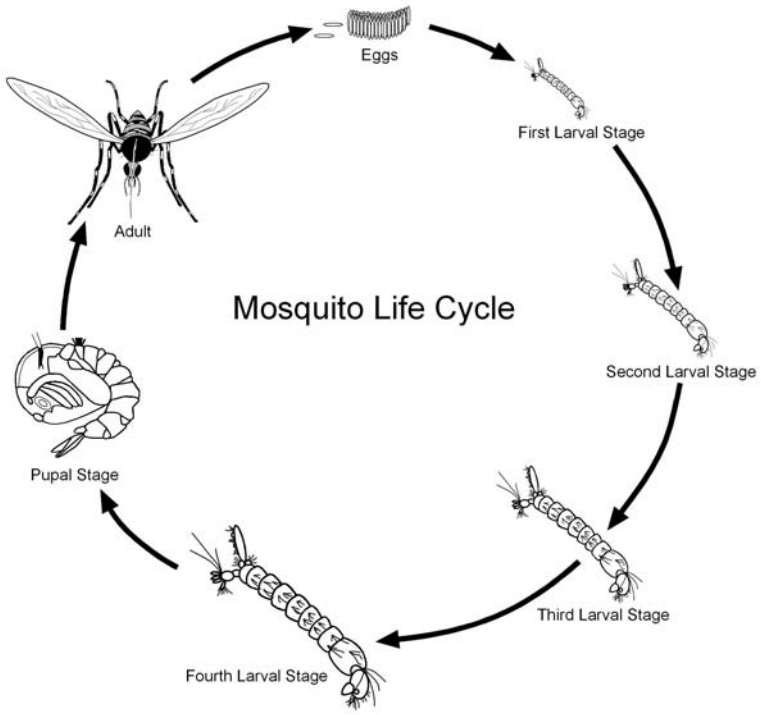


Figure 1. The typical life cycle of mosquitoes in Western Sydney (Source: http://extension.entm.purdue.edu/publichealth/resources.html)

Mosquitoes are small flying insects that belong to the family Culicidae (Diptera), of which more than 300 species have been recognised in Australia. The life cycle of mosquitoes is relatively short and consists of four distinct stages: eggs, four aquatic larval stages (instars), an aquatic pupal stage and a terrestrial adult stage (Fig 1).

The mosquito life cycle is highly dependent on water. While some mosquito eggs (usually those laid by *Aedes* or *Verrallina* species) can be desiccation resistant, most eggs (particularly those laid by *Culex* and *Anopheles* species) will hatch within 2-3 days. On hatching, the young larvae (commonly called wrigglers) feed continuously on aquatic particulate matter and grow through four different instars or moults. The larvae of some mosquito species have developed specialised mouthparts and are predatory, feeding on other mosquito larvae and aquatic invertebrates. The final larval stage (4th instar) develops into a pupa (commonly called a tumbler) from which the adult mosquito emerges approximately 2 days later. The length of larval development is dependent on water temperature (and thus is usually shorter during the warmer months of the year) and the availability of food, but generally is about one to two weeks from the hatching of eggs to the emergence of adults.

On average, a female mosquito may live approximately 2-3 weeks but the male's lifespan is much shorter. Adult mosquitos are most active from dusk until dawn, seeking refuge during the day in cool and humid habitats such as well-vegetated areas or under houses. Many mosquitoes do not travel far from breeding habitats. However, there are some species that can fly up to and beyond five kilometres, and a few species will disperse up to 50 kilometres downwind from the larval habitats.

Within their lifetime, both adult male and female mosquitoes will feed on nectars and other plant sugars, to provide an energy resource, but it is only the female that will seek a blood meal. The blood meal is required to provide protein for egg development. While many mosquitoes are generalist feeders, some specialise in feeding on humans, mammals, birds or amphibians. The 'host seeking' behaviour of female mosquitoes is driven by a combination of different stimuli including carbon dioxide, body odours, and body heat/humidity. Upon locating a suitable host, the female will probe the skin for a blood capillary then inject a small amount of saliva containing chemicals that prevent the blood from clotting. This is often the pathway for potential pathogens such as viruses to enter a host. After engorging on the host's blood the female will find a resting place to digest her meal and develop eggs before flying off to deposit them in a suitable habitat. On average, most mosquitoes will lay up to 3 batches of eggs in their lifetime.

2.2 Mosquitoes of Western Sydney

There are over 60 different mosquito species recorded from Western Sydney. They are a natural part of the Australian environment and it is important to note that mosquitoes play a crucial role in wetland habitats and are an integral part of the food chain for a number of animals. The majority of these mosquitoes pose no serious risk to humans from either nuisance-biting or the transmission of disease-causing pathogens. Some of these species do not bite humans or are only found in very small populations.

Not all mosquitoes found in Western Sydney will be directly associated with constructed wetlands. Some of the key pest species may be associated with estuarine (e.g. saltmarsh) or brackish water (e.g. *Melaleuca* and *Casuarina* forests) wetlands associated with the Hawkesbury River. Some species will be directly associated with ephemeral ground pools within forest or grassland habitats. Some species are found in close association with water-holding containers. Each of these groups of mosquitoes may occasionally cause nuisance-biting problems around constructed wetland and neighboring residential areas and it is important that these pest impacts are disassociated with the wetland before any mosquito control strategies are implemented.

A summary of the most important mosquito species in Western Sydney is provided in Table 1. While there may be a number of different species associated with the habitats, the species of greatest concern, with regard to constructed freshwater wetlands, are *Coquillettidia linealis*, *Culex annulirostris*, *Culex quinquefasciatus* and *Mansonia uniformis*. The biology and ecology of these species varies so that the environmental drivers of mosquito abundance and specific habitat associations for each of these species will vary across Western Sydney.

Mosquitoes associated with non-wetland habitats (i.e. ephemeral ground pools and backyard habitats) may occasionally cause problems around constructed wetlands but not specifically produced from them. Nuisance-biting from these species may often trigger complaints to council.

There are also species that may be associated with stormwater structures constructed in association with the wetlands. Mosquitoes including *Cx. quinquefasciatus* and *Culex molestus* are two species that are known to be associated with highly polluted habitats and/or subterranean habitats (e.g. septic tanks, stormwater drains).

Table 1. Summary of habitat associations and potential public health risks of common mosquitoes of Western Sydney

Mosquito species	Habitat associations	Public health risks
Aedes alternans	Generally found in estuarine habitats but can also be found in freshwater habitats. Larvae are predatory and feed on other mosquito larvae.	Potential nuisance-biting pest but is not considered an important vector of RRV or BFV.
Aedes notoscriptus	Small water holding containers around dwellings such as tins, pots, ornamental ponds, roof guttering, bird baths, as well as water holding plants (eg. bromeliads) and tree holes. Does not travel far from larval habitats.	Severe nuisance-biting pest and vector of RRV and BFV. This is the most important pest mosquito in residential areas of Western Sydney.
Aedes procax	Freshwater and mildly brackish flooded habitats in *Melaleuca* forests. Does not travel far from larval habitats.	Will bite humans but is generally not considered a serious nuisance-biting pest. May play an important role in RRV and BFV transmission.
Aedes vigilax	Generally estuarine habitats but also other saline and brackish water habitats such as flooded sedgelands and coastal swamp forests. Travels many kilometres from larval habitats.	Severe nuisance biting pest and vector of RRV and BFV. One of the most important pest species in coastal NSW.
Coquillettidia linealis	Close association with well vegetated freshwater wetlands. Immature stages have a direct reliance on aquatic macrophytes.	Nuisance-biting pest and may play a role in transmission of RRV and BFV
Culex annulirostris	Close association with well vegetated freshwater wetlands, grassy ephemeral pools and, occasionally polluted urban habitats.	Nuisance biting pest and vector of RRV and BFV. One of the most important pest species across inland NSW.
Culex australicus	Close association with well vegetated freshwater wetlands, grassy ephemeral pools and, occasionally polluted urban habitats.	Not considered a pest species as it prefers to bite birds. However, this species often indicates suitable conditions for *Cx. annulirostris*.
Culex molestus	Associated with subterranean habitats. Most commonly found in Western Sydney where disused septic tanks are found	Nuisance-biting pest but status as vector on RRV and BFV in urban habitats unknown.
Culex quinquefasciatus	Ground pools or artificial structures containing highly organic water such as drains, sullage pits and septic tanks.	Will bite humans but generally not considered a significant nuisance-biting pest. May play a role in the transmission of RRV and BFV.
Culex sitiens	Permanently inundated saline to brackish habitats, including saltmarsh and mangroves.	Is not considered a nuisance-biting pest as it prefers to bite birds and is not considered an important vector of disease.
Mansonia uniformis	Close association with well vegetated freshwater wetlands. Immature stages have a direct reliance on aquatic macrophytes.	Nuisance-biting pest and may play a role in transmission of RRV and BFV

2.2 Factors contributing to the impact of mosquitoes on residential areas

Several factors are known to influence the abundance of mosquitoes associated with constructed wetlands and their potential to impact nearby residential areas.

2.2.1 Meteorological conditions

Temperature

Like most insects, the abundance and activity of mosquitoes is primarily determined by temperature. For this reason, mosquitoes are generally only active in Western Sydney between the months of November and April. Although some species of mosquitoes may be active during the cooler months, temperatures are generally too cool for most pest species. Most adult mosquitoes stop feeding when ambient temperatures fall below 10°C, and temperatures below 10°C or above 35°C will reduce the survival rate of mosquitoes. High temperatures, however, have the effect of warming water or substrate in breeding sites, resulting in shorter mosquito development phases. It is also important to note that much stronger correlations exist between daily minimum temperatures and mosquito abundance than average daily temperatures or maximum daily temperatures. This result means that although there are occasionally periods of hot weather during Spring, minimum temperatures generally remain low and substantial increases in pest mosquitoes during this period are highly unusual.

Rainfall

Along with temperature, rainfall has the most significant impact on mosquito populations in Western Sydney. However, the impact of rainfall on local mosquito populations will vary with both the quantity and temporal distribution of rainfall. Persistent and high rainfall helps maintain permanent mosquito breeding sites as well as creating extensive breeding sites in low lying areas. Rainfall runoff into parklands and other low lying areas during periods of high rainfall enhance conditions for some species. Heavy rains, however, can also flush mosquito larvae from breeding sites and assist in the introduction of fish into constructed wetlands, creating unsuitable conditions for local mosquitoes. There is a suite of mosquitoes closely associated with highly ephemeral rain filled pools in woodland and forest areas and studies have shown that these species can complete their development in less than a week.

Humidity

Influenced by both rainfall and temperature, humidity is an important factor in increasing the survivorship of adult mosquitoes. The longer adult mosquitoes live, the more eggs they can lay and the greater likelihood that they may transmit disease-causing pathogens.

Wind

Mosquitoes are small, flying insects and their flight activity are affected by strong winds, reducing the chance of biting instances. However, strong winds may carry large numbers of mosquitoes from a breeding site to populated residential areas that are normally outside the mosquito’s flight range.

2.2.2 Urban design

Buffer zones

Buffer zones between urban developments and mosquito habitats are often raised as a possible strategy to assist in minimising the impact of nuisance-biting. However, there are no quantitative studies in NSW indicating the appropriate size or vegetation composition of effective buffers. Guidelines developed for buffer distances to preventing biting insect problems associated with estuarine mosquito species range from 50m to over 1km. However, effective

buffer zone distances will be site specific and must be based on the abundance of locally important pest species.

For developments close to constructed freshwater wetlands, given that key pest species such as *Cx. annulirostris* and *Cq. linealis* are known to disperse many kilometers from larval habitats and buffer zones alone are not practical as a management option. However, buffer zones may be considered appropriate to reduce harbourage sites for pest mosquitoes if they can be maintained as clear or sparsely vegetated zones, so as to not provide a corridor for adult mosquitoes moving between the larval habitat and the human population.

Development layout

Where constructed wetlands are planned to be incorporated into new residential developments, consideration should be given to the layout of the development. The proximity of residential allotments may predispose the community to relatively higher pest mosquito impacts. Where possible, open areas of sparse vegetation between either the wetland or any dense stands of terrestrial vegetation should be incorporated into the site design. The use of playing fields, bike trails and jogging tracks can be used as buffers between residential allotments and mosquito habitats.

Residential areas that are located downwind of dominant prevailing winds from a mosquito breeding site will be affected by nuisance biting and be at risk from mosquito-borne diseases. It is, however, important to note that when mosquito populations are high, many mosquitoes will move upwind and cause pest impacts.

Terrestrial vegetation

Vegetation corridors between mosquito breeding sites and residential areas provide harbourage sites for mosquitoes and acts as a dispersal route for mosquitoes to the populated areas. Minimising dense vegetation close to residential areas, particularly immediately surrounding buildings, will reduce the density of mosquitoes in close proximity to residents. As well as contributing to favourable habitat conditions that assist increased longevity of mosquitoes (and consequently increasing the risk of disease transmission), these harbourage sites can act as “stepping stones” (a number of clumps are close together) or “bridges (a continuous corridor of vegetation) that facilitate the movement of mosquitoes into residential areas.

It should also be noted that in new residential developments where street trees and vegetation within residential allotments may be minimal or non-existent, stands of dense terrestrial vegetation around constructed wetlands (particularly fast and dense growing *Casuraina* spp.) can act as local harbourage sites, not only of mosquitoes produced from local wetlands but also of mosquitoes produced in water-holding containers within residential allotments and nearby bushland habitats.

2.2.3 Climate change

It is now widely accepted that climate change is occurring with changes to meteorological conditions predicted to potentially influence mosquito populations and the risk of mosquito-borne disease internationally. In Western Sydney, changes in temperature and seasonal rainfall will influence both mosquito populations and local wildlife but it is difficult to predict the subsequent impact on local mosquito-borne disease risk. While it has been predicted that mosquito populations will increase, there are many non-climatic factors that may also influence local mosquito-borne disease risk. It is often stated that the geographical range of mosquito species (e.g. the dengue mosquito, *Aedes aegypti*) will expand and, therefore, increase the risk of human disease, there is little evidence that such dramatic changes in the geographic distribution of

mosquitoes will occur. The most likely impact of a changing climate may be a shift in the periods of peak mosquito activity and possibly an extension of the typical Western Sydney mosquito season.

2.3 Risks to public health

Notwithstanding the impacts of nuisance-biting, mosquitoes are known to transmit a number of disease causing viruses and parasites to humans. Most notably, diseases such as malaria, dengue and yellow fever internationally. In the Australian region, arboviruses (viruses transmitted by arthropods) that have the most potential for causing severe disease include Murray Valley encephalitis virus, Japanese encephalitis virus and Dengue viruses.

Although causing less severe and non-fatal disease, RRV and BFV are the most widespread arboviruses in Australia [1-4]. There are approximately 5,000 cases of human disease caused by these viruses officially recorded across Australia each year. However, it has long been considered that there are far greater numbers of infections each year with those suffering only mild symptoms unlikely to be diagnosed.

2.3.1 Ross River virus

Ross River virus (RRV) causes the most common mosquito-borne viral disease in Australia, costing the Australian economy between A$2.7 and A$5.6 million per year, mainly due to lost earnings [1]. In Australia, there are approximately 4,300 cases reported each year with NSW reporting approximately 740 cases annually [5].

Symptoms of RRV disease vary greatly between infected individuals, ranging from showing no symptoms to the characteristic syndrome involving a rash, fever, swollen and or painful joints, arthritis, muscle aches, tiredness and headaches. The duration of symptoms can also vary, which can range from several months to several years in rare cases. Notifications of RRV infections usually peak from late summer to early autumn (Fig 2). There is no specific treatment for RRV disease.

RRV is endemic in the majority of rural areas where habitats for large mosquito populations exist in close proximity to abundant populations of reservoir hosts, mainly kangaroos and wallabies. Outbreaks of RRV in metropolitan areas are generally uncommon, even when large populations of mosquitoes are present. However, several outbreaks of RRV have been reported in major metropolitan areas across Australia, suggesting other vertebrate hosts, such as horses and possums, could serve as a reservoir for outbreaks in urban environments.

2.3.2 Barmah Forest virus

Barmah Forest virus (BFV) is less common that RRV and causes a disease that is difficult to distinguish from RRV. BFV has only been found in Australia, with approximately 1,100 cases reported annually [5]. In NSW, there are approximately 450 case reported each year.

Symptoms of BFV disease, like RRV, varies between infected individuals and may include a rash, fever, swollen and or painful joints, arthritis, muscle aches, tiredness and headaches. Duration is usually shorter than RRV disease and there is no specific treatment for BFV disease.

BFV was first isolated from Barmah Forest in northern Victoria in 1974 but is widespread across Australia with higher rates of infection along coastal regions in NSW. The transmission cycle for BFV is not well understood and the reservoir host for BFV remains to be elucidated. Similar to RRV, BFV notifications peak in late summer, early autumn and is also influenced by climatic conditions, such as increased rainfall and high temperatures that result in higher mosquito populations.

2.6 Nuisance biting

Biting mosquitoes can have a negative impact on community well being and lifestyles. Economically, mosquitoes reduce real estate values, adversely affect tourism and related business interests, or negatively impact livestock or poultry production. Furthermore, sever morbidity as a result of infection with a mosquito-borne virus can negatively impact on the economy through lost productivity and high costs of medical treatment.

2.4 Mosquito-borne Disease Risk in Western Sydney

2.4.1 Human notifications in the Western Sydney

The first reported outbreak of RRV in western Sydney occurred in 1997, where 69 cases were investigated, identifying most were locally acquired in a semi-rural setting [6]. Another smaller cluster of cases was identified in 1999, although unlike the previous outbreak, these cases were believed to have been acquired in an urban setting [7].

Since 2000, there have been on average 30 notifications of RRV and BFV among residents in SWAHS each year. The number of cases fluctuate from year to year, which has ranged from a high of 81 cases reported in 2001 to only 4 cases in 2002 (Fig 2). Most notifications had onset of symptoms during late summer and early autumn.

2.4.2 Demographics

Since 2000, the majority of cases of RRV and BFV were aged 20 to 60 years, with a median age of 40 years (Fig 3). Both males and females are equally affected, although the slightly higher number of males in the adult age groups may reflect behaviours that increase their risk of exposure to mosquitoes and disease.

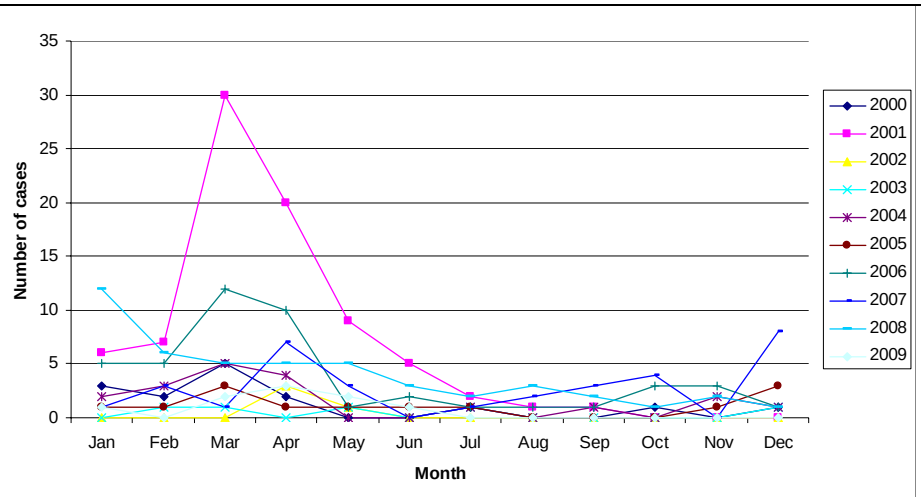


Figure 2. RRV and BFV notifications in Western Sydney LHD by onset dates

(Source: HOIST)

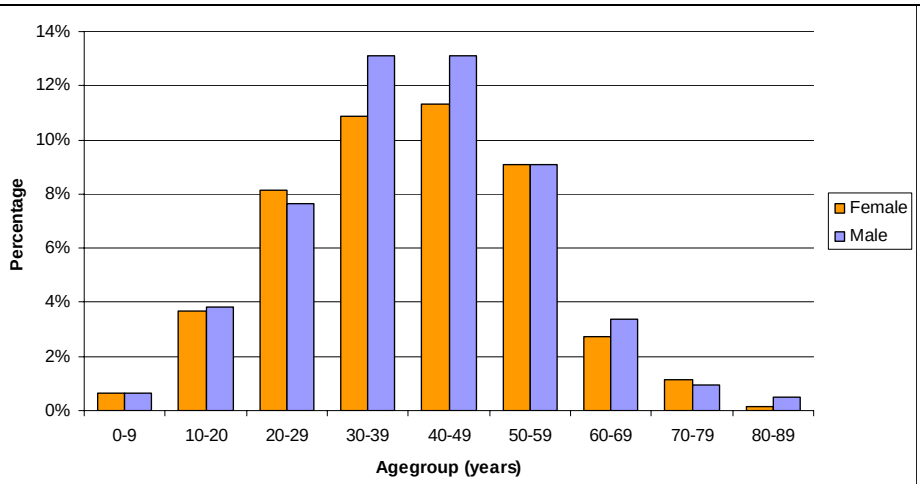


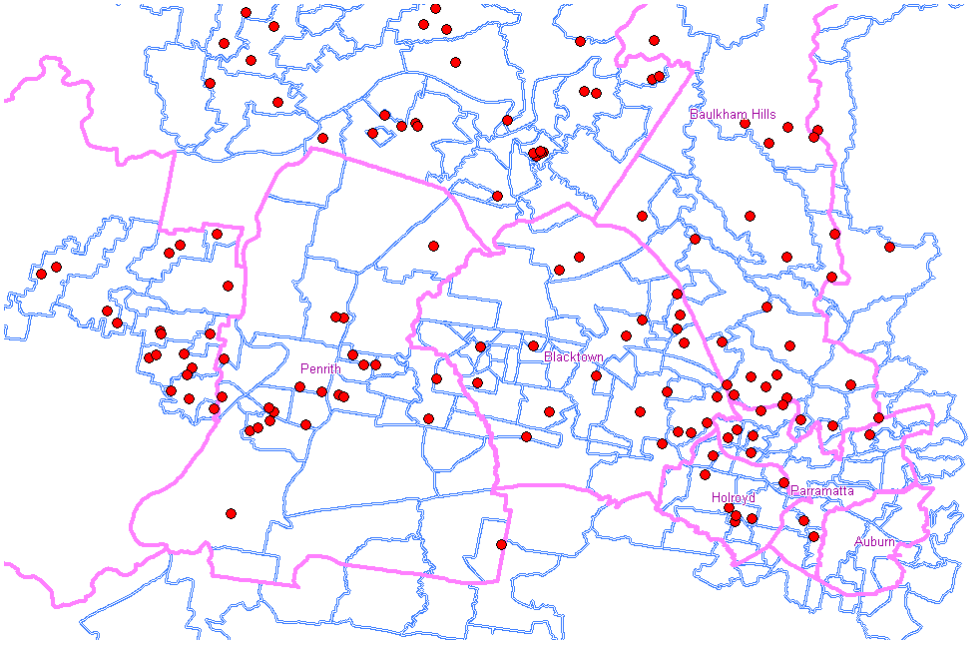
Figure 3. RRV and BFV notifications in Western Sydney LHD by age and sex. (Source: HOIST)

2.4.3 Geographical location

The geographical locations of the residences for all notified cases of human disease cased by RRV and BFV since 2000 were geo-coded on the map for WSLHD (previously SWAHS) (Fig 4). Although not shown in the map, investigations by the Public Health Unit of the reported cases revealed that they had acquired the infection outside of the metropolitan areas, and from areas that are known to have high rates of transmission of RRV and BFV. However, for cases who most likely acquired the infection locally, the location of their residence fail to show an indication of where the infection may have occurred and the mosquito species likely to have been involved in transmission.

It is one of the problems of interpreting human disease notification data based on residential address to determine local risk of mosquito-borne disease. Not only will there be individuals who have been infected after travel to areas of endemic activity, there may also be individuals who are infected during travel within the local area but not at their residential address. It should also be noted that, in rare instances, individuals with travel history to areas of endemic virus activity may also have become infected locally.

In assessing the spatial distribution of risk areas in Western Sydney, it is important that a combination of human notification data as well as data on local mosquito populations, actual and potential mosquito habitats and local knowledge on potential wildlife reservoirs for RRV and BFV be taken into account.



Red dots represent the residence of human cases of RRV and BFV in SWAHS between 2003 and 2009. It is important to note that the locations do not always indicate where the disease was acquired. (Source: HOIST)

Figure 4. Map of notified human cases of human disease caused by RRV and BFV by Local Government Areas in Western Sydney LHD.

2.5 Constructed wetlands

Constructed wetlands are increasingly being incorporated into urban development designs to act as biofilters, reduce nutrients, organic material, suspended solids, litter, heavy metals and pathogens in stormwater or wastewater runoff before flowing into a natural waterway (Fig 5). In addition to these environmental benefits, they function as wildlife habitats, provide passive recreational and landscape value for local residents, and act as a means of flood control.

While constructed wetlands fulfill an important ecological role in improving water quality and providing a habitat for a variety of fauna and flora, if poorly designed and maintained, they have the potential to be much more productive breeding sites for mosquitoes compared to natural wetlands due to the high level of nutrients from urban runoff.

Constructed freshwater wetlands may range from small, simple linear wetlands to large complex multi-component systems. Mosquito management in these systems, whether large or small, is often constrained by the essential requirements of the wetlands to meet specific purposes. Wetlands are typically located close to urban areas, contain (or at least receive) polluted water, include large areas of shallow, slow moving water and thick vegetation and have gently sloping banks. To meet these requirements, site-specific compromises must be implemented into the design, construction and maintenance of the wetland.

Constructed wetlands also attract animals, some of which may act as reservoirs of various arboviruses, such as wallabies which are hosts for RRV. Environments where there is potential for encounters between animal reservoirs and mosquito vectors of arboviruses, particularly within flight range of residential areas, poses a high risk for populations in the nearby areas.

2.5.1 Population expansion in Western Sydney

Recent reports indicate that the number of houses being built in western Sydney has soared since the tripling of first home-owner grants for new constructions. In the year to June 2008, Blacktown, Parramatta and Baulkham Hills local government areas had the largest population increases of all LGAs in Sydney [8].

Furthermore, an additional 140,000 households are expected to be built by 2031 in the North West subregion, according to the NSW Government's Metropolitan Strategy [9]. With this expansion of urban environments onto existing mosquito breeding sites and the incorporation of constructed wetlands in water sensitive urban designs to manage stormwater runoff, there will be increased opportunities for contact between humans and mosquitoes. In addition, the movement of immunologically naïve populations into areas where RRV and BFV have been suspected to circulate could potentially increase rates of notifications of these arboviral diseases in the community.

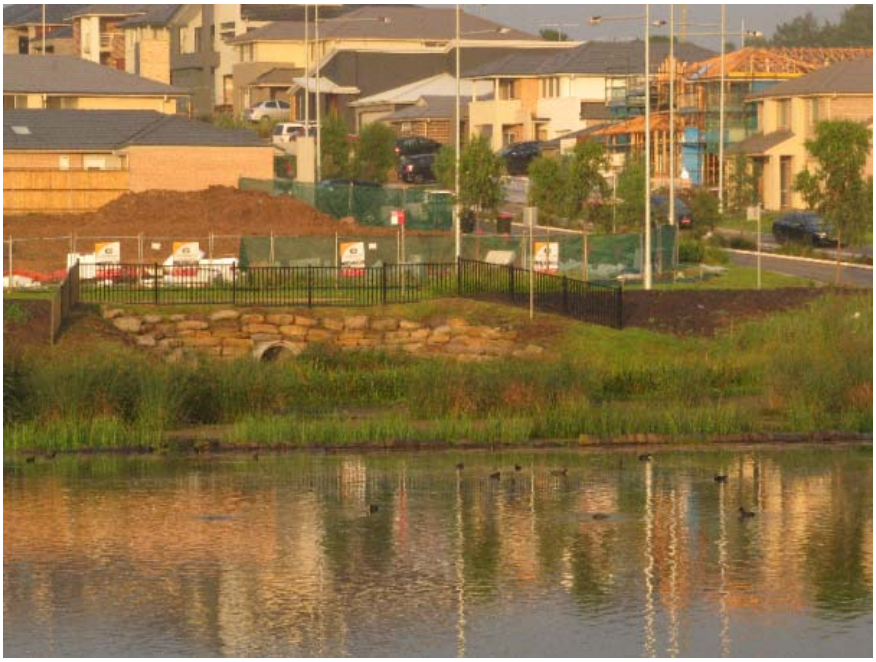


Figure 5. An example of constructed wetland associated with new residential developments in Western Sydney.

3. Risk assessment process

The purpose of conducting mosquito management is to protect the health and well being of the community by reducing the risk of mosquito-borne diseases and reducing the nuisance caused by biting mosquitoes. An assessment of risks to the community should be conducted for any mosquito management program.

The risk assessment guidelines in this document follow the Australian/New Zealand Standard for Risk Management 4360:2004, providing a framework to consider risk in a disciplined approach. The risk assessment and management follows these basic steps:

1. Identify risks (mosquito habitat potential, mosquito-borne disease, nuisance biting)
2. Analyse risks (as a product of hazard and the likelihood of exposure)
3. Evaluate risks (what risks are important)
4. Control risks
5. Evaluate control effectiveness

Step 1 – Identify risks

Assessment and identification of the risk of mosquitoes to the community is to be conducted by a two stage process. The first stage is to assess the potential of a constructed water body for mosquito production by identifying elements that are known to be a factor in supporting mosquito populations. Such factors include the design of constructed water bodies and characteristics of the water. An assessment tool, based on the framework developed by the Midge Research Group of Western Australia and has been modified for use in Western Sydney (Table 2). The second stage is to assess the likelihood for mosquitoes to impact on the health and quality of life of the community and includes factors such as notifications of mosquito-borne disease, nuisance biting complaints from the public and adult mosquito population densities. The risk assessment tool is presented in Table 3.

Step 2 – Analyse risks

From the level of risk for mosquito breeding potential of constructed water bodies (Table 4) and the likelihood of the community being exposed to nuisance biting and mosquito-borne disease (Table 5) it is possible to calculate the level of mosquito risk level using the assessment matrix (Table 6)

Step 3 – Evaluate risks

This stage of the risk assessment process determines whether the mosquito risk level is acceptable or unacceptable for protecting the health and welfare of the community. A risk level that is determined as acceptable should be monitored and periodically reviewed to ensure it remains acceptable. A risk level deemed unacceptable (e.g. High risk) should be managed appropriately.

Step 4 – Control risks

Mosquito management should focus on reducing the mosquito breeding potential of constructed water bodies and reducing the likelihood of mosquitoes coming into contact with humans. Mosquito control measures will need to consider political, social, economical and technical factors. These are discussed in detail in Section 5.

Step 5 – Evaluate control effectiveness

Mosquito control measures should be evaluated for effectiveness in reducing mosquito breeding potential and in minimising human contact by mosquitoes. This could involve trappings for adult mosquitoes, surveys of larval abundance, count and frequency of public complaints and notifications of mosquito-borne diseases.

4. Risk assessment framework for constructed wetlands

4.1 Assessment of potential mosquito populations

A risk assessment should be conducted to determine the potential for mosquito breeding in constructed wetlands. Consideration should be given to wetland design and features of the water body that is conducive to supporting mosquito populations. There are many constraints and compromised required between the objectives of the constructed wetlands and mosquito production but these key design features can be used to assess mosquito risk [10, 11]. Most importantly, the risk assessment process should be undertaken during the planning phase and should not be delayed until after the wetland has already been constructed. A risk assessment tool for assessing mosquito breeding potential of a constructed water body is presented in Table 2.

4.1.1 Aquatic vegetation

Constructed wetlands incorporate semi-aquatic and aquatic vegetation to remove nutrients from stormwater and wastewater and to reduce the potential for algal blooms. However, semi-aquatic/aquatic vegetation have the potential to colonise extensive areas of the wetland, providing harbourage for mosquito larvae and restricting access for larval predators. the most important feature of the constructed freshwater wetlands is the macrophyte zone. This area of a wetland is typically shallow and as vegetation increases and/or accumulated debris or filamentous algal growth restrict water movement, suitable conditions for mosquito production may occur. As vegetation is often a crucial component of constructed wetlands, the incorporation of macrophyte zones can be designed to minimise mosquito populations by locating them in areas surrounded by deeper water or separating sections of dense vegetation by areas of deep water.

The growth form of aquatic macrophytes can vary greatly but both floating (Fig 6) and emergent (Fig 7) vegetation can provide habitat for mosquitoes. There is limited information available on the associations between specific vegetation types and the suitability for mosquito breeding. More structurally diverse stands of vegetation assist the minimisation of mosquito populations by promoting a greater diversity of macroinvertebrates. The plant species of greatest concern are the *Typha* spp. and *Phragmites* spp. that are prone to wetland invasion and exhibit rapid and dense growth. These species may “clog” wetland systems with both actively growing and fallen decaying material that creates refuge and provides enhanced nutrition for mosquito larvae.

Maintenance of aquatic macrophytes is a key factor ensuring that mosquito production from the wetland is minimized. Potential problems arise if regular maintenance is not conducted and if the capacity and funding to undertake routine harvesting of vegetation is not included in a wetland management plan.

4.1.2 Water body’s edge

Constructed wetlands should generally be steep sided (at least 1V:3H) to maximise the effect of wave action on the water body to disrupt mosquito larvae survival. The steep sides can limit the width of marginal macrophyte growth that may provide refuge for mosquito larvae. An alternative strategy, if the recommended bank steepness cannot be maintained for safety or other considerations, a vertical ‘lip’ between 100 - 300mm may be used at the water margin, allowing more gradual slopes above and below the vertical edge (Fig 8).

4.1.3 Water body shape

Simple water body designs allow for good water circulation, improving water quality, and limits areas where mosquito larvae can evade predators. Simple water body shapes also allow for wind exposure to produce surface wave action.

4.1.4 Wind related parameters

Increased wave action disrupts larval respiration and also inhibits the growth of algae and floating plants that provide protection. To maximise wave action, the water body should be orientated so that the long axis is parallel to known prevailing winds during spring and summer. The land adjacent to the water body should be relatively flat to allow for wind exposure.

4.1.5 Water body depth

Shallow vegetated wetlands provide a favoured habitat for mosquito larvae. Shallow water depths result in higher water temperatures which promotes faster mosquito development and the proliferation of emergent vegetation. Shallow aquatic macrophyte zones can provide habitats for mosquitoes but their design will vary from simple (Fig 9) to complex (Fig 10). Ideally, water depth should be between 60cm and 2m, to ensure that sufficient light penetrates the deeper levels for submerged plants and to minimise the chance of stratification. A balance is often required between water depth requirements for water treatment, vegetation growth, wildlife habitats and mosquito management. Often a variety of water depths can be incorporated into the design of the wetland and in complex system, infrastructure can be incorporated into the design of the wetland that allows for regulation of water levels during the season. If mosquito populations are increasing, particularly for a mosquito such as *Cx. annulirostris*, reducing water levels in macrophyte zones can flush immature stages back into deeper water zones where fish may be present. Alternatively, increasing water levels may assist fish accessing immature stages within the macrophyte zone.

4.1.6 Water hydrology

Water bodies that are seasonal are advantageous over permanent water bodies as mosquito breeding is halted once the water body dries out. However, it is important to note that a highly ephemeral wetland may provide habitat for “floodwater” mosquitoes (e.g. *Aedes alboannulatus*, *Aedes multiplex*, *Aedes procax*, *Aedes vittiger*) if rainwater filled ground pools persist for more than a week in summer. Additionally, wetlands are easier to access for maintenance when dry. However, when the water body is refilled, there may be an increase in mosquito development with the hatching of dessication-resistant eggs and algal growth after nutrient rich sediments are submerged with water. A component of a constructed wetland should permanently retain water throughout the year to provide a refuge for fish during the dry season.

4.1.7 Water circulation

Mechanical circulation of water bodies is preferred as aeration of the water minimises algal growth and supports survival of mosquito larvae predators, such as fish. Water circulation mechanisms such as fountains also provides surface disturbance which may reduce larval mosquito survival. However, it is important to note that there are few scientific studies that show that a fountain in the middle of a wetland or pond will significantly impact mosquito production. In some areas, sprinklers have been used to discourage oviposition of mosquitoes.

4.1.8 Stormwater structures

Stormwater structures (e.g. gross pollutant traps, infiltration systems, subterranean pipes) that retain water and are accessible to mosquitoes can provide habitat for mosquitoes including *Cx. quinquefasciatus* and, on occasion, *Cx. molestus* (Fig 11). An accumulation of organic pollution along with debris that creates refuge for both adult and immature mosquitoes. The production of mosquitoes can be avoided by ensuring the structures are self-draining or designed so that the siltation depth shallow enough to encourage evaporative drying.



Figure 6. Dense floating vegetation in a constructed wetland in Western Sydney



Figure 7. Emergent macrophyte zone in a constructed wetland in Western Sydney



Figure 8. Hard edge to wetland margin in a constructed wetland in Western Sydney

4.1.8 Water quality

Water quality is an important determinant in assessing mosquito breeding potential. Water quality should be of sufficient quality to minimise algal blooms, excessive vegetation growth and to support the survival of larvicidal predators. As water quality improves, as will the biological diversity of the wetland and increasing populations of fish and aquatic macroinvertebrates will assist in keeping mosquitoes to tolerable levels.

4.2 Assessment of potential public health risks

In addition to the risk assessment of constructed wetlands for mosquito breeding potential, a risk assessment should also be conducted to determine the likelihood for community residents to be exposed to nuisance mosquito biting and for the risk of transmission of mosquito-borne disease. It is important to record the pre-construction level of mosquito activity as any assessment of future mosquito production associated with a constructed wetland should be done with reference to existing habitats. A risk assessment tool for assessing the risk to community health and well being is presented in Table 3.

4.2.1 Adult mosquito monitoring

A survey of the adult mosquito population should be performed to provide an indication of the potential for nuisance biting and mosquito-borne disease to the community. An analysis of adult mosquito data can provide information on both the local pest and public health risks as well as an indication of local wetland mosquito production. As each mosquito species has species habitat associations, an assessment of the proportion of mosquito populations likely to have originated from the local wetlands (as opposed to nearby estuarine wetlands, bushland or backyard habitats) can be made. It is crucial to determine if mosquitoes responsible for local nuisance-biting impacts are likely to have been produced from the local wetland.

It is recommended that monitoring of adult mosquitoes use carbon dioxide (dry ice) baited Encephalitis Virus Surveillance (EVS) type traps and the trapped mosquitoes sent live to the Department of Medical Entomology, Westmead Hospital for identification. It is important to know which species are collected to determine whether they are potential vectors of disease, common nuisance biting pests or of no pest concern.

There is no predetermined trap collection that will determine pest impacts. The abundance of local mosquitoes should always be reviewed with reference to the local region. Mosquito abundances are relative terms used by the Department of Medical Entomology with a ‘low’ number regarded as less than 50 mosquitoes per trap night and ‘very high’ regarded as more than 1,000 mosquitoes per trap night.

It is crucial that sampling of mosquito populations be undertaken at a time when mosquitoes are most likely to be active. Undertaking mosquito surveys during the period from May until October will not provide a reliable measure of local mosquito populations in Western Sydney.

4.2.2 Larval mosquito monitoring

While it is possible to assess the likely diversity of mosquitoes produced from a constructed wetland by sampling adult mosquito populations, larval sampling will be the only way to confirm the presence of mosquitoes in the wetland. Most importantly, it will enable the identification of key “hot spots” of mosquito production that may assist vegetation management or mosquito control strategies.



Figure 9. Simple macrophyte zone associated with constructed wetland in Western Sydney



Figure 10. Complex macrophyte zones associated with constructed wetland in Western Sydney



Figure 11. Stormwater structure associated with constructed wetland in Western Sydney

4.2.3 Complaints from the public

Complaints from the public about nuisance biting can be a useful indicator of mosquito activity or for identify a new breeding site, but each complaint will need to be assessed as to their location relative to a known constructed wetland and the pest species identified. An overnight EVS trap could be used to identify the offending species and determine the likely source.

The number of complaints received will vary between locations and hence Councils should determine the specific number of complaints that equate to the level of concern and the different risk threshold levels.

It is important to note that the number of complaints to local authorities on mosquito numbers is not a reliable measure of local mosquito populations and is an inappropriate substitute to mosquito surveys.

4.2.4 Notification of local RRV and BFV infections

The number of reported cases of RRV and BFV provide a good indication of mosquito population density and arbovirus circulation. Not all infections result in the development of clinical symptoms or are of sufficient severity for the patient to seek medical assistance. Hence, reported cases are likely to be under-representative of the true number of infections in the community. Notification rates do not provide an indicator of local nuisance-biting impacts.

Information about disease notifications are collected by the WSLHD PHU, with each case investigated for the likely source of infection. Locally acquired cases of RRV and BFV are uncommon in urban environments in Western Sydney, and mainly occur in the semi-rural areas where mosquitoes are likely to encounter virus reservoir hosts.

As rates of infection with RRV and BFV vary between LGAs, the PHU will be able to specify the risk threshold that equates with disease notifications for a particular LGA.

Table 2. Assessment of mosquito breeding potential

Consideration	Risk threshold	Risk rating	Score
Wetland edge	• 80-100% of the water body has a hard vertical edge	1	
	• 50-80% of the water body has a hard vertical edge	2	
	• < 50% of the water body has a hard vertical edge	3	
Wetland shape	• Shape is simple • Facilitates good water circulation	1	
	• Shape is intricate and/or includes angles • Restricts water circulation	2	
Wetland aspect	• The long axis of the water body is in line with known prevailing wind direction or is of a circular nature	1	
	• The long axis of the water body is perpendicular to known prevailing wind direction	2	
Runoff	• Surrounding land is level with the water body preventing surface runoff entering and maximising potential wind action	1	
	• Constructed wetland is located in a depression so that surrounding land slopes down to the water's edge	2	
Water depth	• Seasonal water body which dries out	1	
	• Greater than 2m	2	
	• Between 60cm and 2m	4	
	• Between 30cm and 60cm	5	
	• Less than 30cm	6	
Hydrology	• Water level fluctuates • Water body dries out	1	
	• Water body does not dry out • Water level remains constant	2	
	• Water body does not dry out • Water level fluctuates	3	
Circulation	• Water body circulated every 24 hours or less	1	
	• Water body circulated every 24 hours or longer	2	
	• Minimal water body circulation	3	
Aquatic vegetation	• Small stands parallel to predominant wind direction • Measures to reduce vegetation colonization of remaining water body	1	
	• Small stands parallel to predominant wind direction	2	
	• Large dense stands randomly planted • Not restrained from colonising other parts of the water body	4	
	• No aquatic vegetation	4	
Water quality	• Minimal levels of nutrients	1	
	• Low levels of nutrients	3	
	• Medium levels of nutrients	5	
	• High levels of nutrients	7	
		Total	

Table 3. Level of risk for mosquito breeding potential

Risk potential	Total score	Description
Low	9 – 17	Minimal potential for sufficient mosquito numbers to create a nuisance or pose a health threat
Medium	18 – 24	Increased probability of supporting mosquito populations to create a nuisance and pose a health threat
High	25 - 32	Strong probability of supporting high numbers of mosquitoes to create a nuisance and pose a health threat

Table 4. Assessment of risk to the community health and well being

Consideration	Risk threshold	Risk rating	Score
Adult mosquito density	Low (<50 per trap)	1	
	Moderate (50 - 100 per trap)	3	
	High (101 - 1,000 per trap)	5	
	Very high (>1,000 per trap)	7	
	Extreme (>10,000 per trap)	9	
Complaints from the public	Low (e.g. < 4 per month)	1	
	Moderate (e.g. 4 - 9 per month)	3	
	High (e.g. >9 per month)	5	
Notification of locally acquired RRV and BFV infections in LGA*	Rare (e.g. <1 per month)	1	
	Low (e.g. 1 - 3 per month)	3	
	Moderate (e.g. 4 – 6 per month)	5	
	High (e.g. >7 per month)	7	
Location of water body to residential areas	Low (>10-15km)	1	
	Moderate (>5-10km)	3	
	High (>1-5km)	5	
	Very high (<1km)	7	
Terrestrial vegetation	• Buffer vegetation mainly planted downwind of the water body or surrounding entire water body • Clear open space between buffer vegetation and nearest residence	1	
	• Buffer vegetation mainly planted downwind of the water body • Vegetation grows right up to nearest residence (may act as a dispersal corridor)	2	
	• Vegetation randomly planted • Insufficient quantity to provide an effective buffer	3	
		Total	

Councils should identify specific numbers that equate with the risk threshold level

* The PHU will be able to determine the risk level for a particular LGA

Table 5. Level of risk to community health and well being

Risk	Total score	Description
Unlikely	5 – 13	Minimal probability for the community to be at risk of nuisance biting or disease
Possible	14 – 21	Increased probability for the community to be at risk of nuisance biting or disease
Likely	22 – 29	Strong probability for the community to be at risk of nuisance biting or disease

Table 6. Mosquito risk assessment matrix

Assessment of mosquito breeding potential	Assessment of risk to the community		
Risk level/ potential	**Unlikely**	**Possible**	**Likely**
High	Medium	High	High
Medium	Medium	Medium	High
Low	Low	Medium	Medium

5. Mosquito management in constructed wetlands

The purpose of mosquito management is to reduce the likelihood of residents being exposed to disease carrying mosquitoes, either by reducing the potential of mosquito habitats to maintain high mosquito populations or by the use of mosquito control agents in reducing adult or immature mosquito populations.

It is critically important that no mosquito control program be undertaken before first assessing the actual mosquito risk and identifying the target pest species. Mosquito control can be expensive and may also pose a risk to non-target organisms in the local environment. Unless the target species is identified and appropriate control strategies implemented, the objectives of mosquito control may not be met.

A mosquito control program should aim to use the most cost effective and environmentally safe methods available and be combined with a plan to educate the community about mosquitoes, mosquito borne diseases and personal protection strategies.

5.1 Reducing suitable mosquito habitats in constructed wetlands

Measures that are aimed at reducing the mosquito breeding potential of a water body is considered a cost-effective and long term management strategy for constructed wetlands. However, it far more economically beneficial if this strategy is incorporated into the original design of the wetland. Retro fitting or redesigning a wetland once constructed may be extremely expensive.

5.1.1 Habitat modification

There are elements of constructed water bodies can be altered to reduce their capacity for mosquito production. Such strategies will need to be site specific and consider the physical, chemical and biological components for maintaining low mosquito populations.

Water body redesign

Constructed water bodies can be re-shaped, in particular the edge of the water body, to facilitate wave action on the surface and dredging to increase water depth. Modification may also include rectification of surface depressions in shallow treatment zones and filling and grading landscaped areas to remove surface depressions. Improvement in water movement through the constructed wetland can also help minimise mosquito populations.

Vegetation management

Vegetation management is key to reducing the suitability of constructed wetland habitats for mosquito production. Harvesting of semi-aquatic and aquatic vegetation from shallow treatment zones in the wetland removes mosquito harbourage sites, allows for access by larval predators and improves water movement. The growth of emergent, floating and submerged aquatic macrophytes present a range of risk factors that will be site-specific depending on the locally abundant pest species. These risks may be seasonally variable so no vegetation management should be undertaken with assessing the mosquito-specific risk first.

The key issue for the majoring of wetlands in Western Sydney will be the minimizing of invasive aquatic macrophytes such as *Typha orientalis* and *Phragmites australis.* This species can quickly clog wetlands and enhance habitats for pest mosquitoes. Studies in Western Sydney have shown that wetland originally planted with a matrix of native aquatic macrophytes can relatively quickly become overrun with these invasive species.

Terrestrial vegetation should also be considered when assessing local mosquito risk. Dense vegetation growth can act as refuges for adult mosquitoes and dispersal corridors and should be reduced and clear open space created between vegetation screens and local residences. Extensive plantings of dense and fast growing plants such as *Casuarina* spp can quickly create refuge areas for pest mosquitoes. The increased humidity and protection from wind, rain and heat increase the longevity of mosquitoes and may prolong or amplify pest impacts.

Water flows

Increasing water flow through the wetland will assist in reducing suitable mosquito habitats. As well as the potential to create physical disturbance to immature mosquitoes, increased water flow will assist in improving overall water quality and ecological diversity in the wetland. Increased populations on mosquito predators will contribute to minimizing the production of mosquitoes.

5.1.2 Biological control

A number of organisms have been investigated to determine their suitability as effective predators of either adult or immature mosquitoes. These include aquatic invertebrate (e.g. Diptera and Coleopteran larvae, Crustaceans, Notonectids, Odonates) and vertebrate (fish) predators of immature mosquitoes. While biological control may appear to be an environmentally friendly and sustainable options for mosquito control, in reality, few studies have shown that biological control alone will suppress mosquito production from productive mosquito habitats.

Fish are most commonly employed to act as a biological control agent of mosquitoes in constructed wetlands. The mosquitofish, *Gambusia holbrooki*, was introduced to Australia from North America at the beginning of the 1900s to control mosquitoes but it is now considered a pest and has been implicated in significant adverse impacts on aquatic native fauna. The introduction of any exotic fish species into constructed wetlands should not be undertaken.

A number of native fish has been identified that may be appropriate for mosquito control in Australia. In Western Sydney, many of the constructed wetlands will be heavily polluted and may not provide the ecological conditions suitable for native fish species. The most likely candidates for introduction in constructed wetlands in Western Sydney are *Pseudomugil signifer* (Pacific Blue-eye), *Hypseleotris compressa* (Empire Gudgeon) or *Hypseleotris galii* (Firetail Gudgeon). While native fish introductions alone will not significantly reduce mosquito populations, they do provide an important component of integrated mosquito management and have been shown to provide a valuable link to the wider community promoting environmentally sensitive mosquito management.

5.1.3 Insecticides

With regard to mosquito control in and around constructed wetlands, the term “insecticide” refers to a registered product for mosquito control. Such products may include products targeting adult or immature mosquito populations. Before any product is used, target species should be identified to determine the most appropriate product for effective control.

Adulticides are generally permethrin or synthetic pyrethroid based and are typically applied as either a “fog” or “mist” delivering very small droplet sizes or are applied to the sides of buildings or terrestrial vegetation to form a barrier or kill adults taking refuge within the vegetation. This method of mosquito control is generally not recommended for routine control programs as these products can be expensive, their effectiveness is dependent on favourable weather, multiple treatments are often required and potential non-targets are a concern.

Larvicides are a more appropriate options for constructed wetlands. They target the immature stages and bring with them far fewer potential non-target impacts. The naturally

occurring soil bacterium *Bacillus thuringiensis israelensis* (B.t.i) produces a protein crystal which contains a number of microscopic pro-toxins that when ingested are capable of destroying the gut wall and killing mosquito larvae. This is the most common larvicide used in Australia but there are some limitations to using this product in highly organic habitats.

The insect growth regulator s-methoprene is a synthetic mimic of the juvenile hormone produced by insect endocrine systems and, when absorbed by the larvae, development is interrupted and immature stages fail to successfully develop to adults, usually dying in the pupal stage. This product is commonly used in Australia, particularly in highly organic rich environments (e.g. waste-water treatment ponds, drains, septic tanks) where B.t.i. may not be as effective.

5.2 Managing local nuisance biting and public health risks

There are several strategies for reducing the likelihood for humans to be exposed to mosquitoes. But the most cost-effective methods is to raise public awareness about mosquitoes and mosquito-borne diseases and provide advice on suitable personal protection strategies.

5.2.1 Public education

Informing the community about ways to reduce the risk of nuisance biting and mosquito-borne diseases is an effective way of reducing the impact on community health and well being. An education campaign for the public could include messages such as avoid being outside at dawn or dusk; wear long, loose, light-coloured clothing; apply insect repellent containing DEET or picaridin, in accordance with the manufacturer's recommendations use insect spray to kill any mosquitoes; use bed nets if available; use mosquito coils or plug-in insecticide devices; repair defective insect screens or install insect screens. A guide to personal protection measures has been produced to provide greater insights into the use of these products [12]. If signs of mosquito-borne disease, such as headache, joint pain, muscle pain, fever and rash, are observed, individuals should visit their local health professional for the appropriate blood tests.

Public education messages could be hosted on the Council's website or in situations where there is a significant outbreak of mosquito-borne disease; a letterbox drop of information to residents in the affected area is advised.

5.3 Developing a local mosquito management plan

The development of a local mosquito management plan can be beneficial for local authorities. Elsewhere in NSW, management plans have been developed for the Hunter and Mid-North Coast [13], Central Coast [14] and Byron Bay [15] regions. A mosquito management plan for proposed and actual constructed water bodies in the LGA can be incorporated into the overall mosquito management plan. The management plan should include a description of the purpose of the water body, a routine maintenance program, a complaint investigation procedure, risk assessment procedure, mosquito control actions and an assessment of the estimated cost for the program.

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Appendix F

Literature review on the effects of Bti and S-methoprene on MNES

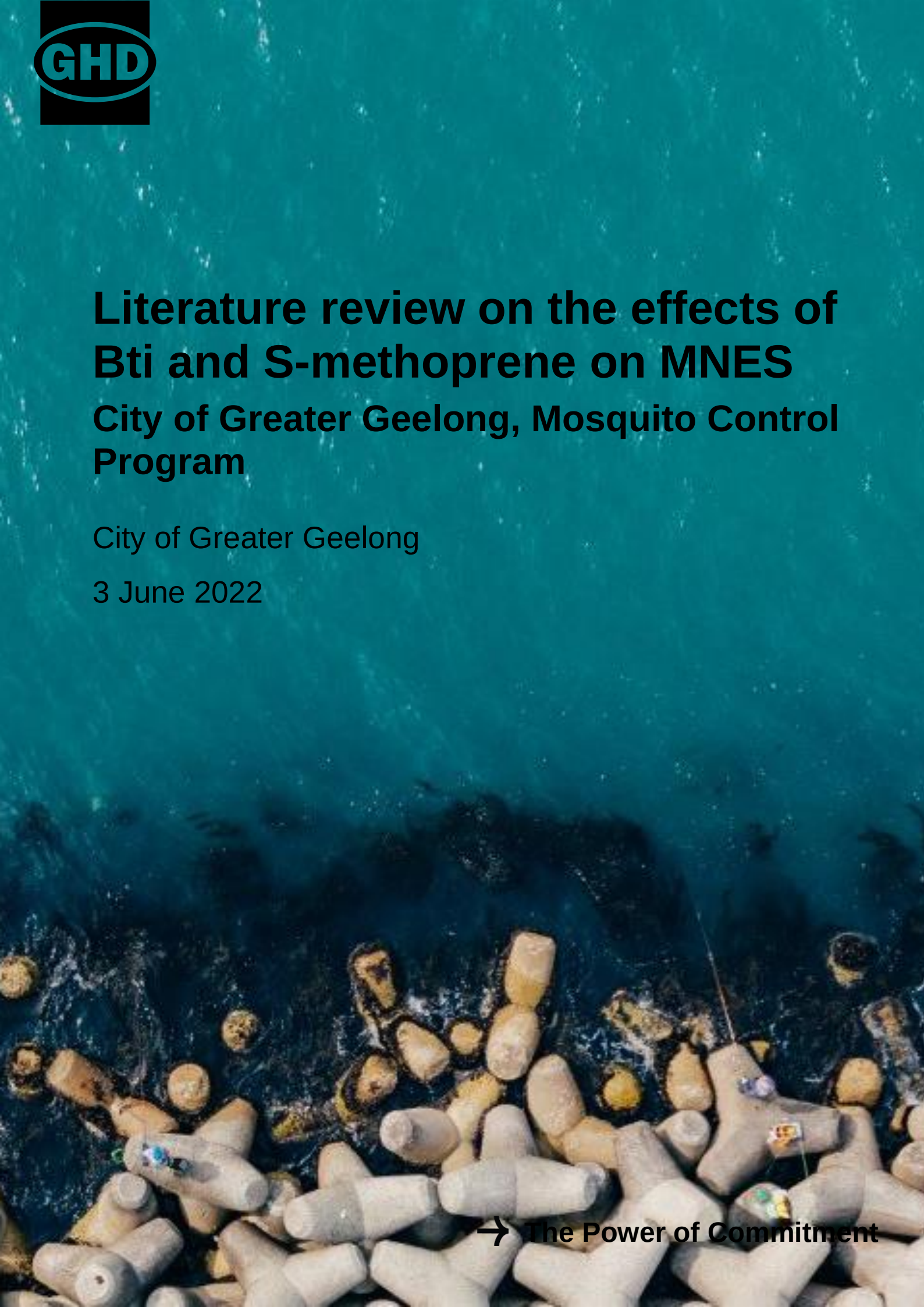
(Appendix F has not been updated for the purpose of this assessment. The outcomes of Appendix F have been considered in section 4 in relation to the updated project description)

Literature review on the effects of Bti and S-methoprene on MNES

City of Greater Geelong, Mosquito Control Program

City of Greater Geelong

3 June 2022



→ The Power of Commitment

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Executive summary

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the Report.

Introduction and methods

The City of Greater Geelong (the City) undertakes a mosquito control program within the City municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire. Two larvicides are used, both of which are widely used for mosquito control around the world: *Bacillus thuringiensis israelensis* (Bti) and S-methoprene. The application of larvicides is complex, determined by active monitoring of site-specific and environmental conditions during the mosquito breeding season, targeting locations near human habitation where mosquitoes are known or likely to breed in large numbers. Larvicide application is done on ground (on foot) or from the air (helicopter).

The City requested GHD to provide a robust and systematic literature review on the effects of Bti and S-methoprene on Matters of National Environmental Significance (MNES), to be used as part of the preliminary documentation for assessment by Department of Agriculture, Water and the Environment (DAWE) for the purposes of approving the continued control program from April 2022 to April 2032 under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The literature review must satisfy a set of requirements defined by DAWE and described in this report.

To achieve a systematic approach for the literature review, a review of online procedures and processes that follow known and accepted literature review guidelines and protocols was undertaken. Following this review an approach similar to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) model was adopted and the scientific literature search engine Google Scholar was selected to undertake all the searches due to its accessibility, search potency and the possibility to save the searches in files compatible with Excel spreadsheets.

The approach included four key steps:

Step 1: Identify appropriate search criteria around research topic

Step 2: Undertake searches for relevant literature

Step 3: Screening and eligibility –evaluate and select most appropriate sources.

Step 4: Analyse, compare and discuss eligible findings.

To define and set appropriate search criteria, six key topics/questions were developed:

1. Are there any published studies that identify potential direct and indirect effects from the application of the larvicides on MNES relevant to this study?
2. Are there any informal studies / grey literature that identify potential direct and indirect effects from the application of the larvicides on MNES relevant to this study?
3. What are the potential direct and indirect impacts of larvicides on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)?
4. Is there potential for bioaccumulation and food chain effects of active ingredients and adjuvants, and subsequent impacts on MNES and non-target organisms?
5. Are there studies investigating multigenerational and endocrine disrupting effects, and indirect effects such as the disruption of diet with regard to Bti and S-methoprene?
6. Are there studies investigating the degradability of Bti and S-methoprene and its potential to mobilize within the environment?

Summary of findings

S-methoprene is widely accepted to be non-toxic to higher vertebrates, including birds, mammals and humans, following comprehensive toxicological evaluations over several decades. The most often reported concern regarding S-methoprene is its non-specificity in the aquatic environment: S-methoprene can negatively impact non-target insect larvae, crustaceans, and potentially amphibians and fish. However, S-methoprene's low persistence in the environment reduces the potential for impacts on non-target organisms. Rapid recovery of negative impacts after application was often observed. The effects of S-methoprene are likely to be inextricably linked to application dose – higher application doses are more likely to result in non-target effects.

The most closely aligned application of S-methoprene discovered in this review was by the Shire of Busselton for the Ramsar-listed Vasse-Wonnerup Wetlands in Western Australia. Investigations relating to that application consistently found no evidence of adverse impacts of larvicide use on non-target organisms - community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application.

There appears to be consensus in the literature reviewed that the need for mosquito control outweighs the potential for non-target impacts caused by Methoprene (including S-methoprene).

Bti has been used worldwide as a larvicide for decades. Exhaustive laboratory tests, necessary for the registration of Bti as a commercial product, have widely confirmed Bti as being relatively safe for vertebrate fauna, most non-target invertebrates, and the environment. The insecticidal crystal proteins in Bti target specific parts of specific larval insects with no harmful effect on vertebrates. There appear to be non-target effects in some chironomid species (chironomids are closely related to mosquitoes).

There appear to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.

In addition to non-target effects in chironomids, two concerns for Bti have been identified, relating to sub-lethal behavioural responses by tadpoles and chironomids, and the indirect food-chain effects reported for birds (House Martins). However, for both of these, there are other studies that show contrasting results, and neither area of concern has been conclusively demonstrated or reinforced by additional studies from other systems, so conjecture remains.

The most closely aligned application of Bti discovered in this review was by the Shire of Busselton for the Ramsar-listed Vasse-Wonnerup Wetlands in Western Australia. Investigations relating to that application consistently found no evidence of adverse impacts of larvicide use on non-target organisms - community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application. However, unlike for S-methoprene, continued sampling was recommended for Bti to achieve more confidence in the conclusion.

Overall, the use of Bti as a larvicide appears to be widely supported. Bti is reported in the scientific literature as one of the most environmentally sound methods of mosquito control available.

The effects of larvicides are likely to be inextricably linked to application dose – higher application doses are more likely to result in non-target effects. At the application rates proposed by the City for Bti and S-methoprene, it can be concluded from this literature review that impacts on non-target organisms are unlikely to be significant.

A summary of responses to the six key topics/questions for the search criteria is presented below:

Question 1 - Are there any published studies that identify potential direct and indirect effects from the application of the larvicides on MNES?

The systematic search provided very limited information linking larvicides to MNES. No published articles identified in the literature search reported effects on specific MNES identified for this project. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world. One article reviewed for Bti reported on a study in a Ramsar site in Europe: Albufera Natural Park (Valencia, Spain), a Ramsar site (no. 454). The majority of information obtained was not relevant to MNES or was more relevant to subsequent questions, particularly question 3.

Question 2 - Are there any informal studies / grey literature that identify potential direct and indirect effects from the application of the larvicides on MNES?

The search for grey literature and other sources provided limited results linking either larvicide to MNES. The most relevant reports are from the *City of Busselton, Western Australia EPBC Act referral number 2016/7780,* which relate to aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, a Ramsar wetland. This study is discussed in detail in this literature review report.

The remaining relevant articles were used to address subsequent questions in this review, particularly question 3.

Question 3 - What are the potential direct and indirect impacts of larvicides on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)?

For Bti, the systematic literature review on non-target aquatic organisms resulted in 25 relevant studies providing toxicity information of several aquatic invertebrates including copepod and cladoceran species, with amphibian tadpoles also reported as being sensitive to Bti.

For S-methoprene, the systematic review provided 27 relevant papers with toxicity data for invertebrates and vertebrates, including molluscs, amphibians and, principally, crustaceans, with the fiddler crab identified as the most sensitive species.

The review was complemented with review papers and grey literature that compiled a robust review of studies focused on measuring ecological effects in the environment after Bti or S-methoprene applications rather than effects in the laboratory. The conclusions of the majority of these studies are that both Bti and S-methoprene were not harmful for vertebrate species.

Bti is reported to have caused declines mainly in non-target populations of chironomids, which have generally shown rapid recovery after treatment. There are also reports of sub-lethal (behavioural) responses by amphibian tadpoles, possibly leading to higher mortality through predation.

S-methoprene has been reported in numerous laboratory studies as being toxic to several non-target invertebrate species, principally crustaceans. However, other studies concluded that, at the recommended applications rates, the environmental concentrations of S-methoprene were not toxic for the vast majority of the species.

An on-going concern regarding the use of both larvicides is the potential impact that seasonal declines in mosquito numbers could have on the ecological food web. Bti takes both larval and adult mosquitoes out of the system, while S-methoprene takes adults, but not larvae, so potentially affects the terrestrial food chain only (not aquatic). Notably few studies report on this. One study reported on food-chain impacts on House Martins in Europe, but there is on-going conjecture about the repeatability of those findings. Of the MNES in question for the City's project, none are likely to depend on mosquitoes as a food source: i) shorebirds tend to probe for invertebrate fauna, rather than eat flying insects, ii) waterfowl (as part of Ramsar) tend to eat plant matter or aquatic food, rather than flying insects, iii) egrets, herons, bitterns etc eat aquatic fauna, and larger prey than mosquitoes, iv) frogs (e.g., Growling Grass Frog) eat mosquitoes, but will eat a range of other, often larger, invertebrates, and even vertebrates (smaller frogs).

Question 4 - Is there potential for bioaccumulation and food chain effects of active ingredients and adjuvants, and subsequent impacts on MNES and non-target organisms?

The results of the systematic review combined with the review papers and grey literature for the potential bioaccumulation effects of Bti and S-methoprene provided very limited results.

While S-methoprene has been reported to bioaccumulate in some fish and crayfish, it tends to be only for a short period, and there are no reports of biomagnification in the food chain. No studies consulted or discovered for this report provided information about potential Bti bioaccumulation, which is identified as a knowledge gap in this literature review.

Question 5 - Are there studies investigating multigenerational and endocrine disrupting effects, and indirect effects such as the disruption of diet with regard to Bti and S-methoprene?

No relevant studies were identified that showed endocrine disruption effects of the larvicides in non-target organisms. Only two studies investigated an endocrine disrupting effect in mosquito species. From the extended review, the only study that mentioned endocrine disrupting effects found no sign of endocrine activity in several Bti formulations. No relevant information was identified for the potential endocrine disruption effects of S-methoprene, which is identified as a knowledge gap in this literature review.

Question 6 - Are there studies investigating the degradability of Bti and S-methoprene and its potential to mobilize within the environment?

Several studies identified in the systematic literature review reported that S-methoprene and Bti are readily degraded by microbial activity and sunlight, resulting in a rapid decrease in the larvicide concentrations after treatment. S-methoprene mobility is considered to be limited given this degradability and the affinity to bond to sediments (but only at concentrations considerably below the toxicity thresholds).

Key conclusions

Overall, the authors consider that the literature discovered and assessed in this report adequately represents what is known and not known about the potential direct and indirect effects of Bti and S-methoprene as larvicides. The following conclusions have been reached following the systematic literature review:

– There is limited literature available on the topic of larvicide effects on MNES, vertebrates, and non-target organisms, particularly from recent years and from Australian ecosystems. Much of the literature on this topic globally is older (pre-2010), and more recent studies do not appear to have produced conflicting findings.
– Both Bti and S-methoprene are widely used larvicides globally, and have been the subjects of comprehensive toxicological evaluations over several decades.
– No studies identified potential direct or indirect effects from the application of S-methoprene or Bti on species identified as MNES for this project. One study provides information for a monitoring program assessing impacts on aquatic invertebrates due to S-methoprene and Bti on the Western Australian Vasse-Wonnerup Ramsar site (a MNES). After seven years of aquatic invertebrate sampling, that study has found no evidence of adverse impacts on non-target organisms due to Bti or S-methoprene use.
– No articles were identified in the literature search that reported on effects on specific MNES identified for this project. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world.
– Almost all the literature reviewed concluded that S-methoprene and Bti are not directly toxic to vertebrates.
– The effects of S-methoprene on non-target invertebrates are likely inextricably linked to application dose. Higher application doses are more likely to result in non-target invertebrate effects. However, when used at recommended application rates, the literature generally concludes that there is a low risk to non-target species, including estuarine invertebrates. Low persistence in the environment (when used at recommended does rates) means that impacts on water quality are low. Given the way larvicides tend to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are considered unlikely.
– The effects of Bti include some non-target effects on Chironomid species (non-biting midges; closely related to mosquitoes), although there is no clear consensus in the literature. There appears to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.
– An on-going concern regarding the use of both larvicides is the potential impact that seasonal declines in mosquito numbers could have on the ecological food web. Notably few studies report on this, and there is on-going conjecture about the repeatability of the findings from the main one that does. Of the MNES in question for the City's project, none are likely to depend on mosquitoes as a food source. Indirect impacts of larvicides on the food chain are partly mitigated by the availability of untreated areas of mosquito habitat as sanctuaries for mosquitoes and natural mosquito predators

– According to information found in this literature review, it can be concluded with reasonable confidence that, at the application rates proposed by the City for Bti and S-methoprene, non-target organisms are unlikely to be significantly affected. It is noted that direct supporting evidence for this is currently limited and more studies in other areas and at different applications rates would be needed to firm this conclusion.
– The literature is relatively consistent in the conclusion that, among the products used for mosquito control, Bti and S-methoprene are among the safest for the environment and for non-target organisms, particularly vertebrates.

Knowledge gaps

The systematic literature review has highlighted a number of knowledge gaps in relation to the effects of S-methoprene and Bti. A number of these knowledge gaps limit the ability to address all issues raised as part of the proposed action. Ultimately, these knowledge gaps should form the basis of on-going monitoring program done in association with future mosquito control programs. The main gaps identified include:

– There are very few published studies that have investigated the indirect impact on the wider environment of an ongoing significant reduction in adult mosquito populations resulting from a long-term broad-scale mosquito control program.
– Without local long-term studies, or quantitative studies identifying the relative importance of mosquitoes (or susceptible non-target taxa such as Chironomids) as specific components of the ecosystem (e.g. as a food source, pollinator, nutrient recycler, or disease vector), it is difficult to accurately assess the indirect long-term environmental impacts of this specific mosquito control program.
– With year-to-year fluctuations across a range of environmental variables, natural changes in the abundance, diversity and behaviour of local wildlife further complicate our understanding of the ecological effects of mosquito control. We have not taken into account some of these natural factors or anthropogenic variables – e.g. surrounding land use, nutrient run off etc and how that impacts the habitats of the species.
– The potential effects of other ingredients used in S-methoprene and Bti products and formulations remains unknown – some articles suggest that associated ingredients may be more toxic than the larvicide itself.
– The potential for endocrine disruption associated with the use in S-methoprene and Bti remains uncertain due to a lack of research.
– More research is needed to clarify the potential for S-methoprene to bioaccumulate in the food web.
– The potential for intergenerational indirect effects of slow release Bti granules (i.e. Vectobac G granules) has been identified as a data gap and there is little information about the pace at which these granules break down and expose the Bti to the environment. It is noted that while slow release exposures last relatively long periods (e.g., 30 – 150 days) the nature of their composition is to expose only a low concentrations of the active ingredient at a given time. However, the application of some slow release products, like the S-methoprene Prolink briquets or VectoPrime FG-Granules, which are designed to remain in the environment for an extended period (e.g. 150 and 120 days respectively) is limited to a few sites within residential areas to prevent re-emergence of mosquito larvae after treatment and would not be applied to areas with MNES or tidal or marine habitats, thus reducing the risk to MNES.

Although there are knowledge gaps with regard to the potential direct and indirect impacts on MNES as a result of the proposed action these are partly mitigated because of several factors including the area of treated and untreated mosquito habitat, and timing and frequency of treatments.

The City completed a review of its treatment program and revised the treatment sites where some that were treated historically have been removed and others combined due to their proximity with neighbouring sites. This has resulted in a reduction of the overall number of sites requiring ground-based (from 99 to 36) or aerial treatment (from 49 to 36) for the proposed program (overall reduction in sites from 148 to 72).

Not all available mosquito habitat is treated each season within the proposal area and therefore large areas of untreated habitat remain for mosquitos and natural mosquito predators. It is difficult to quantify the area of mosquito breeding habitat within the proposal area, however it can be assumed with confidence that the area of untreated habitat is much larger than the area being treated as part of the proposed program. For example site 3.13 – Lake Connewarre East site area = 318.9 ha (seasonal treatment area = 35.08 ha or 11%). This site is part of the larger Lake Connewarre area at c. 880 ha. Although not all of Lake Connewarre is considered suitable mosquito breeding habitat due to it being tidal and depth of water, large portions including the western shoreline will not be treated

During a typical treatment season 40 of the 72 sites receive one or fewer treatments per season (i.e. some sites treated every two to three years). Meaning there is a gap of at least six months between treatments for the majority of sites allowing for a period of recover and recruitment. Although the remaining sites (n = 32) may receive two or more treatments per season, this scenario (i.e. multiple treatments per season) is more likely to occur every two to three years.

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1. Introduction

1.1 Project background

The City of Greater Geelong (the City) submitted a referral to the Department of Agriculture, Water and the Environment (DAWE) for the proposed mosquito control program, within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire (EPBC ref: 2020/8782). Figure 1 displays the extent of the proposed program area.

On 12 November 2020, a delegate of the Minister for the Environment decided that the proposed action is a controlled action and that it requires assessment by preliminary documentation. DAWE has requested that further information is required to be able to assess the relevant impacts of the proposed action, including a literature review of the potential direct and indirect impacts of the two larvicides (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) proposed for the program.

The City has requested GHD to provide a robust and systematic literature review on the effects of *Bacillus thuringiensis israelensis* (Bti) and S-methoprene on Matters of National Environmental Significance (MNES), as discussed in Attachment A of the Request for Additional Information (pages 7-8) provided by DAWE (herein referred to as the DAWE request for information).

1.2 Scope and purpose of this report

The purpose of this report is to provide a current literature review to understand the potential direct and indirect impacts on MNES from the use of two larvicide products (*Bacillus thuringiensis israelensis* (Bti) and S-methoprene) by the City of Greater Geelong for their proposed April 2022 – April 2032 Mosquito Control Program.

The literature review is a component of the Preliminary Documentation information required by the Minister under section 95A ofthe *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the assessment of the relevant impacts of the proposed action - City of Greater Geelong, Mosquito Control Program (EPBC 2020/8782).

The impact assessment must include, but not be limited to, an assessment of the direct and indirect impacts on MNES as a result of the proposed action (e.g. helicopter disturbance and collision, application of larvicides). For application of the larvicides Bti and S-methoprene, the literature review component of the impact assessment must consider:

– Direct ingestion of or exposure to pesticide products
– Potential direct and indirect impacts over the expected timeframe of use of the larvicides, including cumulative, multigenerational and food chain effects, on MNES, including listed species, migratory species and Ramsar site impacts
– Potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)
– Potential for metabolism and degradation of active ingredients and adjuvants, and subsequent impacts on MNES from metabolites and degradants

When discussing the direct and indirect impacts from the application of larvicides (Methopreneand Bti) on MNES, the above impact assessment should be informed by:

– A robust systematic literature review on effects of Bti and S-methoprene
– Information on impacts of similar programs elsewhere, where available

The systematic literature review on the effects of larvicides must include, but not be limited to:

– Procedures and processes that follow known and accepted literature review guidelines and protocols (e.g. PROSPERO, PRISMA, MESH terms, Cochrane, etc).
– Details of how the literature review was carried out (methodology), including but not limited to:
  - the questions that the review sought to answer?
  - what literature was included in the review and why?
  - what literature was excluded from the review and why?
  - how many items were finally selected for review
– Information on the limitations of the literature review (these limitations are separate to the profession limitations discussed in section 1.3 of GHD [2017])
– Critical consideration of studies that investigate similar pesticide use patterns (application rates, formulations, frequency over a 10 to 15-year period) preferably in similar environments
– Consideration of studies investigating multigenerational and endocrine disrupting effects, and indirect effects such as the disruption of diet / food chain effects
– Consideration of degradants and metabolites, i.e. are there any major degradants or metabolites of the active ingredients and adjuvants and if so, what are their potential effects
– A list of references cited or otherwise referred to in the review.

1.3 Limitations and assumptions

This report has been prepared by GHD for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and City of Greater Geelong as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

This review is limited to the potential direct and indirect impacts of using either larvicide product (Bti and S-methoprene) upon MNES and other non-target organisms listed by the DAWE in section 1.2. The review does not include the potential impact as a result of helicopter disturbance, helicopter collision with wildlife or the potential for the product to cause injury/death as a result of hitting an animal as it is deployed from the helicopter.

This literature review reports on literature gathered on mosquito control products and their potential impacts on target and non-target species. The review focuses on literature produced from 2010 with a key focus on literature from 2015 onwards.

Recent literature articles tend to report and build on the findings from past studies, so relevant findings from pre-2010 literature are considered and incorporated into this review. Published articles are scrutinised and peer reviewed at the time of publication, so the validity of the information they report is not questioned here.

It is assumed that the information gathered is of a sufficient quality and encompasses enough research to form a non-biased and scientific contention for the purposes of this report.

2. Project description

2.1 Proposed program

The proposed action comprises the City of Greater Geelong mosquito management program (the proposed program) within the City of Greater Geelong (the City) municipality and in the bordering Borough of Queenscliffe (BoQ) and Surf Coast Shire (SCS).

The City proposes to operate the 10-year program from April 2022 through to end of April 2032. The program will continue the activities described for the current program (refer permit EPBC 2005/2132) including:

– Monitoring of mosquito breeding sites
– Review of monitoring results to determine the need for and type of treatment
– Treatment of up to 72 sites (36 ground-based and 36 aerial) over the course of the 10-year program
– Annual reporting in line with current reporting requirements
– Community education.

The proposed program will operate in line with the Victorian Government's (*2004 Framework for Mosquito Management in Victoria*) and Australian and international best practice guidelines. It will consist of a combination of activities including monitoring of larvae abundance, ground-based (manual/applied by hand) treatments and aerial (helicopter) treatments of larvae in mosquito breeding sites.

The aerial treatment program will operate from 15 August to 15 March each year and the ground-based treatment program will operate from 15 August through to 31 May each year. Generally, mosquito larvae numbers are low during the winter months and, as a result, monitoring and treatment during this period is minimal.

The main mosquito species found in this region is *Aedes camptorhynchus*, a salt-water breeding mosquito that is capable of surviving a broad range of climatic conditions. Its breeding habitat includes the many regional salt marshes around the City. Another predominant mosquito species is *Aedes notoscriptus*. This species breeds in temporary ponds of stagnant fresh water, including domestic containers that fill with rain water. Its presence often indicates household breeding sources like pot plant bases and blocked drains or gutters.

Mosquito breeding sites within the City are and will continue to be monitored on a rotating basis. If larvae are found, staff determine the most effective treatment method for the site. Sites are either treated manually by hand (ground-based) or recommended for aerial treatment. For ground-based treatments, a 4WD vehicle may be used to access heavily vegetated breeding sites, and for aerial treatments, a helicopter is used.

Monitoring will also include setting light traps around the municipality to survey adult mosquito numbers and collect mosquito specimens. The AgriBio Centre at LaTrobe University will be engaged to determine the species and sex of adult mosquitoes and to test the mosquitoes for viruses. This helps to identify any emerging arbovirus issues and potential mosquito breeding sources.

The City will continue to use two mosquito control products for larval management: *Bacillus thuringiensis israelensis* (Bti) and S-methoprene. Both are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA). These products target specific aspects of the mosquito larvae biology.

The proposed program does not involve the removal or modification of any native vegetation or fauna habitat.

FIGURE - **1a**

Proposed action area and treatment sites

POINT HENRY

Ramsar Wetland

Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023

Corio Bay

11.6

11.2

GEELONG

11.8

11.5

EAST GEELONG

NEWCOMB

MOOLAP

THOMSON

LEOPOLD

11.7

11.9

WHITTINGTON

BREAKWATER

ST ALBANS PARK

0 400 800 1,600 m

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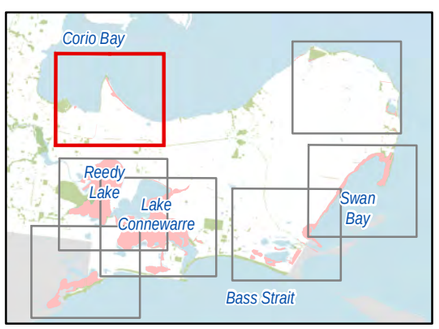


FIGURE - **1b**

Proposed action area and treatment sites
REEDY LAKE

Ramsar Wetland

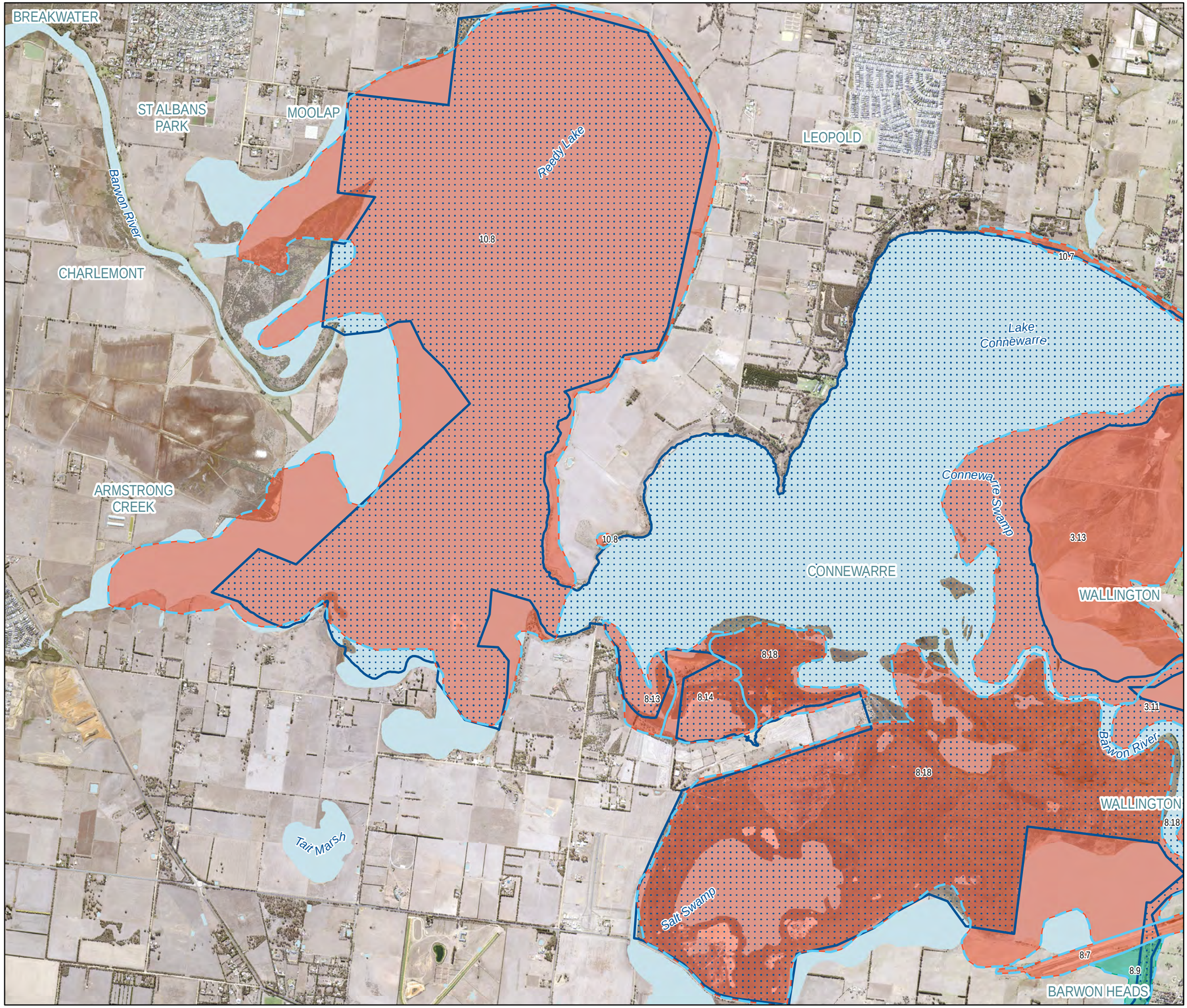
Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023



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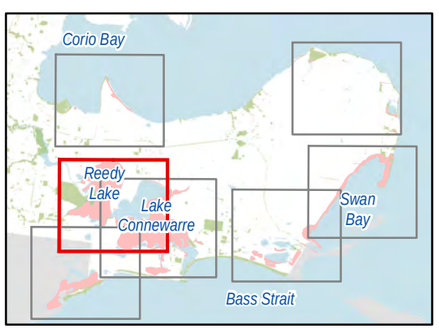


FIGURE - **1c**
Proposed action area and treatment sites
LAKE CONNEWARRE

Ramsar Wetland

Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023

MOOLAP
Reedy Lake
LEOPOLD
ARMSTRONG CREEK
Barwon River
Lake Connewarre
Connewarre Swamp
WALLINGTON
Salt Swamp
CONNEWARRE
Murtnagurt Swamp
BARWON HEADS
Barwon River
Blue Lake
OCEAN GROVE
10.8
10.7
3.9
3.14
3.13
8.18
8.13
8.14
3.12
3.11
3.2
3.8
3.5
3.3
3.16
3.6
3.15
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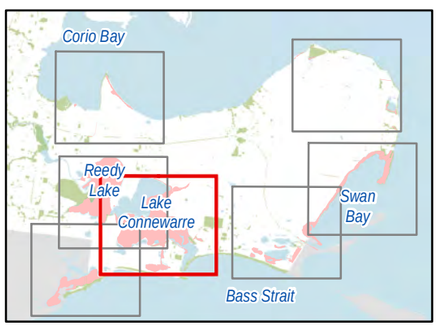
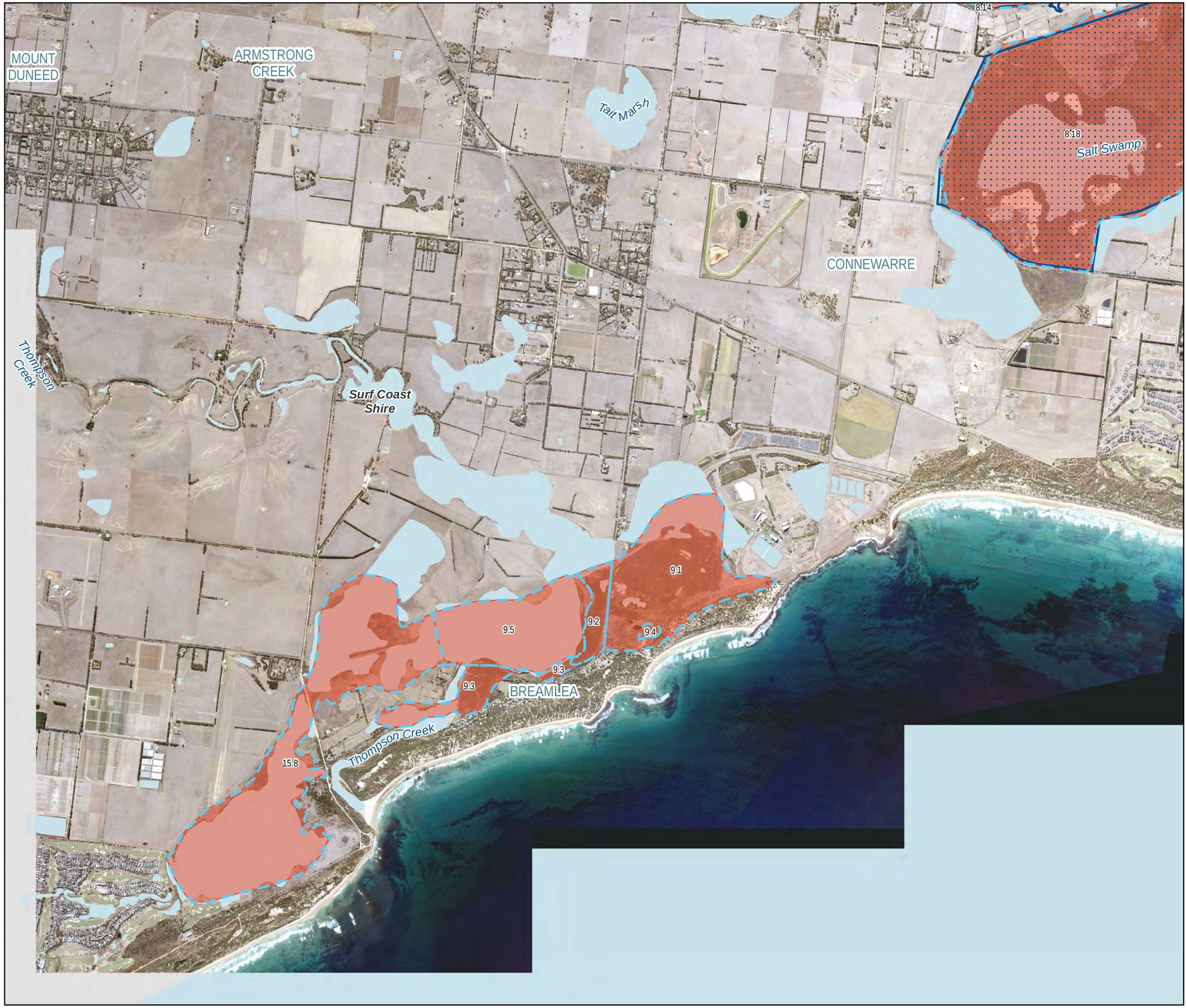


FIGURE - **1d**
Proposed action area and treatment sites
BREAMLEA

Ramsar Wetland

Project Area
Marine National Park

Project Area
Proposed Aerial Treatment 2022-2023
Proposed Ground Treatment 2022-2023



0 400 800 1,600 m

N

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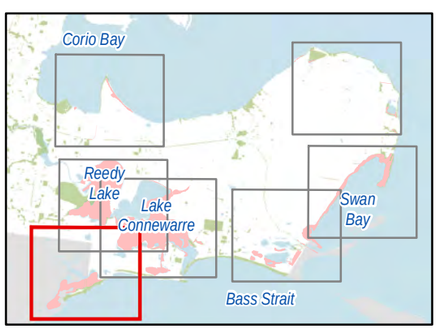


FIGURE -**1e**
Proposed action area and treatment sites
POINT LONSDALE

Ramsar Wetland

Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023



0 400 800 1,600 m

N

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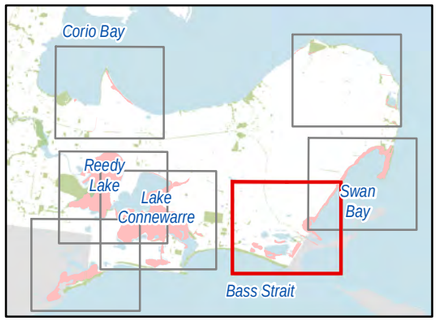


FIGURE - **1f**

Proposed action area and treatment sites

SWAN BAY

Ramsar Wetland

Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023



0 400 800 1,600 m

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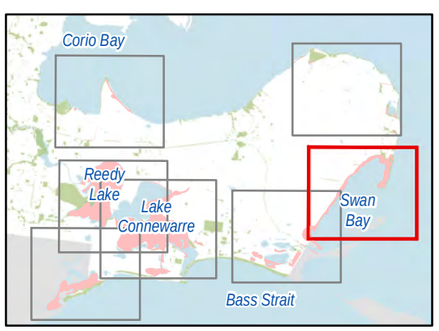


FIGURE - **1g**
Proposed action area and treatment sites
PORTARLINGTON/INDENTED HEADS

Ramsar Wetland

Project Area

Marine National Park

Project Area

Proposed Aerial Treatment 2022-2023

Proposed Ground Treatment 2022-2023

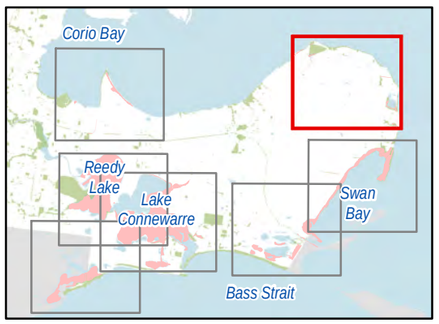


0 400 800 1,600 m

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2.2 Product description

The City currently uses two types of larvicide for the management of mosquito larvae: *Bacillus thuringiensis israelensis (Bti)* and S-methoprene. The City intends to continue the use of both larvicides for the proposed program.

Both products are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and are widely used in Australia and internationally to manage mosquito larvae because of their limited impact on non-target species and the general environment. The Framework for Mosquito Management in Victoria (DSE, 2004) indicates that Bti and S-methoprene are the most targeted larvicides commonly used in Victoria. Bti and S-methoprene are larvicides suggested for use in South Australia's Mosquito Management Guidelines (DH 2006). The Australian Mosquito Control Association Manual lists Bti and S-methoprene as agents that are currently recommended (MCCA 2008).

Bti and methoprene (commonly S-methoprene) are two commonly used larvicides (Lacey 2007; Henrick 2007 cited in Tonjes et al. 2018). Bti is bacterial-based, and derived from natural compounds; few objections are made to its use (Cashin Associates 2006, cited in Tonjes et al. 2018), although effects on some non-target organisms have been found (Boisvert and Boisvert 2000, in Tonjes et al. 2018). Methoprene is synthetic, generally causes more public concern (Cashin Associates 2006a), and its potential non-target impacts have been more widely studied (Glare and O'Callaghan 1999; Stark 2005).

2.2.1 Bacillus thuringiensis israelensis (*Bti*)

Bti is a naturally occurring soil bacterium which produces a protein crystal containing a number of microscopic toxins that, when ingested, are capable of destroying the gut wall and killing mosquito larvae. The insecticidal crystal proteins target specific parts of specific larval insects with no harmful effect on vertebrates or most other invertebrates (NSW Health 2019). Bti, is a variety specific to Diptera, especially mosquitoes and blackflies (Glare et al. 1998). This is one of the most commonly used larvicides in Australian estuarine and freshwater habitats. In heavily polluted environments or those containing a high organic content, the efficacy of this product is reduced (NSW Health 2019).

The toxicity and specificity in the mode of action is related to a toxin mixture of four toxins produced during bacterial sporulation: three Cry toxins (Cry4Aa, Cry4Ba and Cry11Aa) and one Cyt toxin (Cyt1Aa) (Ben-Dov, 2014; Vachon et al., 2012 cited in Allgeier 2019). After ingestion, Bti crystals are made soluble in the alkaline larval midgut where they get activated *in vivo* into toxins by midgut proteases. Following this activation, toxins bind to specific receptor sites in the outer membrane of the gut cells, oligomerize and form pores in cell membranes.

The formation of pores ultimately leads to gut disruption, which, depending on the ingested amount, leads to a fast larval death (minutes to hours) (Ben-Dov, 2014; Bravo et al., 2011; Vachon et al., 2012 cited in Allgeier 2019). The preceding activation of the toxins depends on several factors such as the alkaline condition and the number of receptors in the midgut membrane resulting in varying susceptibilities of targeted species (Bravo et al., 2007 cited in Allgeier 2019). The lethal effect of Bti is due to the proteinaceous toxins binding to the surface membranes of the epithelial cells in the larval midgut and disrupting osmotic balance of the cells (Lacey 2007).

2.2.2 S-methoprene

The insect growth regulator, S-methoprene, is a synthetic mimic of the juvenile hormone produced by insect endocrine systems and, when absorbed by the larvae, development is interrupted and immature stages fail to successfully develop to adults, usually dying in the pupal stage (NSW Health 2019).

S-methoprene is one of the two enantiomer forms of Methoprene, R-methoprene being the other, and the form that is active as a growth regulator. The term S-methoprene is used in this report except when cited as methoprene, in which case the term used by the author is maintained.

This product is commonly used in Australia, particularly in highly organic-rich environments (e.g. waste-water treatment ponds, drains, septic tanks) where Bti may not be as effective. There is a range of commercial formulations (including liquid, granule, pellet and briquette) of this product available that provides flexibility in habitat-specific use and, importantly, some formulations provide residual control of mosquitoes for up to three months, making it useful for providing sustained control following flooding in addition to the potential for "pre-season" treatment of critical mosquito habitats (NSW Health 2019).

2.2.3 Product use

Table 1 provides a summary of the five products used by the City for historical ground-based and aerial larvicide treatments, and includes: product name and type, application rates and container size, ingredients and label details and safety data sheet (SDS) details via hyperlink. It is the intention of the City to continue to use both larvicides for the proposed program. All sites could potentially be treated with Bti or S-methoprene. However, there are some specific sites that would only be treated with one or the other (Table 2).

Table 1 Product description summary

Product Name and type	Time between treatments	Maximum product rates	Container size	Ingredient (1)	Ingredient (2)	Label	SDS	Proposed application
Vectobac G -Granule	Minimum 7 days between treatments*	7 kg/ha	18 kg	Bacillus thuringiensis israelensis (Bti) - 2.85%	Other - 97.2%	Here	Here	Ground/Aerial - used to break breeding cycle of mosquito. Kills larvae in area.
Prolink Pro Sand - Sand	Minimum of 1 to 2 weeks between treatments**	4 kg/ha	20 kg	S-methoprene – 4 gr/kg	Non-Hazardous other – 996 gr/kg	Here	Here	Primarily aerial/ some ground. Dispersed from helicopter in hard to access areas
Prolink XR - Briquets	Between treatments = 150 days applied before	1 Briquets/ 10 m2	100 or 200 briquets	S-methoprene – 18 gr/kg	Non-Hazardous other – 982 gr/kg	Here	Here	Ground only - XR Briquets used to prevent emergence of larvae around residential areas. Not to be used in highly environmental sensitive areas or in tidal water or marine habitats where threatened species are known to occur.
Prolink Pellets - Granule	Minimum 30 days between treatments	4 kg/ha	10 kg	S-methoprene – 40 gr/kg	Non-Hazardous other – 960 gr/kg	Here	Here	Primarily ground/ some aerial
VectoPrime FG -Granule	Minimum of 120 days between treatments	4 kg/ha	18 kg	Bti - 5-10%	S-methoprene <1%	Here	Here	Only ground. Product is new to the market and not to be used in highly environmental sensitive areas or in tidal water or marine habitats where threatened species are known to occur.

Table notes: Time between treatments – the minimum number of days between applications which reflects the time-interval between active constituent releases* - Permit issued by APVMA to the City of Gold Coast which describes this. Permit number 85979 ** - No data is available on this product. Toxicity data is on the active constituent, (S)- Methoprene, has a half-life in soil of approximately 10 days which varies with soil type. The hydrolysis half-life > 4 weeks. Photolysis half-life is < 10 hours. Water solubility is < 2 mg/L.

Table 2 Treatment sites with specific product requirements

Site no.	Product name	Product type (ingredient)	Reason
1.6 Aerial	Prolink Pro Sand Prolink XR Briquets Prolink Pellets	S-methoprene	These pits are continually full of water and always breeding therefore slow release products are more effective
1.7 Ground	Prolink Pro Sand Prolink XR Briquets Prolink Pellets	S-methoprene	These pits are continually full of water and always breeding therefore slow release products are more effective
3.16 Ground	Prolink Pro Sand Prolink XR Briquets Prolink Pellets	S-methoprene	These pits are continually full of water and always breeding therefore slow release products are more effective
7.1 Aerial	Vectobac G	Bacillus thuringiensis israelensis (Bti)	S-methoprene is not used, as a holding period would be required for livestock that consume within 14 days, would need to placed on a clean feed period of 21 days prior to slaughter. Due to this location, the City chose to only apply Bti.
14.3 Aerial	Vectobac G	Bacillus thuringiensis israelensis (Bti)	S-methoprene is not used, as a holding period would be required for livestock that consume within 14 days, would need to placed on a clean feed period of 21 days prior to slaughter. Due to this location, the City chose to only apply Bti.

2.3 Proposed treatments for program

2.3.1 Process for identifying sites, treatment areas, frequency of treatments and maximum intended application rates for the proposed program

The information gained from the review of historical aerial and ground-based treatments (see GHD 2022 - Preliminary documentation report) was used to determine the following for each of the proposed treatment sites for the proposed program:

– *Need for future treatments* (inclusion/exclusion of sites). Some sites treated historically have been removed and others combined due to their proximity with neighbouring sites. This has resulted in a reduction of the overall number of sites requiring ground-based (from 99 to 36) or aerial treatment (from 49 to 36) for the proposed program (overall reduction in sites from 148 to 72).
– *Type of treatment* – ground-based or aerial.
– *Site area* – including for some sites a revision of the site boundary and therefore the size of the site. Some aerial and smaller ground-based sites were combined which has changed the overall area of some sites for the proposed program. Site area is defined as the total area in hectares of the site (e.g. 10 ha) that may be treatable over the 10 year program.

Proposed Treatment Area

– *Aerial sites* – area of the site proposed to be treated during one treatment. For aerial sites, the treatment area was determined by averaging the areas treated historically between 2012-2021.
– *Ground-based sites* – area of the site proposed to be treated during one treatment. For ground-based sites that are less than 1 ha, the entire area may be treated and for sites greater than 1 ha, the area estimate calculation determined from the review was applied.

Proposed Frequency of Treatments

As acknowledged in the review of the historical data, it is clear that some sites may be treated multiple times during one season, and some sites not treated at all for multiple seasons. The historical frequency of treatments allows for calculation of treatments expected across the 10-year program to account for the different scenarios that may be encountered each season, thus allowing for years which may require more treatments, and allowing for some contingency within the program. The frequency of treatments presented in Table 16 – Appendix A (aerial sites) and Table 18 – Appendix A (ground sites) is the maximum number of treatments any site would receive each season. The mode, mean and range are used to calculate the proposed frequency of treatments. The mode is a statistical figure which shows the most frequently reoccurring number in a set of data (i.e., the number of treatments that a site most often gets in a season). The mean provides a number which incorporates all data into a single value by adding the data and dividing by the number of data in a set. The range is calculated by subtracting the minimum number from the maximum number in a set of data – see further explanation in Appendix A.

– *Frequency of treatments (aerial sites)* – proposed number of treatments expected each season (August through to March for aerial sites) over the course of the 10-year (season) program. The frequency of treatments was calculated using the following:
  - Mode = most frequently reoccurring number of treatments (based on historical data range from 2012-2021).
  - Mean = Total number of historical treatments across 9 seasons (based on historical data range from 2012-2021) = XX frequency of treatments. Used when mode = 0.
– *Frequency of treatments (ground sites)* – proposed number of treatments expected each season (August through to end of May for ground-based sites) over the course of the 10-year (season) program. The frequency of treatments was calculated using the following:
  - Mode = most frequently reoccurring number of treatments (based on historical data range from 2005-2021).
  - Mean = Total number of historical treatments across 16 seasons (based on historical data range from 2005-2021) = XX frequency of treatments. Used when mode = 0.

Proposed Seasonal and Program Treatment Areas and Application Rates

Table 16 (aerial sites) and Table 18 (ground sites) in Appendix A provide the maximum seasonal and program treatment rates each site would receive. Most sites are unlikely to receive maximum treatments; the calculations of mode and mean from Tables 16 and 18 were used to calculate the maximum seasonal and program treatment rates, as per the instructions provided by the manufacturer– see further explanation in Section 2.4.7.3 (aerial sites) and 2.4.7.4 (ground sites).

– *Seasonal treatment area* – proposed area of treatment for one season in ha for each aerial and ground-based site. Seasonal treatment area will be calculated by:
  - Frequency of treatments x treatment area = XX ha.
– *Program treatment area* – proposed maximum area to be treated over the course of the 10-year program for one aerial or ground-based site in ha. Calculated using the following:
  - Seasonal treatment area of site x 10 years (assuming a scenario that each site will be treated each year as per the determined frequency each year for 10 years).
– *Seasonal intended application rate* – is the proposed maximum application rate of larvicide to be applied to a site over the course of a season. To calculate the seasonal intended rate, seasonal treatment area is multiplied by the maximum application rates for both products (7 kg/ha for Bti, 5 kg/ha for S-methoprene).
– *Maximum intended application rate* – is the proposed maximum application rate of larvicide to be applied to a site over the course of the proposed 10-year program. To calculate the maximum intended application rate, the seasonal rate is multiplied by ten (the proposed number of seasons) to determine the maximum application rate for the duration of the permit. The proportion of Bti to S-methoprene treatments at each site was determined by consulting with the City's experienced mosquito management officer and historical data of treatments for each site.

The City refers to the manufacturer's labels for both Bti and S-methoprene to determine appropriate seasonal application rates and maximum application rates (Table 1).

The City has provided calculations for both the amount of product (including all constituents) and actual amount of product (only active constituent) applied during treatments in Tables 16 – Appendix A (aerial sites) and Table 18 – Appendix A (ground sites).

2.3.2 Summary of treatment sites

The proposed program will include treatment of up to 72 sites (36 ground-based and 36 aerial) over the course of the 10-year program.

Table 3 provides a summary of the treatment types (aerial and ground-based) by comparing the combined geographic area of the sites with the combined area of the treatment types.

Table 4 provides a summary of the seasonal and maximum (program) intended application rates for each of the treatment types (all sites combined for each treatment type).

Table 16 - Table 19 (Appendix A) provide summaries of the following for each of the aerial and ground-based treatment sites for the proposed program including:

– Site number and site description
– Location with regard to Ramsar site
– Treatment product name, product type
– Proposed treatment area
– Historical frequency of treatments mode and range i.e. maximum treatment number – minimum treatment number
– Proposed frequency of treatments
– Proposed seasonal treatment area
– Program treatment area
– Seasonal and maximum (program) intended application rates for each product including for all constituents (Ingredients 1 and 2 Table 1) and the active constituent (Ingredient 1 either Bti or S-methoprene Table 1). Example calculations are provided below each table in Appendix A.

Table 3 Summary of proposed treatment types

Treatment type	No. of sites	No. of sites within Ramsar site	Site area (all sites combined) – ha*	Site area within Ramsar sites (all sites combined) - ha	Seasonal treatment area (all sites combined) – ha*	Seasonal treatment area within Ramsar site (all sites combined) - ha	Program treatment area (all sites combined) – ha*	Program treatment area within Ramsar sites (all sites combined) - ha
Ground-based	36	9	111.42	42.93	89.13	22.64	891.08	226.33
Aerial	36	25	4,158.34	3,623.60	768.39	673.86	7683.74	6,738.35
Total	72	34	4,269.76	3,666.53	857.52	696.50	8,574.82	6,964.68

Table note: * inclusive of sites within or adjacent Ramsar sites

Table 4 Summary of proposed seasonal and maximum (program) intended application rate per treatment type

Application type	Ground-based treatment all sites combined	Aerial treatment sites all sites combined	Totals – all ground-based and aerial sites combined
S-methoprene			
Seasonal intended rate S-methoprene (kg)*	213.63	592.101	805.731
Actual amount of S-Meth for seasonal rate (kg)**	0.853	2.369	3.222
Maximum (program) intended app rate S-methoprene (kg)*	2,136.282	5,921.001	8057.283

Application type	Ground-based treatment all sites combined	Aerial treatment sites all sites combined	Totals – all ground-based and aerial sites combined
Actual amount of S-methoprene used for Maximum rate (kg)**	8.543	23.684	32.227
Bti			
Seasonal intended rate Bti (kg)*	319.629	4542.293	4,861.922
Actual amount of Bti used for seasonal rate (kg)**	9.111	129.268	138.379
Maximum (program) intended app rate of Bti (kg)*	3,196.247	45,357.341	48,553.588
Actual amount of Bti used for Maximum rate (kg)**	91.094	1,291.020	1,382.114

Table notes: *amount includes ingredients 1 and 2 listed in Table 1 **amount includes only ingredient 1, either Bti or S-methoprene

2.3.3 Aerial treatment sites

Aerial treatment sites are mosquito breeding sites that are too large or too inaccessible to be treated in a timely manner by ground-based application. These sites can only be accessed via helicopter. Sites are large natural wetland/waterbody areas away from residential areas. They are areas that don't have any, or very limited, access for manual application. Most areas are too large for it to be viable to treat efficiently by hand as it is cost prohibitive and may take too long to be effective.

The helicopter may be required to fly back and forth across a site to adequately treat the area and apply the product according to the advice provided from the manufacturer. Flying duration at any site ranges from 15 minutes for smaller sites, to an hour for the larger sites. The entire area tends not to be treated every time an aerial application is scheduled; typically, 30% or less of the sites are treated in a season, with only 20 aerial treatments in a season occurring. This is due to the presence of water in enough volume or sufficient depth to reduce mosquito breeding in large extents of numerous sites. There is no need to apply product to areas within a site that are uninhabitable for mosquito larvae.

The City anticipates that some sites will be treated more frequently than others over the course of a season, and the 10-year program. Tables 16 and 17 provide *seasonal* and *maximum intended application rates*, however it is highly unlikely these will be achieved for each site as determined from the review of historical data. A treatment season is more likely to consist of the following for the 36 aerial sites (see Table 5):

– Eight sites will most likely receive one treatment per season
– Six sites will most likely receive one treatment every two to three years (therefore less than one per season)
– The remaining 22 sites may be treated twice or more each season, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every two to three years.

Given the change in climate and unpredictability of weather patterns, the City proposes that the range reported in Table should serve as an indicator to the number of aerial treatments expected to be required to effectively reduce mosquito numbers. The uniqueness of each season requires treatment decisions based on the mosquito larvae levels identified during monitoring. Flooding and arbovirus outbreaks will also be used as triggers for additional treatments in a season. The maximum number of treatments per season (Table) a site may receive is determined by the above factors.

Aerial applications are subject to weather and tide conditions and are only conducted when it is safe to do so for the pilot and officer involved. Safety considerations are mainly focused on weather forecasts as the scheduled date approaches; wind conditions must be below 30 km/h to ensure both safety and appropriate application of product. Wind speed and direction affect how the product moves once within the aerial site and must also be accounted for in the days after a treatment is conducted. Rain forecast also causes delays in application, as larvicide applied during rain would be washed out of the intended treatment area. Incoming high tides above 1.5 metres will force a reschedule of an aerial treatment, as any product applied prior to a high tide has the potential to be washed outside of the intended treatment area.

The type of product used in an aerial treatment will be dependent on the stage and abundance of the mosquitoes breeding at each site. S-methoprene provides the City with the capacity to delay the life cycle of mosquitoes, preventing progression into pupae and adults. This is particularly useful where there is a range of different stages present at an aerial site, as Bti will not have any effect on late-stage larvae.

Once officers can identify that most of the larvae are within the treatment stages of a Bti product, the mosquito larvae can be killed with a treatment involving Bti. Historically, for most of a season 41% of all aerial applications involved the sole use of Bti with a slow release formula that can be maintained at larvicidal concentrations for three to five days.

Officers return to aerial sites post treatment to determine the success of the treatment on mosquitoes at the site. S-methoprene will result in similar numbers of larvae but the larvae will be deformed and unable to fly if they do not die before emerging. Bti results in the death of larvae which is easily seen when conducting sample dips. These results are recorded in the Atlas of Environmental Health app.

A review of the dispersal method was undertaken to understand the potential impacts to MNES. The information presented below is a summary from the City (2019):

– Bti based products were solely used in 41% of treatment dates from 2005-2019
– S-methoprene based products were solely used in 28% of treatment dates from 2005-2019
– A combination of S-methoprene and Bti were used on 29% of treatment dates from 2005-2019
– The larvicide is delivered in two forms – Pellets (Vectobac G / Bti) at 3-8 mm diameter and Granular (Altosand, now called Prosand/ S-methoprene) at 0.5-1 mm diameter
– Both are delivered under pressure toward the ground via an ejector chute located below the helicopter
– Typical width of area covered by dispersal is between 20-30 m by the time the larvicide contacts the ground, water surface

2.3.4 Ground-based treatment sites

Ground-based sites are mosquito breeding sites that cannot be treated safely by helicopter application. These sites can be accessed manually or ‘on foot.’ Sites include roadside pits and drains, constructed wetlands and freshwater lakes/ponds/easements within residential areas. They are generally smaller areas within townships and are considered too close to roads, houses or power lines and infrastructure for the helicopter to treat them safely. In addition, sometimes when only a small area of the broad acre (a term used by the City to define the broader area usually treated by helicopter) has high larvae numbers, it is more cost effective to treat those areas by ground-based methods.

As for the aerial sites, the City anticipates some ground-based sites will be treated more than others over the course of a season, and 10-year program. Table and Table present the *seasonal* and *maximum intended application rates,* however it is highly unlikely these will be achieved for each site for each season. A treatment season is more likely to consist of the following for the 36 ground-based sites (see Table 5):

– Seven sites will most likely receive one treatment per season
– 19 sites will most likely receive treatment every two to three years (less than one treatment per year)
– The remaining 10 sites may be treated more than twice each season, however this scenario (e.g. multiple treatments per season) may not occur each season, but more likely to occur every two to three years.

The City proposes that the range reported in Table should serve as an indicator to the number of ground-based treatments required to effectively reduce mosquito numbers. Weather patterns and climate can be unique to each season, with some seasons encountering unforeseeable events such as floods. If additional treatments are required during any season due to triggers such as the weather, environmental conditions or high larval counts, the range amounts (proposed maximum number of treatments) will be utilised. Flooding and arbovirus outbreaks will also be used as triggers for additional treatments in a season. The maximum number of treatments per season (Table 18) a site may receive is determined by the above factors.

Ground applications around or in Ramsar wetlands will only occur between 15 August and 31 May. The decision to treat includes consideration of:

– Is it safe for an officer to walk around the treatment site? Is there the potential for snakes/other venomous animals?
– Is rain forecast for the next few days? Rain can wash product out of designated area.
– What will the temperature be over the next few days? Higher temperatures speed up the pupation of mosquito larvae.
– How many mosquito larvae are present? Is there an infestation or are the numbers of larvae low enough to monitor for another week? Numbers are determined using a dip method to sample approximately 100 ml of the water at a site.
– What stage are the larvae? Instar stages I to III can be treated, but later stages (IV and pupae) cannot. A mix of different stages would also require one product over the other.
– What is the volume of water? Higher volumes of water are less favourable for mosquito larvae.
– How big is the area requiring treatment? Calculating the area and weighing the amount of product ensures proper application rates.

When attending a ground-based treatment site, officers will first assess the condition and safety of the area (debris causing an OHS issue, waste building up, overgrowth of vegetation) and record this in the contextual environmental data section of the Atlas of Environmental Health Medical Entomology application (the app).

Once determined safe to enter, officers take five samples (dips) of the water using a technique appropriate for the environment. Each sample is assessed for the abundance (number of mosquitoes) and life cycle stage (instar I to pupae), which is entered into the app. Using the flow chart for ground-based applications, officers decide to either treat or hold off and monitor again in a week or fortnight.

Officers predominantly monitor ground-based treatment sites unless the above conditions require treatment. There are some historical ‘hotspots’ where mosquito breeding has been a community concern for many years. At these sites, officers use their knowledge of the site and current season to pre-empt mosquitoes emerging. This can be done by ensuring continuous application of S-methoprene to halt larvae growth, done in accordance with the application rates on the product labels.

Treatments are recorded in the app and include information about the type and quantity of product used, and officers can attach comments that provide extra information if required. To ensure the correct amount of product is applied to a given area, officers weigh the amount of product using portable scales and calculate estimations in square metres for the area coverage required. Applications of any product strictly adhere to the product labels to ensure safe usage.

Once a site has been treated, officers return to the site to check on the condition of the larvae and ensure that the treatment has been successful. The timeline for a return depends on the time of year, as in the hotter months, sites need to be monitored two to three days after a treatment. The success of a treatment is determined by examining the larvae numbers, health and by the product applied. S-methoprene will result in similar numbers of larvae but the larvae will be deformed and unable to fly if they do not die before emerging. Bti results in the death of larvae which is easily seen when conducting a dip. These results are recorded in the Atlas of Environmental Health app.

Conducting ground-based applications allows the City to respond to localised breeding sites that the Greater Geelong community reports using the Request for Service (RFS) system. Although the majority of mosquito population control depends on aerial application, ground-based application allows the control of smaller man-made wetlands that are becoming more popular in the new estates being developed, and other bodies of water that are difficult or impossible to treat aerially due to the sites’ proximity to residential areas.

2.3.5 Summary of a proposed typical treatment season

The purpose of this section is to clarify the proposed patterns of use and provide a summary of a typical treatment season for the 72 treatment sites within the program area. Of the 72 sites (aerial and ground-based combined) 40 receive one or less treatments per season (some sites treated every 2-3 years). Meaning there is a gap of at least six months between treatments for the majority of sites. Although the remaining sites (n = 32) may receive two or more treatments per season, this scenario (i.e. multiple treatments per season) is more likely to occur every 2-3 years. Table 5 provides a summary of a typical treatment season.

Table 5 Summary of a typical treatment season

Treatment type and number of sites	Number of treatments per typical season	Product type	Time between treatments
Aerial (no sites = 6) In/adjacent to Ramsar and/or documented MNES value = 2.4, 2.5, 2.17, 3.10, 8.7, 8.14 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 0	< 1 per year, every 2-3 years	Primarily Vectobac G -Granule (Bti), occasionally Prolink Pro Sand – Sand (S-methoprene)	At least 10 months, possibly more between treatments
Aerial (no sites = 8) In/adjacent to Ramsar and/or documented MNES value = 3.1, 9.1, 9.2, 9.3, 9.4, 9.5, 10.7, 11.2 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 0	1	Primarily Vectobac G -Granule (Bti), occasionally Prolink Pro Sand – Sand (S-methoprene)	At least 6 months , possibly more between treatments
Aerial (no sites = 22) In/adjacent to Ramsar and/or documented MNES value = 3.8, 3.9, 3.11, 3.12, 3.13, 3.14, 4.3, 4.5, 4.6, 7.1, 7.2, 7.3, 7.4, 7.5, 8.1, 8.4, 8.13, 8.14, 8.18, 10.8, 14.3, 14.4, 15.8 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 0	2 or more – some sites may receive more, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every 2-3 years	Primarily Vectobac G -Granule (Bti) then Prolink Pro Sand – Sand (S-methoprene) Site 7.1 and 14.3 – Vectobac G -Granule (Bti) only	At least 7 days between treatments within a season (Bti) At least 14 days between treatments within a season (S-methoprene) At least 5 months between seasons (i.e. no treatments from mid March to Mid August)
Ground (no sites = 7) In/adjacent to Ramsar and/or documented MNES value = 3.2, 3.7, 8.11, 11.8 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 4.2, 4.12, 11.5	< 1 per year, every 2-3 years	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-methoprene), then Vectobac G -Granule (Bti)	At least 10 months, possibly more between treatments
Ground (no sites = 19) In/adjacent to Ramsar and/or documented MNES value = 1.4, 4.1, 3.6, 4.7, 5.1, 5.2, 8.3, 8.6, 8.9, 8.16, 11.6 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES =, 3.4, 3.5, 3.15, 3.16, 4.8, 4.13, 14.11, 14.7	1	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-methoprene), then Vectobac G -Granule (Bti) Site 3.16 S-methoprene (mix of Prolink Pro Sand, Prolink XR Briquets, Prolink Pellets)	At least 6 months , possibly more between treatments

Treatment type and number of sites	Number of treatments per typical season	Product type	Time between treatments
Ground (no sites = 10) In/adjacent to Ramsar and/or documented MNES value = 4.10, 8.2, 14.1,14.8 Not in Ramsar or no documented MNES/unlikely to provide important habitat value for MNES = 1.1, 1.7, 3.3, 5.3, 11.7, 11.9	2 or more – some sites may receive more, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every 2-3 years	Primarily Prolink Pro Sand – Sand (S-methoprene) or Prolink Pellets-Granual (S-methoprene), then Vectobac G -Granule (Bti) Site 1.7 S-methoprene (mix of Prolink Pro Sand, Prolink XR Briquets, Prolink Pellets)	At least 14 days between treatments within a season (Prolink Pro Sand - S-methoprene) At least 30 days between treatments within a season (Prolink Pellets, Granual, S-methoprene) At least 7 days between treatments within a season (Bti) At least 3 months between seasons (i.e. no treatments from May to August)

Table notes: The aerial treatment program will operate from 15 August to 15 March each year and the ground-based treatment program will operate from 15 August through to 31 May each year

3. Literature review

3.1 Approach

The main objective was to undertake a current, systematic and robust literature review of the potential direct and indirect effects of Bti and S-methoprene on the identified MNES. In order to achieve a systematic approach, a review of online procedures and processes that follow known and accepted literature review guidelines and protocols (e.g. PROSPERO, PRISMA, MESH and Cochrane) was undertaken. Following this review, an approach similar to the PRISMA model was adopted (see Figure 2) and the scientific literature search engine Google Scholar was selected to undertake all the searches due to its accessibility, search potency and the possibility to save the searches in files compatible with Excel spreadsheets. The approach included four key steps:

Step 1: Identify appropriate search criteria around research topic

The purpose of this step was to develop key questions to meet the main objective and then set appropriate search terms and parameters (search criteria) to keep the literature review focussed on the DAWE requirements. Section 3.2 provides further detail regarding this step.

Step 2: Undertake searches for relevant literature

The search criteria developed during step 1 were entered into Google Scholar and other online databases and sources (e.g. the DAWE EPBC referral register, Council websites) to identify relevant articles. The list of articles derived from the search was saved as an Excel file in standard citation format including: author(s), year, title, journal title (if relevant), publisher. Original lists were saved for each search then filtered to remove duplicates for easy screening.

The assessed information provided by the City in previous reports and other relevant reports were used to identify information that could be used to answer some of the key questions.

A list of literature that was considered is provided in Appendix B. A list of information sources considered is provided in Appendix C.

Step 3: Screening and eligibility – evaluate and select most appropriate sources.

List outputs from Step 2 were then screened using a pre-determined classification process following a Best Professional Judgement (BPJ) approach by the authors which was modified according to the key question and search terms (Table 6). The qualifications and experience of the key authors are discussed below. The classification process aimed to:

– Identify what literature was included in the review and why?
– Identify what literature was excluded from the review and why?
– Identify how many items were finally selected for review?

Each of the articles reviewed was classified into one of the five categories, considering the key search words, information provided in the title and the abstract and, if necessary, the full document. The relevant results, considered as categories 1, 2 and 3, are presented Appendix B and discussed in Section 3.4.

Table 6 Classification of the results according to relevance

Classification category	Definition	Example of relevant article content
1	Relevant and key term/s found in the article Key terms must not be limited to title, and also within body of the article and preferably within the same sentence or multiple sentences.	E.g. search according to - Question 1, Table 6 Search A Article includes the term 'orange-bellied parrot', with exact phrase S-methoprene, with at least one of the following words…impact or bioaccumulation
2	Relevant (article included), but not all key term/s not found in the article. Article may be missing one or more of the key terms however may contain text that is relevant to the broader understanding of the question or useful surrogate information.	Article includes 'parrot' (but not 'orange-bellied parrot), with exact phrase S-methoprene, with at least one of the following words…impact or bioaccumulation
3	Relevant (article included), but for another question. Article may contain some key terms, but does not provide information linking key terms to the question. Article may contain information about a topic for consideration.	As above – can be useful to understand broader bioaccumulation issues but does not provide a relationship between MNES and the topic.
4	Not relevant (article excluded) – contains one or more of the above search terms however terms provided in unrelated / isolated sentences in document.	-
5	Not accessible (article excluded) (e.g. not in English)	-

Professional qualification and experience of report authors

Victor Perez-Landa

Qualifications – PhD in Marine Science (Ecotoxicology, Sediment Quality Guidelines and Ecological indices of disturbance) University of the Basque Country. 2006; Master of Science, Marine science, University of Cadiz 1996; Master of Applied Science, Environmental science, University of Sydney 2008.

Relevance to project - Victor is an aquatic ecotoxicologist scientist with more than 15 years' experience in aquatic ecotoxicology and ecological risk assessment associated with a variety of activities, including: dredging, mining and WWTW discharges to marine environments. Victor has investigated, designed and evaluated ecotoxicity tests to help governments to regulate the marine environment, in particular, to provide new life-cycle marine sediment test for the Australian Sediment Quality Guidelines.

Victor has conducted numerous impact assessment to a wide range of environments and contaminants. Typical contaminants includes: PFAS, metals, brine, pesticides, organics (including BTEX, TPH and PAHs), nutrients, flocculants and radionuclides. Experienced in the design and collection of waters, sediment and marine organism and in the use of Species Sensitive Distributions (SSD) to derive trigger values for substance discharged in the environment, including the development of PFOS and PFOA new ANZECC guidelines.

Victor is author and co-author of numerous peer-reviewed papers covering a wide spectrum of the marine science including ecotoxicology, marine ecology, water and sediment quality assessments, sediment contamination, taxonomy, and bioaccumulation.

Richard Retallick

Qualifications – Ph D in Terrestrial Zoology (Determinants of assemblage structure of tadpoles in the streams of Eungella National Park) James Cook University 2002; B Sc (Hons), Zoology, University of Melbourne 1992.

Relevance to project – Richard is a terrestrial ecologist, specialising in vertebrate fauna, with nearly 30 years' experience in ecological studies. He has an excellent understanding of ecological processes, and is knowledgeable on the species, communities, habitats and areas relevant to this project (including shorebirds and their migrations, the Orange-bellied Parrot, frogs (including Growling Grass Frog), wetlands, saltmarsh, the Bellarine Peninsula and the relevant Ramsar site). Richard has been an ecological consultant with GHD for 15 years.

Richard is author or co-author of numerous peer-reviewed articles, mainly relating to amphibians and the effects of chytrid fungus. Richard has also written or contributed to countless impact assessment reports for projects seeking approval under state (Victoria, Tasmania, NSW, Queensland, Northern Territory) and/or federal legislation (EPBC Act).

Simon Harrow

Qualifications – Master's Degree (M.Sc.) Marine Resource Development and Protection – Heriot-Watt University, Edinburgh. Bachelor's Degree (B.Sc. Hons.) Biological Sciences – Napier University, Edinburgh.

Relevance to project – Simon has over 15 years' experience managing a diverse range of projects for State government and private industry clients, with an emphasis on assessing compliance with relevant state and federal legislation. With wide-ranging aquatic science experience, he has worked on numerous projects across Australia - focussing on values and functions of aquatic ecosystems in a range of environments, with emphasis on freshwater fish and macroinvertebrate communities. He has worked with the Victorian state government on a range of projects related to the management and monitoring of fish in relation to the Sustainable Diversion Limits sites on the Murray River and WaterNSW in relation to management of threatened fish populations for the Chaffey Dam to Tamworth pipeline project. He has directed a wide range of projects for various water authorities including long-term macroinvertebrate and mosquito monitoring and fish monitoring programs.

Craig Grabham

Qualifications – B App Sc (Hons). Relevance to project – Craig is a Senior Ecologist with GHD based in Geelong Victoria with 25 years' experience in conducting ecological studies. He has a strong understanding of the species, communities, habitats and areas relevant to this project including shorebirds, the Orange-bellied Parrot, Growling Grass Frog and the Bellarine Peninsula and the relevant Ramsar site. Craig has been an ecological consultant for 16 years with GHD focussing on ecological impact assessment and approvals within Australia. The majority of Craig's work has involved the assessment and management of environmental impacts resulting from linear infrastructure projects particularly road, and also water and water pipeline, power line, gas, rail and resource extraction projects. He has completed migratory and wetland bird surveys for this project and others in the project area.

Step 4: Analyse, compare and discuss eligible findings.

During this step, eligible literature was used to answer the key questions, particularly to understand the direct and indirect impacts of the application of the larvicides on MNES.

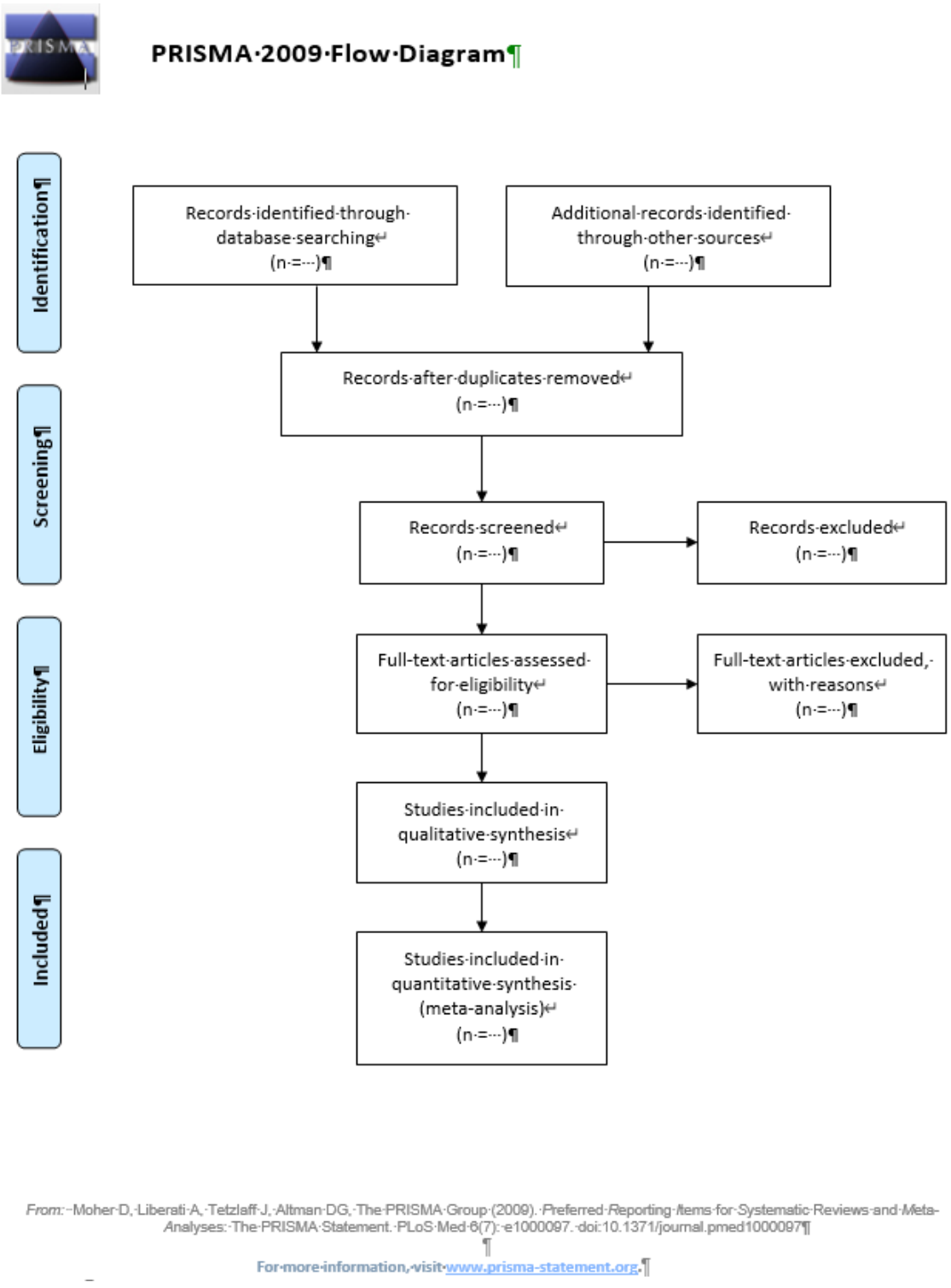


Figure 2 ***PRISMA flow diagram***

3.2 Set appropriate search criteria

Search terms and parameters were chosen to filter the recent literature published since 2010 to the present (July 2021) with a key focus on literature from 2015 onwards that contained information about effects of S-methoprene and/or Bti on MNES and non-target species. MNES and non-target species were searched for separately, according to slightly different strategies as detailed in Section 3.3.1.

The following key questions/topics were developed:

1. Are there any published studies that identify potential direct and indirect effects from the application of the larvicides on MNES? (Herein referred to as Question 1). Whilst searching for literature for this question the following was also considered:
    - Information on impacts of similar programs elsewhere, where available.
    - Potential direct and indirect impacts over the expected timeframe due to use of the larvicides, including cumulative, multigenerational and food-chain effects, on MNES, including listed species, migratory species and Ramsar site impacts.
2. Are there any informal studies / grey literature that identify potential direct and indirect effects from the application of the larvicides on MNES? (Herein referred to as Question 2). Whilst searching for information for this question the following was also considered:
    - Information on impacts of similar programs elsewhere, where available.
    - Potential direct and indirect impacts over the expected timeframe of use of the larvicides, including cumulative, multigenerational and food-chain effects, on MNES, including listed species, migratory species and Ramsar site impacts
3. What are the potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)? (Herein referred to as Question 3).
4. Is there potential for bioaccumulation and food-chain effects of active ingredients and adjuvants, and subsequent impacts on MNES and non-target organisms?[1] (Herein referred to as Question 4).
5. Are there studies investigating multigenerational and endocrine-disrupting effects, and indirect effects such as the disruption of diet with regard to Bti and S-methoprene? (Herein referred to as Question 5).
6. Are there studies investigating the degradability of Bti and S-methoprene and its potential to mobilize within the environment? Are there any major degradants or metabolites of the active ingredients and adjuvants and if so, what are their potential effects with regard to Bti and S-methoprene? (Herein referred to as Question 6).

The following were also addressed:

– Identify the key studies informing on physico-chemical characteristics including degradation and fate and transport properties of the larvicides of concern (Questions 4 and 6)

– Identify studies informing on the bioaccumulation and multigeneration and endocrine-disruption effects on key species (Question 1 and 2)

– Key studies/reports that investigate similar pesticide use patterns and environments (Questions 1, 2 and 3).

3.3 Search outputs for relevant literature

The search criteria developed during Step 1 were entered into Google Scholar and other online databases and sources (e.g. the DAWE EPBC register of projects, local council websites) to identify relevant studies. The list of articles derived from using the search criteria was saved as an Excel file in standard citation format including: author(s), year, title, journal title (if relevant), publisher. Original lists were saved for each search then filtered to remove duplicates for easy screening. Relevant information provided by the City was also assessed. After the removal of duplicates, 748 articles from published and/or peer reviewed sources were considered for Questions 1, 3, 4, 5 and 6 (Appendix B) and 76 other sources of information (e.g. council websites, DAWE referral list) were considered for Question 2 (Appendix C).

[1] Question 4, 5 and 6 have been rearranged with regards to the original question provided in the scope given the level of overlap of similar concepts within those questions

3.3.1 Question 1

The Google Scholar advanced search included words and commands for each MNES listed below as listed in Table 7 (search A and B). In order to filter the search to detect local studies, the word 'Australia' was also included in the key parameters, however searches were not limited to local studies and included relevant information from international sources. In addition to MNES specific searches, broader search terms that encompassed species groups e.g. fish, wader, shorebird etc (Table 10, search C) were also used to capture information. Table 7 provides a summary of the search outcomes. A complete list of all these studies and their corresponding classification is provided in Appendix B.

Key MNES included in the search terms:

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Migratory, Marine
– Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site

Table 7 Question 1 – search parameters

Search	Google scholar advanced search commands	Key parameters	Summary of search outcomes (number of studies for each search)
A	With all the words	MNES item from list e.g. orange-bellied parrot OR Neophema chrysogaster	
	With the exact phrase	S-methoprene OR bacillus thuringiensis israelensis	
	With at least one of the words	impact, direct, indirect, bioaccumulation, bioaccumulative, acute, endocrine disruption, degradation, fate transport	2 articles between 2015 – 2021, and 6 articles (no date)
B	With all the words	MNES item from list e.g. orange-bellied parrot OR Neophema chrysogaster	
	With the exact phrase	literature review	2 articles between 2015 – 2021, and 6 articles (no date) - duplicates from search A
	With at least one of the words	S-methoprene, bacillus thuringiensis israelensis impact, direct, indirect, bioaccumulation, bioaccumulative, acute, endocrine disruption, degradation, fate transport	
C	With all the words	S-methoprene OR bacillus thuringiensis israelensis	
	With the exact phrase	-	
	With at least one of the words	fish, wader, shorebird, duck, waterbird, plover, frog, sandpiper, species, wetland, Ramsar impact, direct, indirect, bioaccumulation, bioaccumulative, acute, endocrine disruption, degradation, fate transport	669 dated between 2015 - 2021

3.3.2 Question 2

In order to search for grey literature (defined as unpublished or not peer reviewed) two processes were used:

– Internal search option of an organisation's website (e.g. DAWE referral portal search tool or internal search option on a council website)
– Standard Google search using a combination of key words.

In addition to MNES-specific searches, broader search terms that encompassed species groups were also used to capture information. A total of 76 sources of grey literature were considered. Table 8 provides a summary of the search type, sources of information and outcomes. Appendix C provides further detail.

Table 8 Question 2 – Database sources and search parameters

Search type	Database source / search function / request type	Summary of search outcomes
Organisation database (no date limitations)	DAWE – Referrals list: http://epbcnotices.environment.gov.au/referralslist/ Search - filter by title Search terms - mosquito OR S-methoprene OR bacillus thuringiensis israelensis No date	Six projects/referrals containing search terms in title including two from the City of Greater Geelong. Of particular interest - City of Busselton/Water Management and Use/Layman Road, Busselton, WA/Western Australia/Aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, WA See Appendix C for details
Google – then internal organisation search (no date limitations)	Google search Search term combinations for mosquito control programs in local government / shire council areas across Australia Search terms - mosquito control shire OR mosquito control council OR mosquito control city – all refined to Australian sites (results reviewed limited to pages 1- 5 for each search combination)	53 shire council/local government areas across Australia report mosquito control management, however only two report information of relevance to this literature review. See Appendix C for details
Information request to City of Greater Geelong	GHD requested information from the City for any background reports or additional information relating to the topic (18/2/2021)	One document - NSW Health, 2019 New approaches to managing mosquitoes and mosquito-borne disease; building on the current mosquito management strategies of City of Greater Geelong, Borough of Queenscliffe, and Surf Coast shire, Victoria. See Appendix C for summary
Google – then internal organisation search (no date limitations)	Google search – focus on key studies including 10 year plus studies, literature reviews focusing on direct and indirect effects to MNES and other ecological values Search term combinations for long term studies OR literature review then S-methoprene OR bacillus thuringiensis israelensis (results reviewed limited to pages 1- 5 for each search combination) Within each article additional key search terms were used including MNES and fish, wader, shorebird, duck, waterbird, plover, frog, sandpiper, species, wetland, Ramsar	16 articles (5 relevant) See Appendix C for details

3.3.3 Question 3

The searching strategy consisted of dividing the non-target species into several taxa, i.e., invertebrates, fish and amphibians. The Google Scholar advanced search included words and commands for each taxon as indicated in Table 9 and Table 10. A complete list of all these studies and their corresponding classification is provided in Appendix A.

In order to filter the search to detect local studies, the word 'Australia' was included in the key parameters. Key parameters addressing the typical endpoint metrics (LC50[2], EC50[3], NOEC[4], NOAEC[5], NOAEL[6], LC10[7], EC10[8], LD 10[9]) etc.) were added to filter studies that provided endpoint values on the effect of the larvicides in species belonging to the particular taxa.

For the invertebrate taxa, the word 'non-target' was added to the search. This term was added to avoid the studies assessing the effectiveness of the larvicides in targeted mosquito species, as the primary objective of the literature review is to identify effects on non-target species.

Given nil results were obtained from the systematic search for algae, a non-systematic search of S-methoprene effects in algae was also undertaken which also provided near-zero results, with the exception of a study mentioned in Competent Authority Report (2016), where a 48 h EC50 of 2.264 mg/L was reported for the alga *Selenastrum capricornutum*. No details were provided on the exposure concentrations and the calculations of the reported value. Whilst it seems unlikely that a synthetic hormone designed to regulate insect growth could interact with microalgae, this study indicates that S-methoprene may have some effect in algae species, although at very elevated concentrations compared with concentrations that affect invertebrates and that are used in field applications.

Table 9 Question 3 – Database sources and search parameters (S-methoprene) and summary of search outcomes.

Taxa	Commands	Key parameters	Summary of search outcomes (number of studies)
Algae[1]	With all the words	algae Australia	N.A
	With the exact phrase	S-methoprene	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Invertebrates	With all the words	non-target invertebrates Australia	38
	With the exact phrase	S-methoprene	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Fish	With all the words	Fish Australia	35
	With the exact phrase	S-methoprene	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Amphibians	With all the words	Frogs Australia	6
	With the exact phrase	S-methoprene	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Total number of studies			80
[1] Search not conducted due to the low relevance of S-methoprene, a synthetic hormone, in algae toxicity			

[2] Concentration that is lethal for 50% of the species population.
[3] Concentrations that produce a certain adverse effect in 50% of the species population.
[4] No Observable Effect Concentration: the maximum concentration that does not cause observable effect in the species tested.
[5] No Observed Adverse Effect Concentration: the highest dose level/concentration of a substance that under defined conditions of exposure causes no observable/detectable adverse effect.
[6] Lowest Observed Adverse Effect Concentration: the lowest dose level/concentration of a substance that under defined conditions of exposure causes observable/detectable adverse effect.
[7] Is the concentration that is lethal for 10% of the species population.
[8] Is the concentration that produce a certain adverse effect in 10% of the species population.
[9] [9] Is the dose that is lethal for 10% of the species population (used when is inoculated as a dose and not as concentration in a medium).

Table 10 Question 3 – Database sources and search parameters (Bti) and summary of search outcomes.

Taxa	Commands	Key parameters	Summary of search outcomes
Algae	With all the words	algae Australia	25
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Invertebrates	With all the words	non-target invertebrates Australia	38
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Fish	With all the words	Fish Australia	47
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Amphibians	With all the words	Frogs Australia	10
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	LC50 EC50 LD50 NOEC NOAEC NOAEL LC10 EC10 LD10	
	Dated between	2015-2021	
Total number of studies			110

3.3.4 Question 4

Question 4 referred to the studies of the larvicides' bioaccumulation potential. The key parameters selected were also filtered for local studies by adding the word 'Australia' and searched for recent literature dated from 2015 - 2021. An initial search using the bioaccumulation metrics BAF (Bioaccumulation Factor) and BCF (Bioconcentrations Factor) did not generate sufficient results to be of use, and the more general words 'bioaccumulation' and its derivative words 'bioaccumulative' and 'bioaccumulate' were used to filter for studies mentioning or referencing bioaccumulation.

A total of 49 studies were reviewed using the Google Scholar advanced search that included words and commands for each taxa as indicated in Table 11 and Table 12. A complete list of all these studies and their corresponding classification is provided in Appendix B.

3.3.5 Question 5

Question 5 aimed to find information on potential endocrine disruption effects in non-target species through the use of the larvicides. In addition to the words added to filters for local and recent studies, the word 'endocrine' was added to the search. The word 'disruption' was removed to avoid the addition of an excessive number of irrelevant results.

A total of 77 studies were reviewed using the Google Scholar advanced search that included words and commands for each taxa as indicated in Table 11 and Table 12. A complete list of all these studies and their corresponding classification is provided in Appendix B.

3.3.6 Question 6

Question 6 referred to the studies on the degradation, fate and transport of the larvicides, which is intrinsically related to the degradability and biodegradability of the substances. Hence, the key parameters added to the search were 'biodegradation' and 'fate', in order to refine the search without adding the words 'transport', which would have added a considerable number of irrelevant results to the search.

A total of 41 studies were reviewed using the Google Scholar advanced search that included words and commands for each taxa as indicated in Table 11 and Table 12. A complete list of all these studies and their corresponding classification is provided in Appendix B.

Table 11 Key parameters and summary of search outcomes for questions 4 to 6 (S-methoprene)

Taxa	Commands	Key parameters	Summary of search outcomes
Question 4: Bioaccumulation	With all the words	Australia	16
	With the exact phrase	S-methoprene	
	With at least one of the words	Bioaccumulation bioaccumulative bioaccumulate	
	Dated between	2015-2021	
Question 5: Endocrine disruption	With all the words	Australia	38
	With the exact phrase	S-methoprene	
	With at least one of the words	Endocrine	
	Dated between	2015-2021	
Question 6: Fate and transport	With all the words	Australia biodegradation fate	6
	With the exact phrase	S-methoprene	
	With at least one of the words	2015-2021	
	Dated between	2015-2021	

Table 12 Key parameters and summary of search outcomes for questions 4 to 6 (Bti)

Taxa	Commands	Key parameters	Summary of search outcomes
Question 4: Bioaccumulation	With all the words	Australia	33
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	Bioaccumulation bioaccumulative bioaccumulate	
	Dated between	2015-2021	
Question 5: Endocrine disruption	With all the words	Australia	39
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	Endocrine	
	Dated between	2015-2021	
Question 6: Fate and transport	With all the words	Australia biodegradation fate	35
	With the exact phrase	Bacillus thuringiensis israelensis	
	With at least one of the words	2015-2021	
	Dated between	2015-2021	

3.4 Literature findings

3.4.1 S-methoprene

The systematic literature review provided 27 relevant results (4 of classification 1 and 23 of classification 2). All classification 1 results provided endpoint values for target species such as the mosquito *Aedes aegypti* (Ramirez-Villalobos 2020) and fruit fly *Bactrocera tryoni* (Ahmed 2021). However, those endpoints were not useful as they were either combined with other larvicides or measured effects too indirectly in relation to S-methoprene. The results classified as classification 2 also included four studies on target species including the mosquito *Culex quinquefasciatus* (Judd, 2018), fly *Parasarcophaga argyrostoma* and the ant *Anoploepis gracilipes* (Bakr and Tanani, 2018; Ghoneim and Al-Keridis, 2019). Yeeles *et al.* (2020) and Staples (2016) studied the efficacy of a mosquito treatment in Kalamunda (Africa) but provided metrics on mosquito population changes rather than effect concentrations.

Overall, the literature search found two studies providing effect endpoints for non-target invertebrate species. Padmanabhan et al (2017) studied the impact of S-methoprene on the spermatogenesis of the crab *Travancoriana schirnerae*, but exposure to S-methoprene was through direct injections rather than in the media water. Hu (2019) studied methoprene effects in the development and reproduction of two freshwater crustaceans, *Neocaridina davidi* and *Moina macrocopa.*

The remaining studies from classification 2 did not provide effect endpoints but provided information relevant for other questions referred to in section 3.2. Beetle et al. (2015) provided information about doses and application rates for methoprene application in Arkansas. Richardson et al. (2020) provided relevant information of mosquito treatments with Bti (see next section).

Two review studies Lawler (2017) and Wijayaratne et al (2018) focused on the S-methoprene effect endpoints in non-target and target species respectively. The review by Lawler (2017) provided the most relevant result for question 1 as it provided a compilation of effect endpoints for numerous species and taxa, including fish, amphibians and aquatic invertebrates, as well as terrestrial vertebrates (birds and livestock) and other non-target insects. A summary of these endpoints is provided in Table 13.

Searches for question 2 search did not provide any bioaccumulation metrics such as BCF or BAF and only provided two studies that mentioned bioaccumulation unrelated to S-methoprene exposure (Tonjes et al. 2018; Sánchez-Bayo, 2019).

Searches for question 3 provided one study that provided an overview of the use of hormone in pest management, including S-methoprene. Several other studies already referenced (Lawler, 2017; Adnan et al., 2018; Wijayaratne, Arthur and Whyard, 2018; Ghoneim and Al-Keridis, 2019; Yeeles et al., 2020) were found in the search but no significant information of endocrine disruption was recalled.

Whilst the fate and transport search did not produce any relevant results, a study detected in several searches (Tonjes et al., 2018) specifically assessed the fate of S-methoprene in temperate salt marshes.

One particularly relevant compilation of studies and assessments pertains to mosquito management undertaken by the Shire of Busselton for the Vasse-Wonnerup Wetlands, which are wetlands of international importance, protected under the Ramsar Treaty. This compilation was identified from the search process for Question 2 using the DAWE EPBC Act referral register, rather than by the systematic literature search. For the Busselton project, mosquito control was implemented by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control.

3.4.1.1 Studies that involve MNES relevant to this project

Questions 1 and 2

The systematic search provided limited results to answer Question 1 - directly linking the two larvicides to MNES. All results from search A and B (Table 10) were classified as 2 (relevant but key term e.g. MNES not found) or 4 (not relevant). The majority of results from search C (Table 10) were classified 4 (n = 566), with many results classified as 2 (58) or 3 (relevant for another question, n = 37). The results presented here are also relevant for this question with regard to Bti.

The search for grey literature and other sources provided limited results to answer Question 2 - directly linking the two larvicides to MNES. The review considered 76 information sources of which six provided relevant information. Of particular interest was the City of Busselton, Western Australia EPBC Act referral (referral number 2016/7780 – see Appendix C) for aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, Western Australia. The referral provides detail regarding the project area, project description and nature of impacts on MNES. It is supported by seven studies of the potential of larvicide application to aquatic invertebrate prey species (Paice 2009, 2010, 2011, 2012, 2013, 2014, 2015). The referral also refers to current literature at the time regarding the effects of using the larvicide on aquatic invertebrates from other countries (e.g. Lagadic, et al., Marina et al., 2014 and Butler et al., 2010).

The remaining five of the seven relevant articles (Allgeier 2019, Land and Miljand 2014, Glare and Callaghan 2005, Russell 2006, and Staples 2016) were classified as 2 and were used to address subsequent questions in this review. The results presented here are also relevant for this question with regard to Bti.

Summary of relevant information

Since 2009, the Shire of Busselton (Western Australia) has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty, so are considered to be a MNES. Mosquito control was implemented by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control.

Rankine (2010) reviewed the mosquito management program for the Shire of Busselton, but the review was more of an investigation into the effectiveness of the management program, rather than an evaluation of its environmental effects.

As part of the Shire of Busselton's investigations into the management of mosquitoes at the Vasse-Wonnerup Wetlands, Paice (2016) undertook monitoring of non-target aquatic invertebrates from 2009 to 2015 in an attempt to determine whether or not food resources for waterbirds are negatively impacted by the use of larvicide. Specifically, Paice investigated pre-and post-treatment sampling in three treatment and three control wetlands associated with 19 applications of S-methoprene and 3 applications of Bti. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti. The conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. Community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application. It was also concluded that the indirect impact on waterbirds through reduced availability of aquatic invertebrates as a food resource was highly unlikely. Paice (2016) considers the results for S-methoprene to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and Paice suggested that continued sampling was required to achieve more confidence in the conclusion.

The action of implementing mosquito control measures in these areas was referred to the Department for the Environment, Heritage, Water and the Arts (DEWHA) in keeping with the requirements of the EPBC Act. The decision from DEWHA was that the action was *not a controlled action if undertaken in a particular manner*.

No other articles reporting effects on specific MNES identified for this project were identified in the literature search. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world.

3.4.1.2 Potential direct and indirect impacts

Question 3

The focus for this literature review was on the effects on non-target organisms. Many of the reviewed articles make no mention of non-target organisms, other than a standard introductory statement based on earlier research, that biological agents are considered safe for the environment, with low impact on non-target organisms (e.g., Bakr and Tanani, 2018).

Some of the non-target organisms of interest here are vertebrates (fish, frogs, reptiles, birds). Many of the studies that consider vertebrates are concerned with effects of larvicides on human health (e.g., Competent Authority Report, 2016); Simmering et al. 2005)). Consequently, there is a focus on mammals, particularly lab-reared mammals such as rats, mice, rabbits, guinea-pigs, cats and dogs. There are also studies that investigate the effects on agricultural animals, including pigs, sheep, cattle. Mammals were not identified as a focal group for this literature search, but the searches resulted in many articles that included information on mammals, as well as other vertebrate groups of interest (e.g., birds).

Effects on vertebrates

Almost all of the literature reviewed concluded that methoprene and S-methoprene are harmless and non-toxic to vertebrates. Much of the research into the effects of this hormone was carried out in the 1990s, prior to the focal period for the literature search (2015 - 2021). Recent articles tend to refer back to the original research, or provide updates to results, rather than repeat the tests for effects.

Competent Authority Report (2016) evaluated S-methoprene and reviewed numerous other studies up to 2009 that focused on the effects of the larvicide on mammals (e.g., Kuhn 1999a, Kuhn 1999b, Kuhn 1999c, Kuhn 1999d, Kuhn 1999e, Leeper 1999, Ford 2009, Ford 2010, Szakonyi 2002, Hernadi 2002, Beres 2002, Beres 2003, Torok 2007, Kolep 2009)[10]. A lot of specific information has been redacted in the freely accessible version of the report, but the outcomes and conclusions for most applications of the larvicide are accessible. Almost invariably, studies found no lethal or consistent sub-lethal effects on mammals (Glare and O'Callaghan 1999; USEPA 2000 and ESFWS 1984 in Anon 2017), unless doses are extraordinarily high (Simmering et al. 2005), and far higher than any field application would be able to achieve. Fairly consistently, the advice given following an evaluative review of each study concluded that: "S-methoprene remains unclassified and requires no symbols or risk phrases".

No evidence was found that S-methoprene is mutagenic (Hernadi 2002, Beres 2002, in Competent Authority Report 2016; Simmering et al. 2005), clastogenic (causes chromosomal aberrations) (Beres 2003, in Competent Authority Report 2016), oncogenic (tumour causing), a skin sensitiser, or has effects on vertebrate (mammals and birds) reproduction (Simmering et al. 2005). One study (Kuhn 1999d, in Competent Authority Report 2016) observed minor eye irritation in rabbits, which was quickly reversible.

Non-lethal effects on birds have been reported at very high doses. Effects included "slowness, reluctance to move, sitting, withdrawal, and poor coordination, potentially decreasing bird survival by making them temporarily more susceptible to predation" (Hudson et al. 1984, in Simmering et al. 2005). Anon (2017) also reported methoprene has slight acute avian toxicity, observing some reproductive impairment in Mallards at a dietary dose of 30 ppm, but no effects at 3 ppm (USEPA 1991). Anon (2017) calculated the estimated environmental concentration of Methoprene as 3 ppm (in short grass) after application of Altosid, calculated as a dose rate of 0.13 lbs a.i/a.c., equivalent to 0.15 kg a.i./ha. This rate is similar to the application rates proposed by the City (Table 15).

Methoprene may have slightly higher toxicity to fish (USEPA 2000, ESFWS 1984; in Anon 2017; Glare and O'Callaghan, 1999). While a description of the effects could not be found in the articles reviewed, Glare and O'Callaghan (1999) conclude that acute fish toxicity would not be expected during mosquito control programmes as the methoprene concentration remains well below the levels needed to induce the effect (Anon 1973 and Ross et al. 1994b; in Glare and O'Callaghan 1999). Other studies also acknowledge that S-methoprene can have negative impacts on fish (Kuo et al., 2010, in Staples 2016).

[10] Unpublished reports, as referred in Competent Authority Report (2016)

Anon (2017)) concludes that, for birds, fish and mammals, the RQ (risk quotient) for Methoprene is below the LOC (level of concern) for the USA Environment Protection Authority (EPA). For most risk assessments, EPA uses a deterministic approach or the quotient method to compare toxicity to environmental exposure. Calculation of risk quotients are based upon ecological effects data, pesticide use data, fate and transport data, and estimates of exposure to the pesticide.

The lack of effects observed in vertebrates generally is explained by the way S-methoprene works, and comparing invertebrates with vertebrates (mammals, in this case): "…toxicity to insects is manifest through interference with metamorphosis, a process without parallel in mammals." (Simmering et al. 2005).

S-methoprene may affect amphibians more than other terrestrial vertebrates. Methoprene (not specifically S-methoprene) was implicated in observations of frog deformities in the USA in the mid-1990s. However, extensive subsequent investigations into this association were never able to replicate the effects and, with more likely explanations now forthcoming (e.g., infection with parasitic Trematodes), it is now thought to be unsubstantiated (reported in Simmering et al. 2005; Stark 2005).

Pauley et al. (2014) investigated the effects on tadpoles of three forms of mosquito control used in the USA: 'Mosquito Dunks', 'Mosquito Bits' (both are formulations of Bti) and 'Mosquito Torpedoes' (a methoprene formulation). Use of the methoprene formulation resulted in the lowest tadpole survival rates when applied in the presence of tadpole predators (aquatic). 'Mosquito Dunks' also reduced tadpole survival in the presence of predators, while 'Mosquito Bits' had no survival effect on tadpoles. Other studies also acknowledge that S-methoprene can have negative impacts on amphibians (Kuo et al., 2010, in Staples 2016).

While the reduced survival of tadpoles with Methoprene is concerning (as concluded by Pauley et al. 2014), context around the observations is required. 'Mosquito Torpedoes' are designed for slow release of Methoprene for longer-term mosquito control (up to 60 days), which differs from aerial application of S-methoprene. Also, aquatic tadpole predators prey on aquatic invertebrates also. S-methoprene is toxic to many aquatic invertebrates, and it is possible that the methoprene served to remove prey choice from the predators, thereby resulting in more tadpoles being eaten (Pauley et al. 2014). Also, Pauley et al. (2014) noted that the commercial products tested are likely to have contained active or inert ingredients other than methoprene, and that the effects of those ingredients are unknown. Ingredients are not disclosed in the MSDS of the products listed Table 2 (Vectobac G -Granule, Prolink XR -Briquets and ProLink ProSand) and are labelled as "secret", protected by patent of the product.

No reference to reptiles was found during the review.

Non-target invertebrates

S-methoprene is a synthetic hormone that regulates insect growth, preventing larvae from developing into adults and reproducing (Simmering et al 2016). It is used for mosquito control, but its effects are non-specific to mosquitoes. It is not surprising, therefore, that many of the reviewed articles reported effects in non-target aquatic invertebrates (e.g., Glare and O'Callaghan 1999; Siemering et al. 2005; Kuo et al., 2010, in Staples 2016; Anon 2017).

The New Zealand Government evaluated the use of Methoprene as a pesticide more than 20 years ago (Glare and O'Callaghan 1999). They reported: "Methoprene is toxic to a range of insects from 12 orders, including Diptera, Lepidoptera and Coleoptera. Methoprene also kills some mite species. It is most toxic to Diptera, but has been used in the field against a number of pests such as mosquitoes, biting flies, hornflies, ants, hemipteran pests and termites."

Methoprene (not reported specifically as S-methoprene) was found to have detrimental effects on two aquatic non-target crustaceans, where chronic exposure reduced body length and moulting frequency, and for one species, caused shortened life expectancy, repressed body development, and reduced fecundity (Hu 2019). Padmanabhan et al. (2017) found that sublethal doses impaired ovarian growth and resulted in a reduced proportion of mature oocytes in non-target freshwater crabs.

Tonjes et al. (2018) reported on a localised collapse of a lobster industry, thought to be associated with use of Methoprene: "*The 1999 collapse of the Long Island Sound lobster fishery was linked by litigants and in the press to widespread pesticide use following the initial West Nile virus (WNV) outbreak in the New York City area. It was suspected that the pesticides applied in urban settings and marshes washed into open waters where it would not affect mosquitoes but could impact other organisms, such as lobsters. An investigation of the die-off did not find methoprene or other mosquito pesticides to be important factors (but did not rule out potential contributory effects) (Pearce and Balcom 2005).*"

Tonjes et al. (2018) also reported effects on non-target invertebrate populations in areas where mosquitoes develop in numerous studies since the 1970s. Taxa included: mayflies and dytiscid beetles (Norland and Mulla 1975, in Tonjes et al. 2018), scud, shrimp and prawn populations, flies, midges, chironomidae larvae, and several species of beetles (Breaud et al. 1977, in Tonjes et al. 2018), insects generally, especially predatory insects, and most especially chironomidae (Hershey et al. 1998 in Tonjes et al. 2018; Stark 2005).

However, other studies reported by Tonjes et al. (2018) did not find impacts (Lawler et al. 2000; Pinckney et al, 2000). Breaud et al. (1977, in Tonjes et al. 2018) found that, alongside negative effects on insects, water boatmen nymphs, moth fly larvae, diving beetles, and crawfish populations increased. Butler et al. (2010) undertook field and laboratory trials, and found no evidence of reduced abundance of any invertebrate taxa attributable to methoprene application, and no consistent changes in community-level parameters related to methoprene application.

Many earlier studies were done in laboratories or mesocosms, rather than in the field. Whether the doses that caused effects in experiments match those experienced in the field during mosquito control operations is not certain. Glare and O'Callaghan (1999) suggested that doses used in the field are typically low: "The lethal dose required to kill common mosquitoes is generally around 1 part per billion. Field application rates used against mosquitoes would be unlikely to be lethal to many other insects"

An assessment of impacts of Methoprene on non-target soil invertebrates and soil function indicated that, at an application rate of 2 kg/ha 3 times a year, no detectable effects were seen in the measured variables (Fuessel 2013).

Dose

The effects of Methoprene are likely to be inextricably linked to application dose. Lawler (2017) concluded that "*realized environmental concentrations of methoprene were usually 2–5 µg/kg (range 2–45 µg/kg) and that its motility is limited. These levels were not toxic to the vast majority of vertebrates and invertebrates tested in laboratories, except for a few species of zooplankton, larval stages of some other crustaceans, and small Diptera. Studies in natural habitats have not documented population reductions except in small Diptera*".

In the early 1990s, concerns expressed by the US EPA resulted in a thorough review of the toxic effects of S-methoprene. The review found that, when used at recommended mosquito-control doses, S-methoprene poses a low risk to non-target species, including estuarine invertebrates (US EPA, 2001; in South Australia 2006).

Effects on non-target organisms generally appear to have been at doses considerably higher than label recommendations (Glare and O'Callaghan 1999). According to Glare and O'Callaghan (1999), the dose of Methoprene required to kill mosquitoes is generally approximately 1 ppb[11], and field application rates used against mosquitoes are unlikely to be lethal to many other insects.

3.4.1.3 Bioaccumulation, degradability, multigeneration, endocrine disruption and long-term effects

Questions 4, 5 and 6

Little was found on bioaccumulation, multigeneration effects, or endocrine disruption as a result of S-methoprene application.

The literature reports fairly consistently that Methoprene breaks down quickly in the environment and appears to have few lasting effects after treatment (review of numerous studies by Glare and O'Callaghan 1999).

[11] Parts per billion

Methoprene is reported to have low persistence in soils, with a half-life up to 10 days (US EPA 1982, Glare and O'Callaghan 1999; in Fuessel 2013). Its breakdown is thought to be attributable to microbial degradation, but it also degrades rapidly in sunlight (US EPA 1991, in Fuessel 2013). The solubility of methoprene in water has been reported as 1.4 mg/L (ANZG 2018) which indicates that at environmental concentrations, expected to be much lower than 1.4 mg/L, S-methoprene degrades rapidly in water (Menzie 1980, Hartley and Kidd 1991, in Fuessel 2013).

Methoprene is not persistent in mammals, and is rapidly and completely broken down and excreted, mostly in the urine and faeces (EXTOXNET 1996, in Siemering et al. 2005), and mostly within 24 to 48 hours of administration (Ford 2009, in Competent Authority Report 2016). Whether this breakdown occurs similarly in other vertebrates was not evident in the articles reviewed. No bioaccumulation was observed in animals that ate mosquito or midge larvae treated with Methoprene (Siemering et al. 2005).

There appears to be some evidence of short-term bioaccumulation of Methoprene in some organisms. Methoprene residues were reported to bioconcentrate in fish and crayfish, but it was noted that up to 95% of the residue in fish was excreted within 14 days (USEPA 1991, in Anon 2017). It must be noted that this was reported from a toxicity test and not a bioaccumulation test, hence standard depuration rates have not been reported.

Many of the early toxicology studies were done in laboratories or mesocosms. One study investigated the long-term ecological impacts of S-methoprene (and Bti) under field conditions, with results that contradicted those from many laboratory-based experiments (Hershey et al. 1998, in Russell 2006). In that study, density of freshwater insects was found to be significantly reduced for 3 years during repeated applications of Bti and S-methoprene. Another, however, found that Methoprene was close to undetectable within 1 day in 1-m deep saltmarsh ditches, and present but without accumulation in marsh sediments, despite repeated applications (Tonjes et al. 2018). Tonjes et al. (2018) further noted that Methoprene concentrations observed in the saltmarsh ditches were below those found to be of ‘toxicological significance’ in other studies.

Given the way S-methoprene tends to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are not expected Stark (2005). Rapid recolonisation of sites by target mosquitos themselves, thereby requiring repeated treatments, attests to this too.

In relation to the potential effect of metabolites of degradant products, it is noted that adverse effects were observed in embryonic development of the amphibian species *Xenopus laevis* after exposures of 1µL/L of several S-methoprene degradants (La Clair et al 1998).

3.4.1.4 Key studies using similar applications

Nearly all articles reviewed related to the use of Methoprene as a mosquito control agent. However, no study reviewed reported on an application exactly the same as the one used or proposed by the City. Tonjes et al. (2018) shows most similarity - aerial application of S-methoprene (and Bti) in saltmarsh environments in north-eastern USA.

Another particularly relevant article focussed on mosquito control, using Bti and Methoprene, to suppress human disease outbreaks at an American wildlife refuge, which had been established to provide habitat for migratory birds, in particular waterfowl (Anon 2017). The larvicidal products were chosen because of their safe environment record and low impacts on non-target organisms.

Perhaps the most similar application found for review is that of the mosquito management actions and investigations by the Shire of Busselton. Since 2009, the Shire of Busselton has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands, in Western Australia. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty. Mosquito control was implemented by the use of S-methoprene (sand-based formulation) and involved helicopter application for expansive areas requiring control. Rankine (2010) reviewed the mosquito management program for the Shire of Busselton, but the review was more of an investigation into the effectiveness of the management program, rather than an evaluation of its environmental effects. Elscot (2009) reported on bird disturbance effects for helicopter application of S-methoprene in the Vasse-Wonnerup Wetlands, and emphasised the important distinction between observable responses (effects) and longer term, non-observable population responses (impacts).

As part of the Shire of Busselton's investigations into the management of mosquitoes at the Vasse-Wonnerup Wetlands, Paice (2016) undertook monitoring of non-target aquatic invertebrates from 2009 to 2015 in an effort to determine whether or not food resources for waterbirds are negatively impacted by the use of larvicide. Specifically, Paice investigated pre-and post-treatment sampling in three treatment and three control wetlands associated with 19 applications of S-methoprene and three applications of Bti. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti. The conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. Community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application. It was also concluded that the indirect impact on waterbirds through reduced availability of aquatic invertebrates as a food resource was highly unlikely. Paice (2016) considers the results for S-methoprene to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and Paice suggested that continued sampling was required to achieve more confidence in the conclusion.

The management program is relevant to the City's application in that it relates to larvicide treatment in the Vasse-Wonnerup Wetlands, which are wetlands of international importance, protected under the Ramsar Treaty. Mosquito control was implemented by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control.

3.4.1.5 Key studies for dietary effects and secondary poisoning

No evidence of secondary poisoning was found in articles reviewed, but few articles investigated or focussed on this aspect. One study reported that: "no bioaccumulation of methoprene has been seen in animals that have eaten mosquito or midge larvae treated with Methoprene" (Siemering et al. 2005). Niemi et al. 1999 (in Anon 2017) reported that birds are not negatively affected by feeding on foods exposed to Methoprene (or Bti) – no effects were seen in Red-winged blackbirds breeding in mosquito treatment areas.

No evidence was found of indirect food-chain effects (i.e., effects of reduced insect population on insect predators). In the USA, the US EPA (1996) found no substantial evidence to support the suggestion that waterbirds and waterfowl are affected. Siemering et al. (2005) concluded for aquatic systems: "although methoprene, at label rates for mosquito control, can prevent adult emergence of midges, it does not directly kill mosquito or midge larvae and therefore does not remove them from the food chain".

In the terrestrial system, Hanowski et al. (1997, in Anon 2017) found no negative effects in 19 different bird species on wetlands two years before treatment and three years after treatment using Methoprene (and Bti).

3.4.1.6 Summary of key findings – S-methoprene

Methoprene is widely accepted to be non-toxic to higher vertebrates, including birds and mammals (and humans), following "repeated, comprehensive toxicological evaluations of methoprene and S-methoprene over several decades" (Siemering et al. 2005).

The most often reported concern regarding methoprene is its non-specificity in the aquatic environment. S-methoprene can negatively impact non-target insect larvae, crustaceans, and potentially amphibians and fish (Kuo et al., 2010, in Staples 2016). However, Methoprene's low persistence in the environment reduces the potential for impacts on non-target organisms and evolution of resistance (Wolterink et al. 2001, in Fuessel 2013), and Glare and O'Callaghan (1999) noted that, while negative impacts on some organisms were observed, recovery after application was rapid.

There appears to be consensus in the literature reviewed that the need for mosquito control outweighs the potential for non-target impacts caused by Methoprene. According to Glare and O'Callaghan (1999), "Methoprene will have some non-target impacts, but breaks down rapidly after application and should cause less environmental disruption than most available mosquitocidal chemicals". Russell (2006), too, concluded that applications of S-methoprene are "one of the most environmentally sound methods of mosquito control currently available."

The effects of Methoprene are likely to be inextricably linked to application dose. Higher application doses are more likely to result in non-target effects. Doses used historically, and proposed for continued use, by the City are invariably low, compared with lethal doses.

The most closely aligned application of S-methoprene discovered in this review was by the Shire of Busselton for larvicide treatment in the Ramsar-listed Vasse-Wonnerup Wetlands in Western Australia. Reports from investigations relating to that application have consistently concluded that there was no evidence of adverse impacts of larvicide use on non-target organisms - community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application (Paice 2016).

3.4.2 Bti

The systematic literature review provided 18 key articles for review on Bti only. Articles focused on a broad range of applications, potential effects and potential non-target organisms, including: rats, bats, birds, tadpoles, arthropods, other aquatic invertebrates, non-standard microcrustacean species and flies. Other studies focussed more on human concerns (Malaria, food safety, plants and vegetables), but still presented information relevant to this literature review. In addition, a number reported on the general environment and distribution of Bti.

Seven articles provided toxic effects endpoints (classification one). Four of these correspond to the targeted mosquitoes *Culex quinquefasciatus* (Judd, 2018), *Aedes caspius* (Ahmed et al., 2021) and *Aedes aegypti* (Alto and Lord, 2016; Nair et al., 2020), and the fly species *Musca domestica* (Salama, Ismail and Khattab, 2016).

Three studies provided endpoints for non-targeted species including *Chironomus riparius* (Bordalo et al., 2021), amphibian tadpoles species *Rhinella arenarum*, *Rhinella fernandezae*, and *Physalaemus albonotatus* (Junges et al., 2017) and five microcrustacean species, i.e. two copepods, *Tropocyclops prasinus* and *Acantocyclops americanus* and three cladocerans, *Ceriodaphnia reticulata*, *Chydorus sphaericus*, and *Daphnia cf. pulex* (Olmo et al., 2016). A summary of the above endpoints is provided in Table 14.

The remaining studies are classified as classification 2 and, hence, do not provide direct measurement of the effect of Bti in non-target species. However, some of these studies correspond to a doctoral thesis that provided an extensive literature review that included references to toxic effect endpoints (Suter et al., no date; Tamilselvan, 2015; Miller, 2019; Gowelo, 2020; Rizali, 2020). In particular, the research conducted by Miller (2019), also provided information about application forms of Bti, mode of action and environmental factors affecting the efficacy to control targeted populations.

The review of the bioaccumulation studies for Bti provided only one result that included the word bioaccumulation in the references (Bordalo et al., 2020). Similarly, whilst the *endocrine disruption* search found three studies mentioning the word “endocrine” all were in the references section (Junges et al., 2017; Lawler, 2017) or mentioned briefly in the introduction (Lagadic et al., 2016). The *fate and transport* search identified four studies, one of them also resulted in mention in the reference section (Lawler, 2017). Two studies provided reviews of the fate and transport of emerging contaminants, including Bti (Dara, Goble and Shapiro-Ilan, 2018; Pignotti, 2018) but only provided vague information. The most relevant result of the fate and transport search was a study by Maletz et al., (2015), where endocrine-disrupting effects are investigated on targeted mosquito species.

Several of the remaining results corresponded to general studies about insecticides (Sánchez-Bayo and Tennekes, 2017; Arora, 2019) with no direct information useful to answer the questions specified in section 3.3. Lawler, (2017) also provided a review of environmental effects for several pesticides, including Bti, but information was vague and relied on other studies.

One particularly relevant compilation of studies and assessments pertains to mosquito management undertaken by the Shire of Busselton for the Vasse-Wonnerup Wetlands, which are wetlands of international importance, protected under the Ramsar Treaty. For the Busselton project, mosquito control was implemented mostly (but not entirely) by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti.

3.4.2.1 Studies that involve MNES relevant to this project

Questions 1 and 2

Since 2009, the Shire of Busselton (Western Australia) has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty, so are considered to be an MNES. For the Busselton project, mosquito control was implemented mostly (but not entirely) by the use of S-methoprene (sand-based formulation), and involved helicopter application for expansive areas requiring control. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti.

The action of implementing mosquito control measures in these areas was referred to the Department for the Environment, Heritage, Water and the Arts (DEWHA) in keeping with the requirements of the EPBC Act. The decision from DEWHA was that the action was *not a controlled action if undertaken in a particular manner*.

The City of Busselton and Shire of Capel obtained a permit (2012 to 2017) to apply solid (VECTOBAC G) or liquid (TEKNAR 1200 SC) forms of Bti application at a rate of 7 kg/ha (solid) or 1.2 l/ha (liquid). For each application, permission was to treat up to a maximum total area of 1,500 ha per year.

No other articles reporting effects on specific MNES identified for this project were identified in the literature search. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world.

One article reviewed reported on a study in a Ramsar site in Europe: Albufera Natural Park (Valencia, Spain)(Ramsar site no. 454) (Olmo et al. 2016).

3.4.2.2 Potential direct and indirect impacts

Questions 3

The focus for this literature review was effects on non-target organisms. Many of the reviewed articles make little or no mention of non-target organisms, other than a standard introductory statement based on earlier research, that Bti is reported to be environmentally safe because it does not cause adverse effects on humans, livestock or other non-target beneficial species.

Effects on vertebrates

Bti is widely considered safe for vertebrate fauna. Laboratory tests, necessary for the registration of Bti as a commercial product, have confirmed the safety of Bti for other vertebrates, including mammals (Saik et al. 1990, Siegel and Shadduck 1990, Sudha Rani 1996, Siegel 2001, Arteaga et al 2014; in Tamilselvan 2015; Recluse et al no date).

In an evaluative review of numerous articles, Anon (2017) reports that Bti has practically no acute or chronic toxicity to mammals, birds, fish or vascular plants, and no acute toxicity to amphibians, fish or crustaceans. Furthermore, environmental exposure to Bti is considered to be negligible for most birds, mammals, bees, and non-target arthropods other than bees (EFSA 2013).

For mammals (laboratory rats, dogs, mice, rats, guinea pigs and rabbits) using oral exposure, inhalation exposure, intravenous exposure, intraperitoneal exposure, dermal exposure, little or no adverse effects were reported, even at very high doses (EFSA 2013; Ahmad et al. 2015). Mild symptoms were seen in albino rabbits (minor skin irritation around eye). For birds (Mallard and Northern Bobwhite), LC50s were very high, which suggests very low toxicity (EFSA 2013). For fish, long exposure times and high LC50s also suggest low toxicity (EFSA 2013). Note that these studies used LC50/LD50 and NOEC (no observed effects concentration), which do not reflect long-term exposure effects such as cancer, birth defects, or reproductive toxicity.

Nair et al. (2020) provide an explanation for the general absence of effects in vertebrates: "*the insecticidal crystal proteins, called δ-endotoxins, target specifically pathogenic insects with no harmful effect on vertebrates (Lacey, 2007; Merritt et al., 1989; Lee and Scott, 1989*)" (in Nair et al. 2020).

For birds, pesticides such as Bti may have no direct effects on avian populations, but they may impact prey availability, thereby influencing time spent for foraging (Brunk et al 2019). Work by Poulin et al. (2010) (cited in Brunk et al 2019) raised concern for the safety of Bti with birds in France, thereby re-igniting the debate about the environmental safety of Bti (Lagadic et al 2016). For Bti and the House Martin (*Delichon urbanicum*), the intake of Diptera (Nematocera) and predators of Diptera (Arachnida and Odonata) decreased significantly at treatment sites: "*At treated sites, two effects occurred: a significantly higher rate of very small prey was consumed, but total foraging rates were lower. Clutch size and nestling survival were significantly lower at treatment sites*" (Poulin, 2012; Poulin et al., 2010; in Brunk et al 2019).

Similarly for insectivorous bats, indirect effects may include reduced food, which could have knock-on effects of habitat selection and community dynamics, and ingestion of contaminated prey (Brunk et al 2019). For bats, direct exposure is likely to be low, because bats are secreted away during the daytime when application would occur.

For amphibians, tadpoles of three species (*Rhinella arenarum*, *Rhinella fernandezae*, and *Physalaemus albonotatus*) were exposed to commercial formulations of insecticides, including a commercial liquid formulation of *Bacillus thuringiensis* var. *israelensis* (Introban®) (Junges et al. 2017). Acute toxicity was evaluated in terms of median lethal concentration (LC50), no observed effect concentrations (NOEC) and lowest observed effect concentrations (LOEC). The results showed that tadpole species were affected differently depending on the chemical properties of the pesticide and on a dose response effect of the insecticide. The main finding for Bti (Introban®) was that sub-lethal effects were observed – treatment tadpoles were less active in their swimming, which could have implications for predation (Junges et al. 2017).

Lajmanovich et al. (2015) also found that Introban® affected tadpoles. Introban® was found to be relatively toxic for tadpoles of *Leptodactylus latrans* (LC50–48h=22.45mgl−1), and also "*altered enzymes of oxidative stress, induced genotoxicity, and caused intestine damage at sublethal concentrations*" (in Junges et al. 2017).

Allgeier (2019) found that Bti treatment alone did not lead to acute toxic effects on amphibian larvae (European common frog *Rana temporaria*), but found hints of sub-lethal effects, in the form of potentially increased energy demand from "investment in subcellular responses to xenobiotics". Allgeier (2019) wrote: "*exposure to Bti induced significant increases of GST (37 - 550%), GR (5 - 140%) and AChE (38 – 137%) irrespectively of the applied formulation, indicating detoxification, antioxidant responses as well as an alteration of neuronal activity*."

Pauley et al. (2014) investigated the effects on tadpoles of two forms of Bti mosquito control used in the USA: 'Mosquito Dunks', 'Mosquito Bits' (both are formulations of Bti). 'Mosquito Bits' had no survival effect on tadpoles, while 'Mosquito Dunks' reduced tadpole survival slightly, and only in the presence of tadpole predators (aquatic). While the reduced survival of tadpoles with 'Mosquito Dunks' is concerning, context around the observations is required. 'Mosquito Dunks' are designed for slow release of Bti for longer-term mosquito control (>30 days), which differs from aerial application of Bti used by and proposed by the City. Pauley et al. (2014) note that the commercial products tested are likely to have contained active or inert ingredients other than Bti, and that the effects of those ingredients are unknown. Anon (2017) provides a similar cautionary note: while Bti itself may not be toxic, other ingredients in Bti formulations are potentially toxic.

Other than once in Brunk et al (2019), no reference to reptiles was found during the review.

Non-target invertebrates

According to Gowelo (2020), "*strains of the bacteria Bacillus thuringiensis var. israelensis (Bti) are widely used as active ingredients in larvicides because they do not cause harm to non-target organisms or the environment* (Kandyata et al. 2012, Aïssaoui and Boudjelida 2014; in Gowelo 2020)." This has been attributed to the specificity of Bti's endotoxins (Gwal et al. 2015, in Gowelo 2020) and its low persistence under field conditions (Davis and Peterson 2008, Tetreau et al. 2012, Fayolle et al. 2016, in Gowelo 2020). Bti did not affect the entire range of organisms that inhabited a saltmarsh community (Russell 2006; Russell *et al.* 2009).

For invertebrates (laboratory and field studies), EFSA (2013) reported that there is little evidence of adverse effects caused by Bti. Studies in lentic and lotic (still versus flowing) habitats have shown little or no effects of Bti on most non-target organisms (Merritt et al. 1989, Lacey and Mulla 1990, Molloy 1992, Boisvert and Boisvert 2000, Jackson et al. 2002, WHO 2007; in Tamilselvan 2015; Caquet et al. 2011, Lagadic et al. 2014, in Junges et al. 2017).

Tamilselvan (2015) tested non-target organisms with a Bti dose at 10 times the concentration of one known to kill 90% of the least susceptible mosquito species (*Anopheles stephensi*), and reported no mortality of organisms during the experimental period.

In a longer-term study (up to four years), Lagadic et al (2016) found no association between the use of Bti for mosquito control and the dynamics of non-target aquatic invertebrates (focussing on Chironomids) in French coastal and continental wetlands, providing the following summary of findings:

"1) Bti dosages recommended for mosquito control do not affect non-target invertebrates.

2) The abundance of most-at-risk chironomids varies independently from Bti treatments.

3) No immediate or long-term effects were shown on invertebrate diversity and abundance.

4) Invertebrate community dynamics are mainly driven by flooding frequency and duration."

WHO (2009; in Junges et al. 2017) considers Bti safe to be used in waterbodies, containers and even in drinking water. Marina *et al.* (2014) investigated the efficacy and non-target impact of Bti and other larvicides in southern Mexico. Aquatic insect diversity were highest in the control and Bti treatments, and lower in treatments using other larvicides. The results found that Bti had little effect on aquatic insects generally.

That said, Bti is engineered to kill selected invertebrates, so detection of effects is likely to depend on which organisms are sampled. Bti is known to affect non-target chironomids (closely related to mosquitos), potentially changing invertebrate community structure (Anon 2017; Stark 2005). The effects of Bti on chironomids is still debated in the scientific community. Some studies show reduced chironomid abundance in wetlands after Bti application (Hershey et al., 1998; Jakob and Poulin, 2016; in Allgeier 2019) while others found no negative effects (Duchet et al., 2015; Lagadic et al., 2016; Lundström et al., 2010b; Wolfram et al., 2018; in Allgeier 2019).

Allgeier (2019) cautions against sampling one group only, and suggests that no observable effects on chironomids (or other non-target organisms) need to be supported by observed and measured reductions in the mosquito abundance. "*Otherwise it could also be possible that the applied concentration was ineffective* [to both mosquitoes and chironomids] *due to environmental conditions*."

Olmo et al. (2016) undertook laboratory experiments, using Bti on zooplankton collected in the wild from wetlands that have been treated with Bti for decades. While responses were variable, the authors found a general pattern of increasing mortality with concentration and time, and conclude that negative effects of Bti, using doses close to those used in field applications, are possible or even probable at the community level (zooplankton).

One study investigated the long-term ecological impacts of Bti under field conditions, with results that contradicted those from many laboratory-based experiments (Hershey et al. 1998, in Russell 2006). In that study, density of freshwater insects was found to be significantly reduced for 3 years during repeated applications of Bti and S-methoprene. The degree to which Bti contributed to this observation is not known. The decrease in insect populations is thought to be from direct toxicity effects (specifically to Diptera) and secondary effects from a disruption to the invertebrate food chain (South Australia 2006).

Dose

As for most pesticides, the effects of Bti may be linked to application dose. However, there appears to be less data in the literature to support this than there is for S-methoprene, and the results of some studies suggest that dose may not be important. Tamilselvan (2015) tested non-target organisms with a Bti dose at 10 times the concentration of one known to kill 90% of the least susceptible mosquito species (*Anopheles stephensi*), and reported no mortality of organisms during the experimental period.

For the Pauley et al. (2014) test of slow-release formulations ('Mosquito Dunks' and 'Mosquito Bits') on tadpoles, reduced tadpole survival may have been linked to the duration of the exposure (30 or 60 days).

The biomass, abundance and diversity of microorganisms were shown to be affected only by a high dosage of VectoBac® G (approx. twice the maximal application rate recommended for mosquito control) applied in outdoor aquatic microcosms (Duguma et al. 2015, in Lagadic et al 2016).

Junges et al. (2017) commented that Bti (Introban®) had low toxicity to tadpoles, but that recommended doses applied to extensive areas of differing depths may result in Bti being applied in doses that are more toxic to tadpoles and other non-target organisms than reported in this study. There are no data for this.

Lagadic et al (2016) concluded that, when following recommended application rates and best mosquito control practices, Bti treatments had "*no detectable influence on the dynamics of non-target aquatic invertebrate communities, including chironomids, in coastal and continental wetlands, where environmental factors are the driving forces of these communities*".

3.4.2.3 Bioaccumulation, multigeneration, endocrine disruption

Questions 4, 5 and 6

Little was found in the Bti literature on bioaccumulation, multigeneration effects, and endocrine disruption.

Lagadic et al (2016) investigated the potential endocrine-disrupting effects of several Bti formulations, but detected no sign of endocrine activity.

EFSA (2013) discussed the potential for transfer of genetic material from Bti to other organisms, given that "*bacilli are known to have the capacity to transfer genetic material through exchange of plasmids*". In the absence of data on this, EFSA (2013) calls for assessment to demonstrate that this transfer does not occur or does not lead to unacceptable effects on the environment.

The literature reports fairly consistently that Bti has low persistence under field conditions (Davis and Peterson 2008, Tetreau et al. 2012, Fayolle et al. 2016; in Gowelo 2020).

Alto and Lord (2016) suggested that mosquitoes that survive treatment with Bti may actually gain an advantage: "*survivors will have a fitness advantage (growth, development, enhanced production of eggs) relative to conspecifics that are not under larvicide pressure. However, under most circumstances, these transstadial effects are unlikely to outweigh reductions in the adult population by Bti*."

Given the way Bti tends to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are not expected Stark (2005).

3.4.2.4 Key studies using similar applications

Nearly all articles reviewed related to the use of Bti as a mosquito control agent. However, no study reported on an application exactly the same as the one used by The City. Tonjes et al. (2018) shows most similarity - aerial application of Bti (and S-methoprene) in saltmarsh environments in north-eastern USA.

Another particularly relevant article focussed on mosquito control, using Bti and Methoprene, to suppress human disease outbreaks at an American wildlife refuge, which had been established to provide habitat for migratory birds, in particular waterfowl (Anon 2017). The larvicidal products were chosen because of their safe environment record and low impacts on non-target organisms.

Olmo et al. (2016) investigated zooplankton collected from a wetland that had been treated with Bti for decades. The wetland is Albufera Natural Park (Valencia, Spain), a Ramsar site (no. 454).

Perhaps the most similar application found for review is that of the mosquito management actions and investigations by the Shire of Busselton. Since 2009, the Shire of Busselton has been investigating the environmental effects of larvicides, alongside its larvicidal management of mosquitoes at the Vasse-Wonnerup Wetlands, in Western Australia. The Vasse-Wonnerup Wetlands are wetlands of international importance, protected under the Ramsar Treaty. For the Busselton project, mosquito control was implemented by helicopter application for expansive areas requiring control. S-methoprene alone was used from 2009 to 2014, after which it was used in association with Bti.

Rankine (2010) reviewed the mosquito management program for the Shire of Busselton, but the review was more of an investigation into the effectiveness of the management program, rather than an evaluation of its environmental effects.

As part of the Shire of Busselton's investigations into the management of mosquitoes at the Vasse-Wonnerup Wetlands, Paice (2016) undertook monitoring of non-target aquatic invertebrates from 2009 to 2015 in an effort to determine whether or not food resources for waterbirds are negatively impacted by the use of larvicide. Specifically, Paice investigated pre-and post-treatment sampling in three treatment and three control wetlands associated with 19 applications of S-methoprene and 3 applications of *Bacillus thuringiensis var. israelensis* (Bti).

The conclusion drawn after seven years of aquatic invertebrate sampling was that no evidence was found of adverse impacts of larvicide use on non-target organisms, for either S-methoprene or Bti. Community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application. It was also concluded that the indirect impact on waterbirds through reduced availability of aquatic invertebrates as a food resource was highly unlikely. Paice (2016) considers the results for S-methoprene to be conclusive, owing to the long-term data set. For Bti, however, only three applications were undertaken and Paice suggested that continued sampling was required to achieve more confidence in the conclusion.

Relationship between application rate and aquatic exposures of Bti

No relevant information has been found in the systematic literature review about the environmental concentrations of Bti after application rates similar to those proposed by The City. Hence, a non-exhaustive literature review was conducted to target studies providing that type of information. This found a study by Weeks and Parris (2020) providing Estimated Environmental Concentration (EEC) for *Bti* based on the USEPA (1996) method. According to that study, an application rate of 2 fl oz/1000 sq. ft (equivalent to 6.1 kg/ha) has a calculated EEC of 0.0042 ml/L in wetlands nearby agricultural application and runoff following rainfall.

3.4.2.5 Key studies for dietary effects and secondary poisoning

No evidence of secondary poisoning was found in articles reviewed, but few articles investigated or focussed on this aspect. Niemi et al. (1999, in Anon 2017) reported that birds are not negatively affected by feeding on foods exposed to Bti – no effects were seen in Red-winged blackbirds breeding in mosquito treatment areas.

One important group of studies provides evidence of direct or indirect food-chain effects (i.e., effects of reduced insect population on insect predators). For birds, pesticides such as Bti may have no direct effects on avian populations, but they may impact prey availability, thereby influencing time spent for foraging (Brunk et al 2019). Work by Poulin et al. (2010) raised concern for the safety of Bti with birds in France, thereby re-igniting the debate about the environmental safety of Bti (Lagadic et al 2016). For Bti and the House Martin (*Delichon urbanicum*), the intake of Diptera (Nematocera) and predators of Diptera (Arachnida and Odonata) decreased significantly at treatment sites: "*At treated sites, two effects occurred: a significantly higher rate of very small prey was consumed, but total foraging rates were lower. Clutch size and nestling survival were significantly lower at treatment sites*" (Poulin, 2012; Poulin et al., 2010; in Brunk et al 2019).

Similarly for insectivorous bats, indirect effects may include reduced food, which could have knock-on effects of habitat selection and community dynamics, and ingestion of contaminated prey (Brunk et al 2019). For bats, direct exposure is likely to be low, because bats are secreted away during the daytime when application would occur.

In the terrestrial system, Hanowski et al. (1997, in Anon 2017) found no negative effects in 19 different bird species on wetlands two years before treatment and three years after treatment using Bti.

Allgeier (2019) investigated indirect effects of Bti (as used in mosquito control) on aquatic food webs, focussing on chironomids, which are a non-target organism potentially affected by Bti (chironomids are closely related to mosquitoes). Because chironomids make up a large proportion of the invertebrate biomass in many wetland systems, reduced abundance of chironomids may have ecological food-chain effects. Allgeier (2019) showed that growth rates in larval newts (amphibians) reduced, most likely as a result of Bti-induced chironomid prey limitation. Further, Allgeier (2019) showed that Bti increased the vulnerability of newt larvae to predation by the dragonfly *Aeshna cyanea* and decreased survival of newt larvae by 27%. Allgeier (2019) proposed from this that entire amphibian populations have the potential to be threatened by mosquito control activities using Bti, if treatment is applied to sites where amphibians occur.

3.4.2.6 Summary of key findings – Bti

Bti has been used as a larvicide for decades. Exhaustive laboratory tests, necessary for the registration of Bti as a commercial product, have widely confirmed Bti as being relatively safe for vertebrate fauna, most non-target invertebrates, and the environment. The insecticidal crystal proteins target specific parts of specific larval insects with no harmful effect on vertebrates. However, there are non-target effects in some chironomid species – chironomids are closely related to mosquitoes.

There appear to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.

Perhaps the greatest concerns for Bti are:

– The indirect food-chain effects reported for birds (House Martins)
– Sub-lethal behavioural responses by tadpoles and chironomids
– Decline of chironomid population after Bti treatment, as shown in some studies

However, for all areas of concern, there are other studies that show contrasting results, and neither area of concern has been conclusively demonstrated or reinforced by additional studies from other systems, so conjecture remains.

As for all insecticide formulations, it is important to isolate the effects of Bti itself from the effects of other ingredients used in the applications.

Russell (2006) concluded "*The non-target impacts of Bti and S-methoprene applications in Australian saltmarshes and mangroves remain to some extent unclear. It is important to note that much of the previous research has been based in the laboratory*."

Overall, the use of Bti as a larvicide appears to be widely supported, and key review studies have also reached this conclusion (Lawler 2017). Russell (2006) suggested that Bti is one of the most environmentally sound methods of mosquito control available, and Suter (2016) suggested that Bti is now an essential tool for mosquito control because no resistance against it has been observed, unlike other pesticides, including methoprene.

The most closely aligned application of Bti discovered in this review was by the Shire of Busselton for the Ramsar-listed Vasse-Wonnerup Wetlands in Western Australia. Reports from investigations relating to that application have consistently concluded that there was no evidence of adverse impacts of larvicide use on non-target organisms - community composition was similar in treatment and control sites, and affected more by natural variation over time than by any measurable effect of larvicide application (Paice 2016). However, Paice (2016) suggested that continued sampling was required for Bti to achieve more confidence in the conclusion.

3.4.3 List of relevant endpoints found in the literature search

A list of all the toxicity endpoints identified in the literature review is shown in Table 13 and Table 14 for S-methoprene and Bti respectively.

Table 13 List of relevant endpoints reported for S-methoprene effects

Taxa	Species	Exposure time	Endpoint	Value (mg/L)	Reference
Targeted species					
Insect (Diptera)	*Parasarcophaga argyrostoma*	Not provided	LC50	0.155 (ug/Larva)	(Bakr and Tanani, 2018)
Non-target species					
Crustacean	*Travancoriana schirnerae*	48 h	LD50	150 ppm (received as an injection of 100 µL)	(Padmanabhan, Raghavan and Ayanath, 2017)
Crustacean	*Moina macrocopa*	48 h	LC50	0.54	(Hu, 2019)
Amphibians	*Xenopus laevis*		NOEC	0.002 [a]	Cited by (Lawler, 2017)
Crustacean	*Lobster larvae (name not provided)*	Not provided	LOEC	0.002-0.050[a]	Cited by (Lawler, 2017)
Crustacean	*Mysid shrimp embryos(name not provided)*	Not provided	LOEC	0.001-0.1[a]	Cited by (Lawler, 2017)
Crustacean	Fiddler crabs		LOEC	0.0001-0.01[a]	Cited by (Lawler, 2017)
Crustacean	Grass shrimp	35 d	NOEC	1mg/Kg	Cited by (Lawler, 2017)
Mollusca	*Physa fontinalis*	Not provided	LC50	10.6 mg/Kg	Cited by (Lawler, 2017)
[a] Converted from value reported as ug/Kg					

Table 14 List of relevant endpoints reported for Bti effects

Taxa	Species	Exposure time	Endpoint	Value (mg/L)	Reference
Targeted species					
Insect (Mosquito)	*Aedes caspius*	24 h	LC50	13	(Ahmed *et al.*, 2021)
Insect (Mosquito)	*Aedes caspius*	48 h	LC50	4.1	
Insect (Diptera)	*Musca domestica*	48 h	LC50	65 ml/L	(Salama, Ismail and Khattab, 2016)
Non-target species					
Crustaceans (Copepods)	*Tropocyclops prasinus*	48 h	NOEC (nauplii) NOEC (Adult)	25 500	(Olmo *et al.*, 2016)
Crustaceans (Copepods)	*Acantocyclops americanus),*	48 h	NOEC (nauplii) LOEC	5 5	(Olmo *et al.*, 2016)
Crustaceans (Cladocerans)	*Ceriodaphnia reticulata,*	48 h	NOEC	5	(Olmo *et al.*, 2016)
Crustaceans (Cladocerans	*Chydorus sphaericus,*	48 h	NOEC	5	(Olmo *et al.*, 2016)
Crustaceans (Cladocerans	*Daphnia cf. pulex*	48 h	NOEC	500	(Olmo *et al.*, 2016)
Amphibians (tadpoles)	*Rhinella arenarum,*	24 h 48 h	NOEC	13.9 12.5	(Junges *et al.*, 2017)
Amphibians (tadpoles)	*Rhinella fernandezae,*	24 h	NOEC	3 3	(Junges *et al.*, 2017)
Amphibians (tadpoles)	*Physalaemus albonotatus*	48 h	NOEC	5 5	(Junges *et al.*, 2017)

3.4.4 Application rates

The application rates for the active ingredients in all the studies mentioned above are presented in Table 15. These indicate that the application rates proposed by the City are very similar or slightly lower than the rates applied in other areas.

Tonjes *et al.*, (2018) reported maximum concentrations of 3,300 ng/L of S-methoprene in aquatic samples taken immediately after a rate application of 280 ng/cm^2. This application rate is equivalent to 0.028 kg/ha, which is similar to some of the application rates proposed by the City (Table 3). In particular, Prolink Pro Sand application rates of 4 kg/ha (S-methoprene is present at 4 g/kg) is the equivalent of 0.016 kg/ha, slightly lower than that used by Tonjes *et al.*, (2018). It is noted that in most of the water samples reported in Tonjes *et al.*, (2018), S-methoprene was not detected. This implies that, on average, the residual concentrations of S-methoprene are likely be much lower than 3,300 ng/L at the application rates proposed. Tonjes *et al.*, (2018) also noted that the S-methoprene concentrations in water samples decreased rapidly post application, reporting that one day after application none of the samples exceeded 25 ng/L.

Lagadic et al (2016) conducted a study applying Bti to eight sites in different parts of France using WDG (37% BYI) and 12AS (11.6% Bti) formulations. This study concluded that the use of Bti did not affect the dynamics of non-target aquatic invertebrates.

Johnson et al (2020) conducted a study to assess the performance of aerial Bti applications in several areas of Moreton Bay (QLD) at an application rate of 0.13 kg a.i/ ha. This study focused on performance of the product selected in high canopy cover areas (i.e. mangroves) and, hence, did not include information about the effects in non-target organisms. However, this information was included in a previous study in the same area conducted by Russell et al (2009). This study included Bti and S-methoprene applications at 0.018 and 0.14 kg a.i./ha at two subtropical saltmarshes also in Moreton Bay. After application, several non-target arthropod taxa were assessed. The authors concluded that the application of Bti and S-methoprene did not impact the abundance and composition of non-target arthropods significantly.

Derua et al (2018) assessed the impact of long-lasting applications of Bti in the form of briquets with the FourStar and LL3 formulations at a rate of 1 briquet/10 m^2, similar to the rate proposed by the City (see Table 3) for the Prolink XR formulation. These authors conducted a comprehensive study of abundance and diversity on non-target organisms, and concluded that no significant differences were observed in diversity of 11 taxa between control and affected areas five months after application.

An *in situ* experiment conducted by Duchet et al (2015) consisted of applying Bti at two rates (0.1 and 0.3 kg a.i/ha) in thirty field enclosures to assess effect in two chironomid species. The results showed that chironomids were not affected at either of the applied rates.

It can be concluded that, at the application rates proposed by the City for Bti and S-methoprene, there is some evidence to suggest that non-target organisms are unlikely to be significantly affected. It is noted that this evidence is currently limited and more studies in other areas and at different application rates and rates within the range proposed by the City are needed to support this conclusion.

Table 15 Application rates proposed by the City compared with those identified in the literature review

Larvicide	Commercial name	Application type	Product type	Application rate per active ingredient
Application rates proposed by The City				
S-methoprene	Prolink Pro Sand	Primarily aerial/ some ground	Sand	0.016 kg a.i./ha
S-methoprene	Prolink Pellets	Primarily ground/ some aerial	Granule	0.16 kg a.i./ha
Bti	Vectobac G	Ground/ Aerial	Granule	0.2 kg a.i./ha
Bti + S-methoprene	VectoPrime FG	Ground/ Aerial	Granule	0.2-0.4 kg a.i./ha (Bti) <0.04 kg a.i/ha (S-methoprene)
Application rates from the literature review				
S-methoprene				0.028 kg a.i./ha
S-methoprene	Altosid		Liquid	0.018 kg a.i./ha
Bti	WDG	N.A	N.A	0.37 kg a.i./ha
Bti	12AS	N.A	Liquid	0.29 kg a.i./ha
Bti	12AS	Aerial	Liquid	0.13 kg a.i./ha
Bti	12AS	Aerial	Liquid	0.14 kg a.i./ha
Bti	12AS	Hand spraying	Liquid	0.1-0.3 kg a.i./ha

3.4.5 Long-term effects on non-target organisms

While very few studies have assessed the long-term environmental effects of Bti or S-methoprene applications, some authors have expressed concerns about the potential cumulative impact after consistent larvicide applications over several years or decades. The effects of significant reduction of mosquito abundances in food webs has been considered by several authors (Land 2019; Lawyer 2017; Stark 2005; Lagadic 2013), with contrasting results. Land (2019) argued that, while direct effects in non-target organisms are minimal, a reduction of >90% of the mosquito population may have ecosystem implications, for example, by altering the diet of birds and other natural mosquito predators. A field study in Minnesota found a decrease in Nematocera abundance and insect genera richness after two years of Bti applications (Niemi et al. 1999). In contrast, Persson Vinnersten et al. (2010) (also referred in Lagadic 2013) found no significant effect in non-target organisms after six years of monitoring. Lagadic (2013) conducted an extensive study on Bti effects in non-target aquatic invertebrates in wetlands over seven consecutive years. The results of this study, while observing variations in taxonomic structure and taxa abundance in non-target invertebrates, showed that those variations are highly driven by abiotic factors rather that the use of *Bti*.

Collectively, the studies referred above indicate that there is no existing evidence that long-term larvicide applications are the cause of significant changes in the ecosystems in the affected areas, with the exception of a few arthropod species, like chironomids. While the treated areas might experience changes in the food web equilibrium, due to the drastic reduction of mosquito abundance, the adjacent untreated areas can serve as ecosystem sanctuaries that could be used by affected species and by mosquito predators.

3.5 Summary of findings

Question no.	Question
1	Are there any published studies that identify potential direct and indirect effects from the application of the larvicides on MNES?

The systematic search provided very limited information linking larvicides to MNES. No published articles identified in the literature search reported effects on specific MNES identified for this project. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world. One article reviewed for Bti reported on a study in a Ramsar site in Europe: Albufera Natural Park (Valencia, Spain) (Ramsar site no. 454). The majority of information obtained was not relevant to the MNES for this project or was more relevant to subsequent questions, particularly question 3.

Question no.	Question
2	Are there any informal studies / grey literature that identify potential direct and indirect effects from the application of the larvicides on MNES?

The search for grey literature and other sources provided limited results linking the two larvicides to MNES. The most relevant reports are from the *City of Busselton, Western Australia EPBC Act referral number 2016/7780,* which relate to aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, a Ramsar wetland. This study has been discussed in detail.

The remaining relevant articles were classified as 2 and were used to address subsequent questions in this review, particularly question 3.

Question no.	Question
3	What are the potential direct and indirect impacts on relevant non-listed aquatic species including, for example, aquatic macroinvertebrates (water bugs), amphibians (frogs), fish, and reptiles (e.g. freshwater turtles, water dragons)

For Bti, the systematic literature review on non-target aquatic organisms resulted in 25 relevant studies providing toxicity information of several aquatic invertebrates including copepod and cladoceran species, with the amphibian tadpoles reported as the most sensitive to Bti.

For S-methoprene, the systematic review provided 27 relevant papers with toxicity data for invertebrates including molluscs, amphibians and, principally, crustacean species, with the fiddler crab identified as the most sensitive species.

The review was complemented with review papers and grey literature that compiled a robust review of studies focused on measuring ecological effects in the environment after Bti or S-methoprene applications rather than effects in the laboratory.

The conclusions of the majority of these studies are that both Bti and S-methoprene were not harmful for vertebrate species.

Bti is reported to have caused declines mainly in non-target populations of chironomids (closely related to mosquitoes), which have generally shown rapid recovery after treatment. There are also reports of sub-lethal (behavioural) responses by amphibian tadpoles, possibly leading to higher mortality through predation.

S-methoprene has been reported in numerous laboratory studies as being toxic to several non-target invertebrate species, principally crustaceans. However, other studies concluded that, at the recommended applications rates, the environmental concentrations of S-methoprene were not toxic for the vast majority of the species.

An on-going concern regarding the use of both larvicides is the potential impact that large seasonal declines in mosquito numbers could have on the ecological food web. Bti takes both larval and adult mosquitoes out of the system in treated areas, while S-methoprene takes adults, but not larvae, so potentially affects the terrestrial food chain only (not aquatic). Notably few studies report on this. One study reported on food-chain impacts on House Martins in Europe, but there is on-going conjecture about the repeatability of those findings. Of the MNES in question for the City's project, none are likely to depend on mosquitoes as a food source: i) shorebirds tend to probe for invertebrate fauna, rather than eat flying insects, ii) waterfowl (as part of Ramsar and other wetlands) tend to eat plant matter or aquatic food, rather than flying insects, iii) egrets, herons, bitterns etc eat aquatic fauna, and larger prey than mosquitoes, iv) frogs (e.g., Growling Grass Frog) eat mosquitoes, but will eat a range of other, often larger, invertebrates, and even vertebrates (smaller frogs). Indirect impacts of larvicides on the food chain would be reduced by setting aside enough untreated areas as sanctuaries for mosquitoes and natural mosquito predators.

Question no.	Question
4	Is there potential for bioaccumulation and food-chain effects of active ingredients and adjuvants, and subsequent impacts on MNES and non-target organisms?

The results of the systematic review combined with the review papers and grey literature for the potential bioaccumulation effects of Bti and S-methoprene provided very limited results.

While S-methoprene has been reported to bioaccumulate in some fish and crayfish, it tends to be only for a short period, and there are no reports of biomagnification in the food chain. No studies consulted for this report provided information about potential Bti bioaccumulation, which is identified as knowledge gap in this literature review.

Question no.	Question
5	Are there studies investigating multigenerational and endocrine disrupting effects, and indirect effects such as the disruption of diet with regard to Bti and S-methoprene?

No relevant studies were identified from the systematic review of endocrine disruption effects of the larvicides in non-target organisms. Only two studies investigated an endocrine disrupting effect in mosquito species. From the extended review, the only study that mentioned endocrine disrupting effects found no sign of endocrine activity in several Bti formulations. No relevant information was identified for the potential endocrine disruption effects of S-methoprene, which is identified as a knowledge gap in this literature review.

Question no.	Question
6	Are there studies investigating the degradability of Bti and S-methoprene and its potential to mobilize within the environment. Are there any major degradants or metabolites of the active ingredients and adjuvants and if so, what are their potential effects with regard to Bti and S-methoprene?

Several studies identified in the systematic literature review reported that S-methoprene and Bti are readily degraded by microbial activity and sunlight, resulting in a rapid decrease in the larvicide concentrations after treatment. S-methoprene mobility is considered to be limited given this degradability and the affinity to bond to sediments (but only at concentrations considerable below the toxicity thresholds). One exception is when slow release products, like the S-methoprene Prolink briquets or VectoPrime FG-Granules, which are designed to remain in the environment for an extended period (e.g. 150 and 120 respectively). However, the application of briquets and FG-Granules is limited to a few sites (see Table 2) to prevent re-emergence of mosquito larvae after treatment, and would not be applied to areas with MNES or tidal or marine habitats (see Table 1).

4. Conclusion

4.1 Key outcomes

Overall, the authors consider that the literature discovered and assessed here adequately represents what is known and not known about the effects of Bti and S-methoprene as larvicides. The following conclusions have been reached following the systematic literature review on the potential non-target impacts of S-methoprene and Bti:

- There is limited literature available on the topic of larvicide effects on MNES, vertebrates, and non-target organisms, particularly from recent years and from Australian ecosystems. Much of the literature on this topic globally is older (pre-2010), and more recent studies do not appear to have produced conflicting findings.
- Both Bti and S-methoprene are widely used larvicides globally, and have been the subjects of comprehensive toxicological evaluations over several decades.
- No studies identified potential direct or indirect effects from the application of S-methoprene or Bti on species identified as MNES for this project. One study provides information for a monitoring program assessing impacts on aquatic invertebrates due to S-methoprene and Bti on the Western Australian Vasse-Wonnerup Ramsar site (a MNES). After seven years of aquatic invertebrate sampling, that study has found no evidence of adverse impacts on non-target organisms due to Bti or S-methoprene use.
- No articles were identified in the literature search that reported on effects on specific MNES identified for this project. Impacts on MNES must be inferred from the results presented for other studies, mostly in different parts of the world.
- Almost all the literature reviewed concluded that S-methoprene and Bti are not directly toxic to vertebrates.
- The effects of S-methoprene on non-target invertebrates are likely inextricably linked to application dose. Higher application doses are more likely to result in non-target invertebrate effects. However, when used at recommended application rates (e.g., as per those recommended by APVMA), the literature generally concludes that there is a low risk to non-target species, including estuarine invertebrates. Low persistence in the environment (when used at recommended does rates) means that impacts on water quality are low. Given the way larvicides tend to be administered (locally in small areas and occasionally), recolonisation by affected non-target organisms is likely from surrounding untreated areas, and long-term negative effects to ecosystem function are considered unlikely.
- The effects of Bti include some non-target effects on Chironomid species (non-biting midges; closely related to mosquitoes), although there is no clear consensus in the literature. There appears to be no bioaccumulation, multigeneration, or endocrine disruption effects, and the literature reports fairly consistently that Bti has low persistence under field conditions.
- An on-going concern regarding the use of both larvicides is the potential impact that seasonal declines in mosquito numbers could have on the ecological food web. Notably few studies report on this, and there is on-going conjecture about the repeatability of the findings from the main one that does. Of the MNES in question for the City's project, none are likely to depend on mosquitoes as a food source and all MNES species will have access to other non-treated habitats within the proposal area. Indirect impacts of larvicides on the food chain are partly mitigated by the availability of untreated areas of mosquito habitat as sanctuaries for mosquitoes and natural mosquito predators (e.g. the program proposes to focus treatment along the northern, eastern and parts of the southern shorelines of Lake Connewarre. Large portions of the lake system including the central portion and western shoreline will not be treated).
- According to information found in this literature review, it can be concluded with reasonable confidence that, at the application rates proposed by the City for Bti and S-methoprene, non-target organisms are unlikely to be significantly affected. It is noted that direct supporting evidence for this is currently limited and more studies in other areas and at different applications rates would be needed to firm this conclusion.
- The literature is relatively consistent in the conclusion that, among the products used for mosquito control, Bti and S-methoprene are among the safest for the environment and for non-target organisms, particularly vertebrates.

4.2 Knowledge gaps

The systematic literature review has highlighted a number of knowledge gaps in relation to the effects of S-methoprene and Bti. A number of these knowledge gaps limit the ability to address all issues raised as part of the proposed action. Ultimately, these knowledge gaps should form the basis of on-going monitoring programs done in association with future mosquito control programs. The main gaps identified include:

– There are very few published studies that have investigated the indirect impact on the wider environment of an ongoing significant reduction in adult mosquito populations resulting from a long-term broad-scale mosquito control program.
– Without local long-term studies, or quantitative studies identifying the relative importance of mosquitoes (or susceptible non-target taxa such as Chironomids) as specific components of the ecosystem (e.g. as a food source, pollinator, nutrient recycler, or disease vector), it is difficult to accurately assess the indirect long-term environmental impacts of mosquito control programs.
– With year-to-year fluctuations across a range of environmental variables, natural changes in the abundance, diversity and behaviour of local wildlife further complicate our understanding of the ecological effects of mosquito control. We have not taken into account some of these natural factors or anthropogenic variables – e.g. surrounding land use, nutrient run off etc and how that impacts the habitats of the species.
– The potential effects of other ingredients used in S-methoprene and Bti products and formulations remains unknown – some articles suggest that associated ingredients may be more toxic than the larvicide itself.
– The potential for endocrine disruption associated with the use in S-methoprene and Bti remains uncertain due to a lack of research.
– More research is needed to clarify the potential for S-methoprene to bioaccumulate in the food web.
– The potential for intergenerational indirect effects of slow release Bti granules (i.e. Vectobac G granules) has been identified as a data gap and there is little information about the pace at which these granules break down and expose the Bti to the environment. It is noted that while slow release exposures last relatively long periods (e.g., 30 – 150 days) the nature of their composition is to expose only a low concentrations of the active ingredient at a given time. Furthermore, the application of some slow release products, like the S-methoprene Prolink briquets or VectoPrime FG-Granules, which are designed to remain in the environment for an extended period (e.g. 150 and 120 days respectively) is limited to a few sites within residential areas to prevent re-emergence of mosquito larvae after treatment, and would not be applied to areas with MNES or tidal or marine habitats, thus reducing the risk to MNES.

Although there are knowledge gaps the potential direct and indirect impacts on MNES as a result of the proposed action are partly mitigated because of several factors including the area of treated and untreated mosquito habitat, and timing and frequency of treatments.

The City completed a review of its treatment program and revised the treatment sites where some that were treated historically have been removed and others combined due to their proximity with neighbouring sites. This has resulted in a reduction of the overall number of sites requiring ground-based (from 99 to 36) or aerial treatment (from 49 to 36) for the proposed program (overall reduction in sites from 148 to 72). Furthermore, not all available mosquito habitat is treated each season within the proposed action area and therefore large areas of untreated habitat remain for mosquitos and natural mosquito predators. For example, the total area of sites including Ramsar wetland within the proposed action area is 3,666.53 ha, however the seasonal treatment area of all Ramsar sites is 696 ha (approximately 19%) within the proposed action area. Having said that it is difficult to quantify the area of mosquito breeding habitat within the proposed action area, however it can be assumed with confidence that the area of untreated habitat is much larger than the area being treated as part of the proposed program. Site specific examples include:

– Site 3.13 – Lake Connewarre East = 378.9 ha (seasonal treatment area = 35.08 ha or 9.25%). This site is part of the larger Lake Connewarre area at c. 880 ha. Although not all of Lake Connewarre is considered suitable mosquito breeding habitat due to it being tidal and depth of water, large portions including the western shoreline will not be treated.
– Site 8.18 Salt Swamp - back of Lake Connewarre Swamp = 900.6 ha (seasonal treatment area = 12.60 ha or 1.4%). A very small portion of this site will be treated each season with large portions of habitat, including mosquito breeding habitat not treated

– Site 10.8 Reedy Lake periphery = 1352 ha (seasonal treatment area = 65.64 ha or 4.85%). A small portion of this site will be treated each season with large portions of habitat, including mosquito breeding habitat not treated.

During a typical treatment season, 40 of the 72 sites receive one or fewer treatments per season (i.e. some sites treated every 2-3 years). Meaning there is a gap of at least 6 months between treatments for the majority of sites for a period of recovery and recruitment. Although the remaining sites (n = 32) may receive 2 or more treatments per season, this scenario (i.e. multiple treatments per season) is more likely to occur every 2-3 years. A typical treatment season is most likely to consist of the following:

– 15 sites (8 aerial and 7 ground-based) will most likely receive 1 treatment per season
– 25 sites (6 aerial and 19 ground-based) will most likely receive 1 treatment every 2-3 years (therefore less than 1 per season)
– 32 sites (22 aerial sites and 10 ground-based) may be treated twice or more each season, however this scenario (i.e., multiple treatments per season) may not occur each season, but more likely to occur every 2-3 years.

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Appendices

Appendix A

Aerial and ground treatment sites

Table A1 Aerial treatment site - number, description, size and proposed treatment area for the proposed program

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of / range/ mode/ historical treatments over 9 seasons	Total historical treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical/maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program treatment area (ha)
2.4	COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK	No	13.2	4 / 2 / 0	14.33	1.43	1 / 3	1.43	14.33
2.5	COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK	No	35.2	7 / 3 / 0	41.73	3.79	1 / 4	3.79	37.94
2.17	SOUTHERN LAKE VICTORIA	No	56.1	3 / 3 / 0	31.82	4.55	1 / 4	4.55	45.46
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER	Yes	3.3	6	51.02	8.50	1 / 2	8.5	85.03
3.8	OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK	Yes	24.5	29 / 5 / 3	75.23	3.58	3 / 8	10.75	107.47
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	14.6	20 / 6 / 0	84.68	4.23	2 / 8	8.47	84.68
3.10	PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER	Yes	45.0	12 / 6 / 0	13.12	14.58	1 / 7	14.58	145.78
3.11	PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS	Yes	180.8	33 / 2 / 5	418.29	6.24	5 / 7	31.22	312.16
3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	10.9	26 / 3 / 4	82.84	1.36	4 / 7	5.43	54.32
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	378.9	39 / 9 / 3	865.19	11.69	3 / 12	35.08	350.75
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	25.5	26 / 6 / 2	140.54	2.70	2 / 8	5.41	54.05
4.3	SWAN BAY NORTH, ST LEONARDS END OF CLIFF ST- BOTH SIDES OF LAKE	Yes	3.7	27 / 5 / 4	43.58	43.58	4 / 9	174.32	1743.20
4.5	SWAN BAY NORTH, ST LEONARDS BEHIND CHARLIES	Yes	13.7	49 / 5 / 4	53.05	1.02	4 / 9	4.08	40.81
4.6	SWAN BAY NORTH, PT EDWARDS RESERVE	Yes	113.1	19 / 4 / 2	402.23	10.59	2 / 6	21.17	211.70
7.1	SWAN BAY NORTH, KNIGHTS RD	Yes	31.0	25 / 4 / 3	481.29	14.16	3 / 7	42.47	424.67

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of / range/ mode/ historical treatments over 9 seasons	Total historical treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical/maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program treatment area (ha)
7.2	SWAN BAY - NYE RD WETLANDS	Yes	25.9	28 / 5 / 3	24.21	0.97	3 / 8	2.91	29.05
7.3	SWAN BAY - IBBOTSON ST	Yes	16.4	28 / 5 / 4	97.25	4.42	4 / 9	17.68	176.82
7.4	SWAN BAY - SOUTH OF SALT LAKE	Yes	2.1	27 / 5 / 4	3.51	0.22	4 / 9	0.88	8.78
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	161.4	33 / 6 / 5	1082.65	18.67	5 / 11	93.33	933.32
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT	Yes	45.2	33 / 5 / 5	401.90	7.58	5 / 10	37.92	379.15
8.4	REAR OF SCHOOL - LAKE MURTNAGHURT PERIPHERY	Yes	73.6	34 / 5 / 6	208.08	3.65	6 / 11	21.90	219.03
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	20.9	22 / 5 / 1	17.31	0.62	1 / 6	0.62	6.18
8.13	LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)	Yes	25.7	32 / 2 / 5	207.82	3.71	5 / 7	23.09	230.91
8.14	LAKE CONNEWARRE, BACKWATERS	Yes	44.7	25 / 6 / 1	43.08	10.77	1 / 7	10.77	107.70
8.18	SALT SWAMP, BACK OF LAKE CONNEWARRE	Yes	900.3	36 / 6 / 2	207.95	6.30	2 / 8	12.60	126.03
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	90.5	33 / 5 / 1	538.94	14.57	1 / 2	29.13	291.32
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	No	13.6	18 / 5 / 1	59.94	1.30	1 / 2	2.61	26.06
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	No	22.2	7 / 4 / 0	30.63	1.91	1 / 2	3.83	38.29
9.4	BREAMLEA SALTMARSHES D (BEHIND SURF CLUB)	No	1.5	25 / 6 / 4	10.66	0.89	1 / 2	1.78	17.77
9.5	BREAMLEA SALTMARSHES BLACKGATE RD	No	68.3	20 / 5 / 1	413.49	10.34	1 / 2	20.67	206.75
10.7	LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD	Yes	17.0	9 / 2 / 1	12.70	6.35	1 / 3	6.35	63.50
10.8	REEDY LAKE PERIPHERY	Yes	1352.5	26 / 5 / 3	809.50	21.88	3 / 8	65.64	656.35

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of / range/ mode/ historical treatments over 9 seasons	Total historical treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed typical/maximum number of treatments per season	Proposed seasonal treatment area (ha)	Program treatment area (ha)
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	47.2	5 / 1 / 1	52.90	1.82	1 / 2	1.82	18.24
14.3	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	72.9	28 / 5 / 3	210.86	5.86	3 / 8	17.57	175.72
14.4	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	30.8	13 / 5 / 3	92.67	3.20	3 / 8	9.59	95.87
15.8	BREAMLEA TIDAL WETLAND LAKES (4 LARGE)	No	176.1	14 / 5 / 2	123.41	8.23	2 / 7	16.45	164.55
	TOTALS		**4158.34 ha**		**7448.40 ha**	**265.26 ha**		**768.39 ha**	**7683.74 ha**

Table A2 Aerial treatment site - proposed seasonal and maximum (program) intended application rate for proposed program

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
2.4	COLLENDINA SOUTH, SALT LAKE AT EAST OF CARAVAN PARK	No	-	-	-	-	10.031	0.286	100.310	2.859	1:0
2.5	COLLENDINA NORTH, SALT LAKE AT EAST OF CARAVAN PARK	No	-	-	-	-	26.555	0.757	265.555	7.568	1:0
2.17	SOUTHERN LAKE VICTORIA	No	-	-	-	-	31.820	0.907	318.200	9.069	1:0
3.1	OCEAN GROVE GOLF COURSE RIVER MARSH, BARWON RIVER	Yes	-	-	-	-	59.523	1.696	595.233	16.964	1:0
3.8	OCEAN GROVE, THACKER ST TIDAL WETLANDS AND CREEK	Yes	-	-	-	-	75.230	2.144	752.300	21.441	1:0

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
3.9	WALLINGTON RD, WETLAND DRAINS LINGS RD	No	-	-	-	-	59.276	1.689	592.760	16.894	1:0
3.10	PACEY'S ISLAND, PERIMETER WETLANDS, BARWON RIVER	Yes	-	-	-	-	102.044	2.908	1020.444	29.083	1:0
3.11	PACEY'S ISLAND, SEVERAL LOW-LYING WETLANDS	Yes	-	-	-	-	218.510	6.228	2185.097	62.275	1:0
3.12	PACEY'S HILL WALLINGTON SWAMP	Yes	-	-	-	-	38.025	1.084	380.249	10.837	1:0
3.13	SALTWATER RIDGE (LAKE CONNEWARRE EAST)	Yes	-	-	-	-	245.527	6.998	2455.269	69.975	1:0
3.14	WALLINGTON-LINGS RD CONNEWARRE WATERCOURSE GULLY	Yes	-	-	-	-	37.838	1.078	378.377	10.784	1:0
4.3	SWAN BAY NORTH, ST LEONARDS END OF CLIFF ST- BOTH SIDES OF LAKE	Yes	174.320	0.697	1743.200	6.973	976.192	27.821	9761.920	278.215	4:1
4.5	SWAN BAY NORTH, ST LEONARDS BEHIND CHARLIES	Yes	4.081	0.016	40.808	0.163	22.852	0.651	228.523	6.513	4:1
4.6	SWAN BAY NORTH, PT EDWARDS RESERVE	Yes	21.170	0.085	211.700	0.847	118.552	3.379	1185.520	33.787	4:1
7.1	SWAN BAY NORTH, KNIGHTS RD	Yes	-	-	-	-	297.267	8.472	2972.674	84.721	1:0
7.2	SWAN BAY - NYE RD WETLANDS	Yes	-	-	-	-	20.336	0.580	203.364	5.796	1:0
7.3	SWAN BAY - IBBOTSON ST	Yes	17.682	0.071	176.818	0.707	99.018	2.822	990.182	28.220	4:1
7.4	SWAN BAY - SOUTH OF SALT LAKE	Yes	0.878	0.004	8.775	0.035	4.914	0.140	49.140	1.400	4:1

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
7.5	SWAN BAY JETTY NORTH AND SOUTH SIDE	Yes	93.332	0.373	933.319	3.733	522.659	14.896	5226.586	148.958	4:1
8.1	BARWON HEADS GOLF COURSE MARSH – PONDS, LAKE MURTNAGHURT	Yes	37.915	0.152	379.151	1.517	212.325	6.051	2123.245	60.512	4:1
8.4	REAR OF SCHOOL - LAKE MURTNAGHURT PERIPHERY	Yes	21.903	0.088	219.032	0.876	122.658	3.496	1226.577	21.903	4:1
8.7	BARWON HEADS LEVY BANK & DRAINS & WETLANDS	Yes	0.618	0.002	6.182	0.025	3.462	0.099	34.620	0.618	4:1
8.13	LAKE CONNEWARRE, STACEY'S RD (ROYCOTT PROPERTY)	Yes	-	-	-		161.638	4.607	1616.378	46.067	1:0
8.14	LAKE CONNEWARRE, BACKWATERS	Yes	10.770	0.043	107.700	0.431	60.312	1.719	603.120	17.189	4:1
8.18	SLAT SWAMP, BACK OF LAKE CONNEWARRE	Yes	12.603	0.050	126.030	0.504	70.577	2.011	705.770	20.114	4:1
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	43.698	0.175	436.978	1.748	142.746	4.068	1427.463	40.683	7:3
9.2	BREAMLEA SALTMARSHES B (WEST SIDE OF BREAMLEA RD)	No	3.909	0.016	39.091	0.156	12.770	0.364	127.698	3.639	7:3
9.3	BREAMLEA SALTMARSHES C (SOUTH SIDE CLOSE TO TOWN)	No	5.743	0.023	57.431	0.230	18.761	0.535	187.609	5.347	7:3
9.4	BREAMLEA SALTMARSHES D (BEHIND SURF CLUB)	No	2.665	0.011	26.650	0.107	8.706	0.248	87.057	2.481	7:3

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg) **	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
9.5	BREAMLEA SALTMARSHES BLACKGATE RD	No	31.012	0.124	310.118	1.240	101.305	2.887	1013.051	28.872	7:3
10.7	LAKE CONNEWARRE MARSH, MOLLERS RD LEOPOLD	Yes	9.525	0.038	95.250	0.381	31.115	0.887	311.150	8.868	7:3
10.8	REEDY LAKE PERIPHERY	Yes	98.453	0.394	984.527	3.938	321.612	9.166	3216.122	91.659	7:3
11.2	PT HENRY FORESHORE MARSH & PONDS WINDMILL RD	No	1.824	0.007	18.241	0.073	10.215	0.291	102.152	2.911	4:1
14.3	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	-	-	-	-	123.002	3.506	1230.017	35.055	1:0
14.4	SWAN BAY BURNT PT END OF FELLOWS RD	Yes	-	-	-	-	59.738	1.516	531.784	13.492	1:0
15.8	BREAMLEA TIDAL WETLAND LAKES (4 LARGE)	No	-	-	-	-	115.183	3.283	1151.827	32.827	1:0
	TOTALS		**592.101**	**2.369**	**5921.001**	**23.684**	**4542.293**	**129.268**	**45357.341**	**1291.020**	

Tables notes: *amount includes ingredients 1 and 2 listed in (all constituents) Table 6 **amount includes only ingredient 1, either Bti or S-Methoprene (active constituent)

Example calculation

Site 9.1 Breamlea Saltmarshes A (East side of Breamlea Road)

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	No. of / range/ mode/ historical treatments over 9 seasons	Total historical treatment area (ha) over 9 seasons	Proposed treatment area (ha)	Proposed frequency of treatments per season	Proposed seasonal treatment area (ha)	Program treatment area (ha)
9.1	BREAMLEA SALTMARSHES A (EAST SIDE OF BREAMLEA RD)	No	90.5	33 / 5 / 1	538.94	14.57	4.11	59.88	598.82

$$\text{Seasonal intended rate S-Methoprene} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate S-Methoprene} = \left(59.98\ \text{ha} \times \frac{5\ \text{kg}}{\text{ha}}\right) \times \frac{3\ *}{10} = 89.823\ \text{kg}$$

$$\text{Actual amount of S-Methoprene used for seasonal rate} = \text{Seasonal intended rate S-Methoprene} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of S-Methoprene used for seasonal rate} = 89.823\ \text{kg} \times \frac{4\ **}{1000} = 0.359\ \text{kg}$$

$$\text{Seasonal intended rate BTI} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate BTI} = \left(59.98\ \text{ha} \times \frac{7\ \text{kg}}{\text{ha}}\right) \times \frac{7\ *}{10} = 293.42\ \text{kg}$$

$$\text{Actual amount of BTI used for seasonal rate} = \text{Seasonal intended rate BTI} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of BTI used for seasonal rate} = 293.42\ \text{kg} \times \frac{2.85\ **}{100} = 8.363\ \text{kg}$$

*- value obtained from Table 16. **- value obtained from Table 1

Table A3 Ground-based treatment site - number, size and proposed treatment area for the proposed program

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range / mode of historical treatments over 16 seasons	Proposed typical/maximum of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
1.1	PT LONSDALE, RAILWAY LINE, MARSH & DRAINS	No	0.65	1	0.65	30 / 1 / 0	2 / 3	1.30	12.96
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	No	2.93	0.6	1.76	33 / 5 / 1	1 / 6	1.76	17.57
1.7	PT LONSDALE, PITS & PIPES SURVEILLANCE	No	3.58	1	3.58	45 / 12 / 8	8 / 20	28.64	286.40
3.2	OCEAN GROVE NATURE RESERVE	No	1.31	0.3	0.39	1 / 1 / 0	1 / 2	0.39	3.93
3.3	OCEAN GROVE BLUE WATER LAKE OPEN DRAINS	No	0.03	0.3	0.01	19 / 4 / 4	4 / 8	0.03	0.34
3.4	OCEAN GROVE BLUE WATER LAKE RES CATCHMENT AREAS	No	0.27	1	0.27	12 / 7 / 1	1 / 8	0.27	2.70
3.5	OCEAN GROVE THACKER ST STORMWATER EASEMENT	No	1.24	0.7	0.87	13 / 3 / 0	1 / 4	0.87	8.71
3.6	OCEAN GROVE BLUE WATER OPEN DRAIN TO THE RIVER	No	7.39	0.3	2.22	9 / 2 / 1	1 / 3	2.22	22.16
3.7	OCEAN GROVE GOLF COURSE CREEK	Yes	0.67	1	0.67	6 / 1 / 0	1 / 2	0.67	6.70
3.15	OCEAN GROVE BLUE WATER LAKE WEIR	No	0.06	1	0.06	5 / 2 / 0	1 / 3	0.06	0.60
3.16	OCEAN GROVE BLUE WATER LAKE CONTAINMENT PIT	No	0.02	1	0.02	10 / 2 / 0	1 / 3	0.02	0.16
4.1	SWAN BAY NORTH, MARSH BEHIND HOUSES CLIFF ST - LOWER BLUFF	Yes	14.95	0.2	2.99	14 / 4 / 1	1 / 5	2.99	29.90
4.2	ST LEONARDS, BLUFF RD MARSH SWAMP	No	0.71	1	0.71	2 / 1 / 0	1 / 2	0.71	7.14
4.7	ST LEONARDS RHONDA AVE SALT MARSH, SALT LAGOON	No	3.07	0.6	1.84	18 / 7 / 0	1 / 8	1.84	18.41
4.8	ST LEONARDS LAKE & DRAINS PLUS SPILLWAY	No	1.71	1	1.71	50 / 7 / 1	1 / 8	1.71	17.10
4.10	ST LEONARDS SALT LAGOON PERIMETER AND BACKWATERS STH SIDE	No	7.56	0.3	2.27	30 / 4 / 1	2 / 6	4.54	45.36
4.12	ST LEONARDS, SALT LAGOON IBBOTSON ST WEST SIDE	No	6.44	0.4	2.58	1 / 1 / 0	1 / 2	2.58	25.76

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range / mode of historical treatments over 16 seasons	Proposed typical/maximum of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
4.13	INDENTED HEAD, BATMAN RD OPEN DRAINS	No	2.24	0.2	0.45	46 / 3 / 0	1 / 4	0.45	4.49
5.1	PORT ARLINGTON, PT RICHARDS MARSH SWAMP FORESHORE	No	2.04	0.6	1.22	6 / 4 / 0	1 / 5	1.22	12.22
5.2	PORT ARLINGTON, RAMBLERS RD PORT MARSH	No	5.84	0.2	1.17	21 / 7 / 0	1 / 8	1.17	11.68
5.3	PORT ARLINGTON, PITS AND PIPES SURVEILLANCE (BOAT RD)	No	0.82	1	0.82	29 / 6 / 0	2 / 8	1.65	16.48
8.2	BARWON HEADS, REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	3.68	0.6	2.21	14 / 4 / 2	2 / 6	4.42	44.16
8.3	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH (LAKE MURTNAGHURT)	Yes	4.55	0.6	2.73	6 / 3 / 0	1 / 4	2.73	27.29
8.6	BARWON HEADS, OLD TURKEY FARM, MARSH AND PONDS, BARWON RIVER	Yes	5.70	0.6	3.42	8 / 6 / 0	1 / 7	3.42	34.19
8.9	BARWON HEADS, JIRRAHLINGA - PONDS AND WETLANDS	Yes	4.24	0.3	1.27	11 / 4 / 0	1 / 5	1.27	12.72
8.11	BARWON HEADS, SHEEPWASH TIDAL WETLANDS, BARWON RIVER	Yes	3.23	0.3	0.97	1 / 1 / 0	1 / 2	0.97	9.70
8.16	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD, BARWON RIVER	Yes	2.53	0.3	0.76	3 / 2 / 0	1 / 3	0.76	7.59
11.5	GEELONG, 2 PONDS AT SALVATION ARMY COMPLEX	No	0.17	1	0.17	5 / 1 / 0	1 / 2	0.17	1.70
11.6	PT HENRY, ALCOA WETLANDS - LAGOONS	No	9.71	0.4	3.88	7 / 6 / 0	1 / 7	3.88	38.83
11.7	NEWCOMB, COONEY ST DRAIN	No	1.58	0.7	1.11	38 / 2 / 3	3 / 5	3.33	33.27
11.8	GEELONG, DRAIN BEHIND ANIMAL HEALTH LAB	No	4.79	0.4	1.91	5 / 2 / 0	1 / 3	1.91	19.15
11.9	NEWCOMB, DRAIN BEHIND PRESTIGE CARAVANS - BELLARINE HWY	No	1.33	0.7	0.93	38 / 3 / 0	2 / 5	1.87	18.67
14.1	PT LONSDALE, MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	3.38	0.8	2.70	73 / 6 / 2	2 / 8	5.41	54.08
14.11	PT LONSDALE, CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	No	1.10	0.8	0.88	19 / 3 / 0	1 / 4	0.88	8.78

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range / mode of historical treatments over 16 seasons	Proposed typical/maximum of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
14.7	PT LONSDALE, YARRUM CREEK, RAILWAY LINES & RD	No	0.78	1	0.78	30 / 5 / 0	1 / 6	0.78	7.78
14.8	PT LONSDALE, CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY	No	1.12	1	1.12	36 / 4 / 0	2 / 6	2.24	22.40
	TOTALS		**111.42 ha**					**89.13 ha**	**891.08 ha**

Table A4 Ground-based treatment site - proposed seasonal and maximum (program) intended application rate for the proposed program

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg)**	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
1.1	PT LONSDALE, RAILWAY LINE, MARSH & DRAINS	No	4.536	0.018	45.359	0.181	2.722	0.078	27.215	0.776	3:7
1.4	PT LONSDALE, SANTAMONICA STORMWATER LAKE	No	7.029	0.028	70.289	0.281	2.460	0.070	24.601	0.701	1:4
1.7	PT LONSDALE, PITS & PIPES SURVEILLANCE	No	114.560	0.458	1145.600	4.582	40.096	1.143	400.960	11.427	1:4
3.2	OCEAN GROVE NATURE RESERVE	No	0.983	0.004	9.825	0.039	1.376	0.039	13.755	0.392	1:1
3.3	OCEAN GROVE BLUE WATER LAKE OPEN DRAINS	No	0.137	0.001	1.367	0.005	0.048	0.001	0.479	0.014	1:4
3.4	OCEAN GROVE BLUE WATER LAKE RES CATCHMENT AREAS	No	1.080	0.004	10.800	0.043	0.378	0.011	3.780	0.108	1:4
3.5	OCEAN GROVE THACKER ST STORMWATER EASEMENT	No	3.483	0.014	34.825	0.139	1.219	0.035	12.189	0.347	1:4

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg)**	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
3.6	OCEAN GROVE BLUE WATER OPEN DRAIN TO THE RIVER	No	8.862	0.035	88.622	0.354	3.102	0.088	31.018	0.884	1:4
3.7	OCEAN GROVE GOLF COURSE CREEK	No	2.680	0.011	26.800	0.107	0.938	0.027	9.380	0.267	1:4
3.15	OCEAN GROVE BLUE WATER LAKE WEIR	No	0.240	0.001	2.400	0.010	0.084	0.002	0.840	0.024	1:4
3.16	OCEAN GROVE BLUE WATER LAKE CONTAINMENT PIT	No	0.064	0.000	0.640	0.003	0.022	0.001	0.224	0.006	1:4
4.1	SWAN BAY NORTH, MARSH BEHIND HOUSES CLIFF ST - LOWER BLUFF	Yes	4.536	0.018	45.360	0.181	25.402	0.724	254.016	7.239	4:1
4.2	ST LEONARDS, BLUFF RD MARSH SWAMP	No	0.714	0.003	7.144	0.029	4.001	0.114	40.005	1.140	4:1
4.7	ST LEONARDS RHONDA AVE SALT MARSH, SALT LAGOON	No	1.841	0.007	18.408	0.074	10.309	0.294	103.086	2.938	4:1
4.8	ST LEONARDS LAKE & DRAINS PLUS SPILLWAY	No	1.710	0.007	17.100	0.068	9.576	0.273	95.760	2.729	4:1
4.10.	ST LEONARDS SALT LAGOON PERIMETER AND BACKWATERS STH SIDE	No	2.268	0.009	22.680	0.091	12.701	0.362	127.008	3.620	4:1
4.12	ST LEONARDS, SALT LAGOON IBBOTSON ST WEST SIDE	No	2.576	0.010	25.756	0.103	14.424	0.411	144.235	4.111	4:1
4.13	INDENTED HEAD, BATMAN RD OPEN DRAINS	No	1.795	0.007	17.950	0.072	0.628	0.018	6.282	0.179	1:4
5.1	PORT ARLINGTON, PT RICHARDS MARSH SWAMP FORESHORE	No					8.555	0.244	85.546	2.438	1:0
5.2	PORT ARLINGTON, RAMBLERS RD PORT MARSH	No					8.177	0.233	81.772	2.330	1:0

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg)**	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
5.3	PORT ARLINGTON, PITS AND PIPES SURVEILLANCE (BOAT RD)	No	6.592	0.026	65.924	0.264	2.307	0.066	23.073	0.658	1:4
8.11	BARWON HEADS, REAR 90 CARR ST SALT MARSH AND DRAINS	Yes	-	-	-	-	6.790	0.194	67.896	1.935	1:0
8.16	REAR OF SCHOOL STATE CONNEWARRE GAME RES MARSH (LAKE MURTNAGHURT)	Yes	-	-	-	-	5.315	0.151	53.149	1.515	1:0
8.2	BARWON HEADS, OLD TURKEY FARM, MARSH AND PONDS, BARWON RIVER	Yes	-	-	-	-	30.913	0.881	309.134	8.810	1:0
8.3	BARWON HEADS, JIRRAHLINGA - PONDS AND WETLANDS	Yes	-	-	-	-	19.104	0.544	191.035	5.445	1:0
8.6	BARWON HEADS, SHEEPWASH TIDAL WETLANDS, BARWON RIVER	Yes	-	-	-	-	23.934	0.682	239.340	6.821	1:0
8.9	WETLANDS NEAR BOARDWALK ON SHEEPWASH RD, BARWON RIVER	Yes	-	-	-	-	8.904	0.254	89.040	2.538	1:0
11.5	GEELONG, 2 PONDS AT SALVATION ARMY COMPLEX	No	-	-	-	-	1.190	0.034	11.900	0.339	1:0
11.6	PT HENRY, ALCOA WETLANDS - LAGOONS	No	3.883	0.016	38.828	0.155	21.744	0.620	217.437	6.197	4:1
11.7	NEWCOMB, COONEY ST DRAIN	No	13.309	0.053	133.087	0.532	4.658	0.133	46.581	1.328	1:4
11.8	GEELONG, DRAIN BEHIND ANIMAL HEALTH LAB	No	4.787	0.019	47.870	0.191	6.702	0.191	67.018	1.910	1:1
11.9	NEWCOMB, DRAIN BEHIND PRESTIGE	No	-	-	-	-	13.070	0.372	130.697	3.725	1:0

Site no.	Site description	Within or adjacent to Ramsar site	Seasonal intended rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for seasonal rate (kg)**	Maximum (program) intended app rate S-Methoprene (kg)*	Actual amount of S-Methoprene used for maximum rate (kg)**	Seasonal intended rate Bti (kg)*	Actual amount of Bti used for seasonal rate (kg)**	Maximum (program) intended app rate (kg)*	Actual amount of Bti used for maximum rate (kg)**	Proportion of treatment Bti: S-Methoprene used in the field
	CARAVANS - BELLARINE HWY										
14.1	PT LONSDALE, MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	16.224	0.065	162.240	0.649	15.142	0.432	151.424	4.316	2:3
14.11	PT LONSDALE, CNR QUEENSCLIFF HWY & FELLOWS RD PONDAGE	No	2.195	0.009	21.947	0.088	3.073	0.088	30.726	0.876	1:1
14.7	PT LONSDALE, YARRUM CREEK, RAILWAY LINES & RD	No	1.946	0.008	19.461	0.078	2.725	0.078	27.246	0.777	1:1
14.8	PT LONSDALE, CORNER MURRAY RD AND FELLOWS RD QUEENSCLIFF HIGHWAY	No	5.600	0.022	56.000	0.224	7.840	0.223	78.400	2.234	1:1
	TOTALS		**213.63**	**0.853**	**2136.282**	**8.543**	**319.629**	**9.111**	**3196.247**	**91.094**	

Tables notes: *amount includes ingredients 1 and 2 listed in (all constituents) Table 6 **amount includes only ingredient 1, either Bti or S-Methoprene (active constituent)

Example calculation

Site 14.1 Murray St Drains & March Nth & Sth of Rail

Site no.	Site description	Within or adjacent to Ramsar site	Site area (ha)	Percentage of area treated	Estimated historical treatment area = Proposed treatment area (ha)	No./ range / mode of historical treatments over 16 seasons	Proposed frequency of treatments per season	Proposed seasonal treatment area (ha)	Proposed program treatment area (ha)
14.1	PT LONSDALE, MURRAY ST DRAINS & MARSH NTH & STH OF RAIL	Yes	3.38	0.8	2.70	73 / 16 / 2	4.56	12.34	123.37

$$\text{Seasonal intended rate S-Methoprene} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate S-Methoprene} = \left(12.34\ \text{ha} \times \frac{5\ \text{kg}}{\text{ha}}\right) \times \frac{3\ *}{5} = 37.0110\ \text{kg}$$

$$\text{Actual amount of S-Methoprene used for seasonal rate} = \text{Seasonal intended rate S-Methoprene} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of S-Methoprene used for seasonal rate} = 37.0110\ \text{kg} \times \frac{4\ **}{1000} = 0.1480\ \text{kg}$$

$$\text{Seasonal intended rate BTI} = (\text{Seasonal treatment area} \times \text{Maximum product rate}) \times \text{Proportion of treatment}$$

$$\text{Seasonal intended rate BTI} = \left(12.34\ \text{ha} \times \frac{7\ \text{kg}}{\text{ha}}\right) \times \frac{2\ *}{5} = 34.5436\ \text{kg}$$

$$\text{Actual amount of BTI used for seasonal rate} = \text{Seasonal intended rate BTI} \times \text{ingredient 1 concentration}$$

$$\text{Actual amount of BTI used for seasonal rate} = 34.5436 \times \frac{2.85\ **}{100} = 0.9845\ \text{kg}$$

*-value obtained from Table 18.**-value obtained from Table 1.

Appendix B

List of all literature for questions 1, 3 – 6

Authors	Title	Publication	Year	Publisher	Clasification	Question	Product
Paice, Robyn;	Assessment of mosquito larvicide impacts on aquatic invertebrates in the Vasse-Wonnerup Wetland System		2016		1	1	Bti
Neto, José Manoel W Duarte; Wanderley, Maria Carolina de A; da Silva, Túlio Alexandre F; Marques, Daniela A Viana; da Silva, Gilvanda R; Gurgel, Josimar Fernandes; de Paula Oliveira, José; Porto, Ana Lúcia F;	Bacillus thuringiensis endotoxin production: a systematic review of the past 10 years	World Journal of Microbiology and Biotechnology	2020	Springer	1	1	Bti
Lawler, Sharon P;	Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control	Ecotoxicology and environmental safety	2017	Elsevier	1	1	Bti
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	1	1	Bti
Allgeier, Stefanie;	Mosquito control based on Bacillus thuringiensis israelensis (Bti)-Ecological effects on wetland food chains and public acceptance of control alternatives		2019	Universität Koblenz-Landau, Campus Landau	1	1	Bti
Judd, Shiloh Dean;	The Effects of Juvenile Exposure to Sub-lethal Concentrations of Pesticides on the Adult Reproductive Biology of the Male Southern House Mosquitoe, Culex quinquefasciatus		2018		1	1	Bti
Wolfram, Georg; Wenzl, Philipp; Jerrentrup, Hans;	A multi-year study following BACI design reveals no short-term impact of Bti on chironomids (Diptera) in a floodplain in Eastern Austria	Environmental monitoring and assessment	2018	Springer	2	1	Bti
Gowelo, Steven A;	A participatory approach for malaria control in southern Malawi: Effects of the environment and community on larval source management		2020	Wageningen University	2	1	Bti
McGregor, Bethany L; Connelly, C Roxanne;	A Review of the Control of Aedes aegypti (Diptera: Culicidae) in the Continental United States	Journal of Medical Entomology	2021	Oxford University Press US	2	1	Bti
Junges, Celina Maria; Maglianese, MI; Lajmanovich, Rafael Carlos; Peltzer, PM; Attademo, Andres Maximiliano;	Acute toxicity and etho-toxicity of three insecticides used for mosquito control on amphibian tadpoles	Water, Air, & Soil Pollution	2017	Springer	2	1	Bti
Allgeier, Stefanie; Kästel, Anna; Brühl, Carsten A;	Adverse effects of mosquito control using Bacillus thuringiensis var. israelensis: reduced chironomid abundances in mesocosm, semi-field and field studies	Ecotoxicology and environmental safety	2019	Elsevier	2	1	Bti
Sánchez-Bayo, Francisco; Tennekes, Henk A;	Assessment of ecological risks of agrochemicals requires a new framework	Environmental Risk Assessment and Remediation	2017		2	1	Bti
Falqueto, Silvia Altoé; Pitaluga, Bruno Faria; de Sousa, Janaína Rosa; Targanski, Sabrina Ketrin; Campos, Mateus Gandra; de Oliveira Mendes, Tiago Antônio; da Silva, Gilvan Ferreira; Silva, Dulce Helena Siqueira; Soares, Marcos Antônio;	Bacillus spp. metabolites are effective in eradicating Aedes aegypti (Diptera: Culicidae) larvae with low toxicity to non-target species	Journal of Invertebrate Pathology	2021	Elsevier	2	1	Bti
Keshavareddy, G; Kumar, ARV;	Bacillus thuringiensis	Ecofriendly pest management for food security	2016	Elsevier	2	1	Bti
Savini, Vincenzo; Fazii, Paolo;	Bacillus thuringiensis Insecticide Properties	The Diverse Faces of Bacillus cereus	2016	Elsevier	2	1	Bti
Osman, GEH; Already, Rasha; Assaeedi, ASA; Organji, SR; El-Ghareeb, Doaa; Abulreesh, HH; Althubiani, AS;	Bioinsecticide Bacillus thuringiensis a comprehensive review	Egyptian Journal of Biological Pest Control	2015	Egyptian Society for Biological Control of Pests	2	1	Bti
Richardson, Elise A; Abruzzo, Nicole O; Taylor, Caitlin E; Stevens, Bruce R; Cuda, James P; Weeks, Emma NI;	Combining DL-Methionine and Bacillus thuringiensis subspecies israelensis: Prospects for a Mosquito Larvicide	Insects	2020	Multidisciplinary Digital Publishing Institute	2	1	Bti
Stone Lakes, NWR;	Compatibility Determination for Mosquito Control on the Stone Lakes National Wildlife Refuge				2	1	Bti
Elgin, Andrew Stephen;	CONSERVING PRAIRIE PONDS FOR SWALLOWS: TREE SWALLOW (TACHYCINETA BICOLOR) FORAGING AND NESTLING DIET QUALITY IN PRAIRIE AGROECOSYSTEMS		2020	University of Saskatchewan	2	1	Bti
Pignotti, Emanuela;	Contaminants of Emerging Concern: occurrence and distribution in aquatic environments		2018	alma	2	1	Bti
Fayolle, Stéphanie; Bertrand, Céline; Logez, Maxime; Franquet, Evelyne;	Corrigendum: Does mosquito control by Bti spraying affect the phytoplankton community? A 5-year study in Camargue temporary wetlands (France)	Annales de Limnologie-International Journal of Limnology	2016	EDP Sciences	2	1	Bti
Zhang, Yang; Chen, Hui; Fan, Yangyang; Yang, Yun; Gao, Jufang; Xu, Wenping; Xu, Zhiping; Li, Zhong; Tao, Liming;	Cytotoxic effects of bio-pesticide spinosad on human lung A549 cells	Chemosphere	2019	Elsevier	2	1	Bti
Zaller, Johann G;	Daily Poison: Pesticides-an Underestimated Danger		2020	Springer Nature	2	1	Bti
Tamilselvan, S;	DEVELOPMENT AND EVALUATION OF FLY ASH BASED BACILLUS THURINGIENSIS VAR. ISRAELENSIS FORMULATIONS FOR MOSQUITO CONTROL		2015	Pondicherry	2	1	Bti
Schneider, Salome; Tajrin, Tania; Lundström, Jan O; Hendriksen, Niels B; Melin, Petter; Sundh, Ingvar;	Do multi-year applications of Bacillus thuringiensis subsp. israelensis for control of mosquito larvae affect the abundance of B. cereus group populations in riparian wetland soils?	Microbial ecology	2017	Springer	2	1	Bti
Schweizer, Mona; Miksch, Lukas; Köhler, Heinz-R; Triebskorn, Rita;	Does Bti (Bacillus thuringiensis var. israelensis) affect Rana temporaria tadpoles?	Ecotoxicology and environmental safety	2019	Elsevier	2	1	Bti
Fayolle, Stephanie; Bertrand, Celine; Logez, Maxime; Franquet, Evelyne;	Does mosquito control by Bti spraying affect the phytoplankton community? A 5-year study in Camargue temporary wetlands (France)	Annales de Limnologie-International Journal of Limnology	2015	EDP Sciences	2	1	Bti
Pauley, Luke R; Earl, Julia E; Semlitsch, Raymond D;	Ecological effects and human use of commercial mosquito insecticides in aquatic communities	Journal of Herpetology	2015	the Society for the Study of Amphibians and Reptiles	2	1	Bti
Chen, Chong; Zou, Wenbing; Cui, Guolu; Tian, Jichen; Wang, Yuncai; Ma, Limin;	Ecological risk assessment of current-use pesticides in an aquatic system of Shanghai, China	Chemosphere	2020	Elsevier	2	1	S-methoprene
Vieira Santos, Vanessa Santana; Caixeta, Evelyn Siqueira; Campos Júnior, Edimar Olegário de; Pereira, Boscolli Barbosa;	Ecotoxicological effects of larvicide used in the control of Aedes aegypti on nontarget organisms: Redefining the use of pyriproxyfen	Journal of Toxicology and Environmental Health, Part A	2017	Taylor & Francis	2	1	S-methoprene
Ahmad, Mohd Najib; Ali, Siti Ramlah Ahmad; Masri, Mohamed Mazmira Mohd; Asmawi, Mohd Zaini;	EFFECT OF Bacillus thuringiensis BAsED-PRODUCTs On RATs	Journal of Oil Palm Research	2015	MALAYSIAN PALM OIL BOARD PO BOX 10620, KUALA LUMPUR, 50720, MALAYSIA	2	1	Bti
Scheff, Deanna S; Subramanyam, Bhadriraju; Arthur, Frank H;	Effect of methoprene treated polymer packaging on fecundity, egg hatchability, and egg-to-adult emergence of Tribolium castaneum and Trogoderma variabile	Journal of Stored Products Research	2016	Elsevier	2	1	S-methoprene
Staples, Kerry; Oosthuizen, Jacques; Lund, Mark;	Effectiveness of s-methoprene briquets and application method for mosquito control in urban road gullies/catch basins/gully pots in a mediterranean climate: Implications for Ross River virus transmission	Journal of the American Mosquito Control Association	2016	BioOne	2	1	S-methoprene
Olmo, Carla; Marco, Amparo; Armengol, Xavier; Ortells, Raquel;	Effects of Bacillus thuringiensis var. israelensis on nonstandard microcrustacean species isolated from field zooplankton communities	Ecotoxicology	2016	Springer	2	1	Bti
Ameka, CM;	Effects of insect growth regulator pyriproxyfen on dragonfly nymphs as predators of Anopheles mosquitoes at Mahanga, Vihiga County, Kenya	Nairobi: MSc thesis, Kenyatta University	2015		2	1	S-methoprene
Initiative, Grasslands Ecosystem;	EFFECTS OF MANAGEMENT PRACTICES ON WETLAND BIRDS: BLACK TERN				2	1	Bti
Collins, CM; Bonds, J; Quinlan, M; Mumford, J;	Effects of removal or reduced density of the malaria mosquito, Anopheles gambiae sl, on interacting predators and competitors in local ecosystems		2018	Wiley	2	1	Bti
Hu, Xue Lei; Niu, Jiao Jiao; Meng, Qi; Chai, Yuet Hung; Chu, Ka Hou; Chan, King Ming;	Effects of two juvenile hormone analogue insecticides, fenoxycarb and methoprene, on Neocaridina davidi	Environmental Pollution	2019	Elsevier	2	1	Bti
Riaz, MA; Riaz, A; Ijaz, B; Rasool, MS; Rahat, S; Nisa, Z Un;	Environment friendly management of mosquito: a short review	Bangladesh Journal of Scientific and Industrial Research	2018		2	1	Bti

Bruehl, Carsten A; Despres, Laurence; Frör, Oliver; Patil, Chandrashekhar D; Poulin, Brigitte; Tetreau, Guillaume; Allgeier, Stefanie;	Environmental and socioeconomic effects of mosquito control in Europe using the biocide Bacillus thuringiensis subsp. israelensis (Bti)	Science of the Total Environment	2020	Elsevier	2	1	Bti
Allgeier, Stefanie; Frombold, Bianca; Mingo, Valentin; Brühl, Carsten A;	European common frog Rana temporaria (Anura: Ranidae) larvae show subcellular responses under field-relevant Bacillus thuringiensis var. israelensis (Bti) exposure levels	Environmental research	2018	Elsevier	2	1	Bti
Staples, Kerry;	Evaluation of a mosquito control intervention and recommendations for development of best practice protocols by the Shire of Kalamunda		2016		2	1	S-methoprene
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of methoprene on oogenesis of the freshwater crab Travancoriana schirnerae Bott, 1969 (Decapoda: Gecarcinucidae)	Brazilian Journal of Biological Sciences	2017		2	1	S-methoprene
Timmermann, Ute; Becker, Norbert;	Impact of routine Bacillus thuringiensis israelensis (Bti) treatment on the availability of flying insects as prey for aerial feeding predators	Bulletin of entomological research	2017	Cambridge University Press	2	1	Bti
Jakob, Christiane; Poulin, Brigitte;	Indirect effects of mosquito control using Bti on dragonflies and damselflies (Odonata) in the Camargue	Insect Conservation and Diversity	2016	Wiley Online Library	2	1	Bti
Recluse, Brown; Earworm, Corn; Fly, House; Marmorated, Brown; Bug, Bed; Bug, Tarnished Plant; Bug, Stink;	Insecticide Recommendations for Arkansas				2	1	Bti
Maletz, Sibylle; Wollenweber, Marc; Kubiak, Katharina; Müller, Annett; Schmitz, Stefan; Maier, Dieter; Hecker, Markus; Hollert, Henner;	Investigation of potential endocrine disrupting effects of mosquito larvicidal Bacillus thuringiensis israelensis (Bti) formulations	Science of the Total Environment	2015	Elsevier	2	1	Bti
Bordalo, MD; Gravato, C; Beleza, S; Campos, D; Lopes, I; Pestana, JLT;	Lethal and sublethal toxicity assessment of Bacillus thuringiensis var. israelensis and Beauveria bassiana based bioinsecticides to the aquatic insect Chironomus riparius	Science of The Total Environment	2020	Elsevier	2	1	Bti
Yeeles, Peter; Strain, Angela; Lenancker, Pauline; Lach, Lori;	Low reduction of invasive ant colony productivity with an insect growth regulator	Pest Management Science	2020	Wiley Online Library	2	1	S-methoprene
Wijayaratne, LKW; Arthur, FH; Whyard, S;	Methoprene and control of stored-product insects	Journal of Stored Products Research	2018	Elsevier	2	1	S-methoprene
Bargar, Timothy A; Anderson, Chad; Sowers, Anthony;	Mortality and Cholinesterase Inhibition in Butterflies Following Aerial Naled Applications for Mosquito Control on the National Key Deer Refuge	Archives of Environmental Contamination and Toxicology	2020	Springer	2	1	Bti
Lagadic, Laurent; Schäfer, Ralf B; Roucaute, Marc; Szöcs, Eduard; Chouin, Sébastien; de Maupeou, Jérôme; Duchet, Claire; Franquet, Evelyne; Le Hunsec, Benoit; Bertrand, Céline;	No association between the use of Bti for mosquito control and the dynamics of non-target aquatic invertebrates in French coastal and continental wetlands	Science of the Total Environment	2016	Elsevier	2	1	Bti
Authority, European Food Safety; Anastassiadou, Maria; Arena, Maria; Auteri, Domenica; Brancato, Alba; Bura, Laszlo; Cabrera, Luis Carrasco; Chaideftou, Eugenia; Chiusolo, Arianna; Crivellente, Federica;	Peer review of the pesticide risk assessment of the active substance Bacillus thuringiensis ssp. aizawai strain ABTS-1857	EFSA Journal	2020	Wiley-Blackwell	2	1	Bti
Poulin, Brigitte; Lefebvre, Gaëtan;	Perturbation and delayed recovery of the reed invertebrate assemblage in Camargue marshes sprayed with Bacillus thuringiensis israelensis	Insect science	2018	Wiley Online Library	2	1	Bti
Brunk, Ingo; Sobczyk, Thomas; Roth, Mechthild;	Pest control in German forests: General patterns of biodiversity and possible impacts of Btk, diflubenzuron and lambda-Cyhalothrin on non-target arthropods, birds and bats–a literature review				2	1	Bti
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	2	1	Bti
Omoya, FO; Akharaiyi, FC;	Physiological changes in Clarias gariepinus induced with Bacillus species used as biological agent in aquatic environment	Journal of Scientific Research and Reports	2015		2	1	Bti
Amiard-Triquet, Claude;	Pollution tolerance in aquatic animals: From fundamental biological mechanisms to ecological consequences	Ecotoxicology	2019	Elsevier	2	1	Bti
Wieck, Stefanie; Olsson, Oliver; Kümmerer, Klaus;	Possible underestimations of risks for the environment due to unregulated emissions of biocides from households to wastewater	Environment international	2016	Elsevier	2	1	S-methoprene
Ketseoglou, Irene; Bouwer, Gustav;	The persistence and ecological impacts of a cyanobacterium genetically engineered to express mosquitocidal Bacillus thuringiensis toxins	Parasites & vectors	2016	BioMed Central	2	1	Bti
Török, Edina; Hochkirch, Axel; Soltész, Zoltán; Tscharntke, Teja; Batáry, Péter;	The Unmeasured ecological effect of mosquito control	European Journal of Ecology	2020		2	1	Bti
Lajmanovich, Rafael C; Junges, Celina M; Cabagna-Zenklusen, Mariana C; Attademo, Andrés M; Peltzer, Paola M; Maglianese, Mariana; Márquez, Vanina E; Beccaria, Alejandro J;	Toxicity of Bacillus thuringiensis var. israelensis in aqueous suspension on the South American common frog Leptodactylus latrans (Anura: Leptodactylidae) tadpoles	Environmental research	2015	Elsevier	2	1	Bti
Nuzula, Sayyidatul Awalia; Gama, Zulfaidah Penata;	Toxicity studies of Bacillus thuringiensis on non-target organism Daphnia sp.(Diplostraca: Daphniidae)	AIP Conference Proceedings	2018	AIP Publishing LLC	2	1	Bti
Alto, Barry W; Lord, Cynthia C;	Transstadial effects of Bti on traits of Aedes aegypti and infection with dengue virus	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	2	1	Bti
Land, Magnus; Bundschuh, Mirco; Hopkins, Richard J; Poulin, Brigitte; McKie, Brendan G;	What are the effects of control of mosquitoes and other nematoceran Diptera using the microbial agent Bacillus thuringiensis israelensis (Bti) on aquatic and terrestrial ecosystems? A systematic review protocol	Environmental Evidence	2019	BioMed Central	2	1	Bti
van Leeuwenhoeklaan, A; Marinković, M; Montforts, M;	1. Mosquito control products				3	1	Bti
Epp, Liam; Morin, Antoine; Poulain, Alexandre;	2017 Field Data Collection from Kanata North, Ottawa, Ontario, Canada 2016-2017 Comparisons Bti Treatment Project		2017		3	1	Bti
Epp, Liam; Morin, Antoine; Poulain, Alexandre;	2018 Field Data Collection from Kanata North, Ottawa, Ontario, Canada 2016-2017-2018 Comparisons Bti Treatment Project		2019		3	1	Bti
Hanford, Jayne Kathryn;	Aquatic Biodiversity and Mosquito Ecology in Urban Wetlands		2020	University of Sydney	3	1	Bti
Strickman, Daniel;	Arthropod Vector Control	Hunter's Tropical Medicine and Emerging Infectious Diseases	2020	Elsevier	3	1	Bti
Benelli, Giovanni; Jeffries, Claire L; Walker, Thomas;	Biological control of mosquito vectors: past, present, and future	Insects	2016	Multidisciplinary Digital Publishing Institute	3	1	Bti
Hameed, AAA; Al-Bander, EHK; Al-Obadi, FAG;	Comparison the effect of fungi (Beauveria bassiana) and bacteria Bacillus thuringiensis (is-raelensis) on a cumulative mortality of culex quinquefasciatus (Diptera: Culicidae). S	Asian J. Life Sci	2017		3	1	Bti
Kästel, Anna; Allgeier, Stefanie; Brühl, Carsten A;	Decreasing Bacillus thuringiensis israelensis sensitivity of Chironomus riparius larvae with age indicates potential environmental risk for mosquito control	Scientific reports	2017	Nature Publishing Group	3	1	Bti
Ferreira, Francisco Augusto da Silva; Arcos, Adriano Nobre; Sampaio, Raquel Telles de Moreira; Rodrigues, Ilea Brandão; Tadei, Wanderli Pedro;	Effect of Bacillus sphaericus Neide on Anopheles (Diptera: Culicidae) and associated insect fauna in fish ponds in the Amazon	Revista Brasileira de Entomologia	2015	SciELO Brasil	3	1	Bti
Aryaprema, Vindhya S; Xue, Rui-De;	Effectiveness and public acceptance of a slow release formulation of Bacillus thuringiensis israelensis (Mosquito Dunks®) in controlling the population density of dengue vectors in Sri Lanka	International Journal of Pest Management	2019	Taylor & Francis	3	1	Bti
Duchet, Claire; Franquet, Evelyne; Lagadic, Laurent; Lagneau, Christophe;	Effects of Bacillus thuringiensis israelensis and spinosad on adult emergence of the non-biting midges Polypedilum nubifer (Skuse) and Tanytarsus curticornis Kieffer (Diptera: Chironomidae) in coastal wetlands	Ecotoxicology and environmental safety	2015	Elsevier	3	1	Bti
Docile, Tatiana; Figueiró, Ronaldo; Molina, Oscar; Gil-Azevedo, Leonardo; Nessimian, Jorge;	Effects of Bacillus thuringiensis var. israelensis on the Black Fly Communities (Diptera, Simuliidae) in Tropical Streams	Neotropical Entomology	2021	Springer	3	1	Bti
Hu, Xuelei;	Effects of Juvenile Hormone Analogue Insecticides, Fenoxycarb and Methoprene, on Neocaridina davidi and Moina macrocopa		2019	The Chinese University of Hong Kong (Hong Kong)	3	1	Bti

Nakazawa, Mitsue Maia; Araújo, Ana Paula; Melo-Santos, Maria Alice Varjal; Oliveira, Cláudia Maria Fontes; Silva-Filha, Maria Helena Neves Lobo;	Efficacy and persistence of Bacillus thuringiensis svar. israelensis (Bti) and pyriproxyfen-based products in artificial breeding sites colonized with susceptible or Bti-exposed Aedes aegypti larvae	Biological Control	2020	Elsevier	3	1	Bti
Garza-Almanza, Victoriano; Ulíbarri, Gérard; Sanchez-Yañez, Juan Manuel;	Efficacy of 2 Commercial Formulations of Bacillus thuringiensis H-14 in Larvae of Anopheles albimanus W and Aedes aegypti L (Diptera: culicidae).		2020	Preprints	3	1	Bti
Gad, Abir A; Al-Dakhil, Abeer A;	Efficacy of Bacillus thuringiensis israelensis (Bti) and four plant extracts on the mortality and development of Culex quinquefasciatus Say (Diptera: Cullicidae)	Egyptian Journal of Biological Pest Control	2018	SpringerOpen	3	1	Bti
MWERESA, NIXON GUNGU;	EVALUATION OF BACILLUS THURINGIENSIS VAR ISRAELENSIS AND BACILLUS SPHAERICUS BRIQUETS AS ANOPHELES MOSQUITO LARVICIDES IN VIHIGA COUNTY, WESTERN KENYA		2016	KENYATTA UNIVERSITY	3	1	Bti
Tamilselvan, Saravanan; Manonmani, Arulsamy Mary; Jambulingam, Purushothaman;	Fly ash-based water dispersible powder formulation of Bacillus thuringiensis var. israelensis: Development & laboratory evaluation against mosquito immatures	The Indian journal of medical research	2017	Wolters Kluwer--Medknow Publications	3	1	Bti
Abokersh, Mohamed; Barakat, Emad;	Identification of haemocytes in the haemolymph of desert locust, Schistocerca gregaria and their activity against Bacillus thuringiensis israelensis	Journal of Egyptian Academic Society for Environmental Development. D, Environmental Studies	2020	Egyptian Academic Society for Environmental Development	3	1	Bti
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of Methoprene on Spermatogenesis of the Freshwater Crab Travancoriana schirnerae				3	1	Bti
Sands, Don PA;	Important issues facing insect conservation in Australia: now and into the future	Austral Entomology	2018	Wiley Online Library	3	1	S-methoprene
El-Kersh, Talaat A; Ahmed, Ashraf M; Al-Sheikh, Yazeed A; Tripet, Frédéric; Ibrahim, Mohamed S; Metwalli, Ali AM;	Isolation and characterization of native Bacillus thuringiensis strains from Saudi Arabia with enhanced larvicidal toxicity against the mosquito vector Anopheles gambiae (sl)	Parasites & vectors	2016	Springer	3	1	Bti
da Silva Carvalho, Karine; Crespo, Mônica Maria; Araújo, Ana Paula; da Silva, Renata Santana; de Melo-Santos, Maria Alice Varjal; de Oliveira, Cláudia Maria Fontes; Silva-Filha, Maria Helena Neves Lobo;	Long-term exposure of Aedes aegypti to Bacillus thuringiensis svar. israelensis did not involve altered susceptibility to this microbial larvicide or to other control agents	Parasites & vectors	2018	BioMed Central	3	1	Bti
de Souza Machado, Anderson Abel; Zarfl, Christiane; Rehse, Saskia; Kloas, Werner;	Low-dose effects: nonmonotonic responses for the toxicity of a Bacillus thuringiensis biocide to Daphnia magna	Environmental science & technology	2017	ACS Publications	3	1	Bti
Gray, EW; Fusco, R;	Microbial control of black flies (Diptera: Simuliidae) with Bacillus thuringiensis subsp. israelensis	Microbial Control of Insect and Mite Pests	2017	Elsevier	3	1	Bti
Iburg, Joseph P; Gray, Elmer W; Noblet, Raymond;	Mortality patterns of Simulium vittatum larvae (Diptera: Simuliidae) following exposure to insecticidal proteins produced by Bacillus thuringiensis var. israelensis	Journal of the American Mosquito Control Association	2015	BioOne	3	1	Bti
Thammasittirong, Anon; Prigyai, Kanchana; Thammasittirong, Sutticha Na-Ranong;	Mosquitocidal potential of silver nanoparticles synthesized using local isolates of Bacillus thuringiensis subsp. israelensis and their synergistic effect with a commercial strain of B. thuringiensis subsp. israelensis	Acta tropica	2017	Elsevier	3	1	Bti
Sutton, Rebecca; Xie, Yina; Moran, Kelly D; Teerlink, Jennifer;	Occurrence and sources of pesticides to urban wastewater and the environment	Pesticides in Surface Water: Monitoring, Modeling, Risk Assessment, and Management	2019	ACS Publications	3	1	S-methoprene
Zghal, Raida Zribi; Kharrat, Marwa; Rebai, Ahmed; Khedher, Saoussen Ben; Jallouli, Wafa; Elleuch, Jihen; Ginibre, Carole; Chandre, Fabrice; Tounsi, Slim;	Optimization of bio-insecticide production by Tunisian Bacillus thuringiensis israelensis and its application in the field	Biological Control	2018	Elsevier	3	1	Bti
Mariano, Wagner S; Azevedo, Saulo B; Gomes, Francisco L; Lima, Liana BD; Moron, Sandro E; Tavares-Dias, Marcos;	Physiological parameters of Piaractus mesopotamicus (Osteichthyes: Characidae) exposed to a biopesticide based on Bacillus thuringiensis	Anais da Academia Brasileira de Ciências	2019	SciELO Brasil	3	1	Bti
Malovichko, Yury V; Nizhnikov, Anton A; Antonets, Kirill S;	Repertoire of the Bacillus thuringiensis virulence factors unrelated to major classes of protein toxins and its role in specificity of host-pathogen interactions	toxins	2019	Multidisciplinary Digital Publishing Institute	3	1	Bti
Chen, Yi; Yang, Yan; Zhu, Haojun; Romeis, Jörg; Li, Yunhe; Peng, Yufa; Chen, Xiuping;	Safety of Bacillus thuringiensis Cry1C protein for Daphnia magna based on different functional traits	Ecotoxicology and environmental safety	2018	Elsevier	3	1	Bti
Henle, Klaus; Dubois, Alain;	Studies on Anomalies in Natural Populations of Amphibians	MERTENSIELLA	2017		3	1	S-methoprene
Mohiddin, Ahmad; Lasim, Asmalia Md; Zuharah, Wan Fatma;	Susceptibility of Aedes albopictus from dengue outbreak areas to temephos and Bacillus thuringiensis subsp. israelensis	Asian Pacific journal of tropical biomedicine	2016	Elsevier	3	1	Bti
Pires, Sílvia; Alves, Joana; Dia, Ibrahima; Gómez, Lara F;	Susceptibility of mosquito vectors of the city of Praia, Cabo Verde, to Temephos and Bacillus thuringiensis var israelensis	Plos one	2020	Public Library of Science San Francisco, CA USA	3	1	Bti
Dawson, Daniel; Salice, Christopher J; Subbiah, Seenivasan;	The Efficacy of the Bacillus thuringiensis israelensis Larvicide Against Culex tarsalis in Municipal Wastewater and Water from Natural Wetlands.	Journal of the American Mosquito Control Association	2019		3	1	Bti
Achari, T Sarita; Barik, Tapan Kumar; Acharya, UR;	Toxins of Bacillus thuringiensis: A Novel Microbial Insecticide for Mosquito Vector Control	Molecular Identification of Mosquito Vectors and Their Management	2020	Springer	3	1	Bti
Maletz, Sibylle Xenia;	“Endocrine activity in the aquatic environment				4	1	Bti
Mainali, Samir; Lamichhane, Ram Sharan; Clark, Kim; Beatty, Shelley; Fatouros, Maria; Neville, Peter; Oosthuizen, Jacques;	“Looking over the backyard fence”: Householders and mosquito control	International journal of environmental research and public health	2017	Multidisciplinary Digital Publishing Institute	4	1	Bti
Chilima, Clement; Soko, Misheck; Pemba, Dylo; Phiri, George;	10 Insect outbreaks in the Lake Chilwa Basin	Socio-Ecological Resilience to Climate Change in a Fragile Ecosystem: The Case of the Lake Chilwa Basin, Malawi	2018	Routledge	4	1	Bti
Beugnet, Frédéric; Franc, Michel; Tielemans, Eric;	1-01 GASTRO-INTESTINAL HELMINTHOSES	PARASITOSES & VECTOR BORNE DISEASES OF CATS	2015		4	1	S-methoprene
Yadav, Kamlesh Kumar; Chandel, Kshitij; Bhagyawant, Sameer S; Veer, Vijay;	14 Midgut Bacterial Microbiota of Important Mosquito Disease Vectors and Its Role in Control of Parasite Transmission	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	1	Bti
Anbalagan, Sankarappan;	20 Microbial Approaches for Black Fly-Targeted Onchocerciasis Control	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	1	Bti
Schowalter, Tim; Cooper, Karen; Kramer, Kathleen; Neely, Elizabeth; Ring, Dennis; Ringe, Penny;	2015 Imported Fire Ant and Invasive Pest Ant Conference		2015		4	1	S-methoprene
Epp, Liam; Morin, Antoine;	2016 Field Data Collection from Kanata North, Ottawa, Ontario, Canada		2017		4	1	Bti
Brannen, Philip; Schnabel, Guido; Burrack, Hannah J; Bessin, Richard; Pfeiffer, Douglas G; Mitchem, Wayne; Jennings, Katie; Lockwood, David; Fernandez, Gina; Sial, Ash;	2016 Southeast Regional Caneberry Integrated Management Guide. Southeastern Small Fruit Consortium		2016		4	1	S-methoprene
Walton, William E;	2019 AMCA Presidential Address: The Times They Are A-Changin'	Journal of the American Mosquito Control Association	2019	American Mosquito Control Association	4	1	S-methoprene
District, Columbia Shuswap Regional;	2020 EARLY SEASON REPORT		2020		4	1	Bti
Oliver, Jonathan; Schnabel, G; Melanson, R; Gauthier, N; Burrack, H; Sial, A; Hale, F; Pfeiffer, Douglas; Mitchem, W; Jennings, K;	2020 Southeast Regional Caneberries Integrated Management Guide. Southern Region Small Fruit Consortium Bull. 47		2020		4	1	S-methoprene
Chinnathambi, Arunachalam; Mathrubutham, Ravikumar;	21 Effective Microbial Compounds for Controlling Flea-Borne Rickettsial Diseases	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	1	Bti
Hovius, K Emil;	28. The protection of European dogs against infection with Lyme disease spirochaetes	Ecology and prevention of Lyme borreliosis	2016	Wageningen Academic Publishers	4	1	S-methoprene

Atkins, Clarke E; Ames, Marisa K;	3-01 FELINE HEARTWORM DISEASE–THE CLINICAL PERSPECTIVE	PARASITOSES & VECTOR BORNE DISEASES OF CATS	2015		4	1	S-methoprene
Smith, GA; Stekolnikov, AA;	41–62, 2006. Shatrov AB, Stylostome formation in trombiculid mites (Acariformes, Trombiculidae). Exp. Appl. Acarology, 49, 261–280, 2009.	Zoonoses: Infectious Diseases Transmissible from Animals to Humans	2015	John Wiley & Sons	4	1	Bti
Vivekanandhan, Perumal; Arunthirumeni, Murugan; Vengateswari, Govindaraj; Shivakumar, Muthugounder Subramanian;	5 Bioprospecting of Novel Fungal Secondary Metabolites for Mosquito Control	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	1	Bti
Martinou, Angeliki F; Schäfer, Stephanie M; Bueno Mari, Rubén; Angelidou, Ioanna; Erguler, Kamil; Fawcett, James; Ferraguti, Martina; Foussadier, Rémi; Gkotsi, Trisevgeni V; Martinos, Christos F;	A call to arms: Setting the framework for a code of practice for mosquito management in European wetlands	Journal of Applied Ecology	2020	Wiley Online Library	4	1	Bti
Michaelakis, Antonios; Balestrino, Fabrizio; Becker, Norbert; Bellini, Romeo; Caputo, Beniamino; della Torre, Alessandra; Figuerola, Jordi; L'Ambert, Gregory; Petric, Dusan; Robert, Vincent;	A Case for Systematic Quality Management in Mosquito Control Programmes in Europe	International Journal of Environmental Research and Public Health	2021	Multidisciplinary Digital Publishing Institute	4	1	Bti
Liu, Xinzhi; Stechlinski, Peter;	A Case Study: Chikungunya Outbreak in Réunion	Infectious Disease Modeling	2017	Springer	4	1	Bti
Guissou, Charles;	A Controversial Bill (HR 897) To Mosquito Control Programs: A Policy Analysis		2016		4	1	Bti
Land, Magnus; Macura, Biljana; Bernes, Claes; Johansson, Sif;	A five-step approach for stakeholder engagement in prioritisation and planning of environmental evidence syntheses	Environmental Evidence	2017	Springer	4	1	Bti
Webb, Cameron; Doggett, Stephen; Russell, Richard;	A guide to mosquitoes of Australia		2016	Csiro Publishing	4	1	Bti
Pruszynski, Catherine A; Hribar, Lawrence J; Mickle, Robert; Leal, Andrea L;	A large scale biorational approach using Bacillus thuringiensis israeliensis (strain AM65-52) for managing Aedes aegypti populations to prevent dengue, chikungunya and Zika transmission	PloS one	2017	Public Library of Science San Francisco, CA USA	4	1	Bti
Contreras, Estefania; Masuyer, Geoffrey; Qureshi, Nadia; Chawla, Swati; Dhillon, Harpal S; Lee, Han Lim; Chen, Jianwu; Stenmark, Pål; Gill, Sarjeet S;	A neurotoxin that specifically targets Anopheles mosquitoes	Nature communications	2019	Nature Publishing Group	4	1	Bti
Fang, Ying; Garcia, Sandra; Byrne, Barbara; Barker, Christopher M;	A new rapid diagnostic test to identify Aedes eggs	PROCEEDINGS AND PAPERS	2016		4	1	S-methoprene
Duval, David; Galinier, Richard; Mouahid, Gabriel; Toulza, Eve; Allienne, Jean François; Portela, Julien; Calvayrac, Christophe; Rognon, Anne; Arancibia, Nathalie; Mitta, Guillaume;	A novel bacterial pathogen of Biomphalaria glabrata: a potential weapon for schistosomiasis control?	PLoS Negl Trop Dis	2015	Public Library of Science	4	1	Bti
Jongejan, Frans; De Vos, Christa; Fourie, Josephus J; Beugnet, Frederic;	A novel combination of fipronil and permethrin (Frontline Tri-Act®/Frontect®) reduces risk of transmission of Babesia canis by Dermacentor reticulatus and of Ehrlichia canis by Rhipicephalus sanguineus ticks to dogs	Parasites & Vectors	2015	BioMed Central	4	1	S-methoprene
Parihar, Kashmira; Telang, Manasi; Ovhal, Ankita;	A patent review on strategies for biological control of mosquito vector	World Journal of Microbiology and Biotechnology	2020	Springer	4	1	Bti
Kollars Jr, Thomas Martin; Kollars, Jason William; Kollars, Eric Lewis;	A Plant Volatile Infused Honey Bait for Control of Aedes aegypti Larvae and Adults				4	1	Bti
Contreras, Marinela; Villar, Margarita; Artigas-Jerónimo, Sara; Kornieieva, Lidiia; Mytrofanov, Sergii; de la Fuente, José;	A reverse vaccinology approach to the identification and characterization of Ctenocephalides felis candidate protective antigens for the control of cat flea infestations	Parasites & vectors	2018	Springer	4	1	S-methoprene
Senthil-Nathan, Sengottayan;	A review of resistance mechanisms of synthetic insecticides and botanicals, phytochemicals, and essential oils as alternative larvicidal agents against mosquitoes	Frontiers in physiology	2020	Frontiers	4	1	Bti
Bacci, L; Lupi, D; Savoldelli, S; Rossaro, B;	A review of Spinosyns, a derivative of biological acting substances as a class of insecticides with a broad range of action against many insect pests		2016	Pagepress	4	1	Bti
Ogunlade, Samson T; Meehan, Michael T; Adekunle, Adeshina I; Rojas, Diana P; Adegboye, Oyelola A; McBryde, Emma S;	A Review: Aedes-Borne Arboviral Infections, Controls and Wolbachia-Based Strategies	Vaccines	2021	Multidisciplinary Digital Publishing Institute	4	1	Bti
Silva Jr, José VJ; Ludwig-Begall, Louisa F; de Oliveira-Filho, Edmilson F; Oliveira, Renato AS; Durães-Carvalho, Ricardo; Lopes, Thaísa RR; Silva, Daisy EA; Gil, Laura HVG;	A scoping review of Chikungunya virus infection: epidemiology, clinical characteristics, viral co-circulation complications, and control	Acta tropica	2018	Elsevier	4	1	Bti
Mancini, Giuseppe; Cvetkovikj, Aleksandar; Santilli, Adriana; Quaglia, Michela; Federici, Valentina; Di Nicola, Francesca; De Ascentis, Matteo; Balenghien, Thomas; Stefanovska, Jovana; Goffredo, Maria;	A survey for Culicoides biting midges in the Republic of Macedonia, 2016-2017		2018	European Society for Vector Ecology	4	1	Bti
Saito, Tais Berelli; Walker, David H;	A tick vector transmission model of monocytotropic ehrlichiosis	The Journal of infectious diseases	2015	Oxford University Press	4	1	S-methoprene
Ment, Dana; Shikano, Ikkei; Glazer, Itamar;	Abiotic factors	Ecology of invertebrate diseases	2017	Wiley-Blackwell	4	1	Bti
Tadei, Wanderli Pedro; Rodrigues, Iléa Brandão; Rafael, Míriam Silva; Sampaio, Raquel Telles de Moreira; Mesquita, HG; Pinheiro, Valéria Cristina Soares; Zequi, João Antonio C; Roque, Rosemary Aparecida; Dos Santos, Joselita Maria Mendes;	Adaptative processes, control measures, genetic background, and resilience of malaria vectors and environmental changes in the Amazon region	Hydrobiologia	2017	Springer	4	1	Bti
ARAÚJO, HRC; CARVALHO, DO; CAPURRO, ML;	Aedes aegypti CONTROL PROGRAMMES IN BRAZIL	Area-wide Integrated Pest Management: Development and Field Application	2021	CRC Press	4	1	Bti
Araújo, Helena RC; Carvalho, Danilo O; Ioshino, Rafaella S; Costa-da-Silva, André L; Capurro, Margareth L;	Aedes aegypti control strategies in Brazil: incorporation of new technologies to overcome the persistence of dengue epidemics	Insects	2015	Multidisciplinary Digital Publishing Institute	4	1	Bti
Weetman, David; Kamgang, Basile; Badolo, Athanase; Moyes, Catherine L; Shearer, Freya M; Coulibaly, Mamadou; Pinto, João; Lambrechts, Louis; McCall, Philip J;	Aedes mosquitoes and Aedes-borne arboviruses in Africa: current and future threats	International journal of environmental research and public health	2018	Multidisciplinary Digital Publishing Institute	4	1	Bti
Wang, Yifan;	Aedes Mosquitoes in Alabama–Population Dynamics and Sensitivity to Insecticides		2018		4	1	Bti
Monteiro, Valter Vinícius Silva; Navegantes-Lima, Kely Campos; de Lemos, Alessandra Bittencourt; Da Silva, Guilherme Liberato; de Souza Gomes, Rafaelli; Reis, Jordano Ferreira; Rodrigues Junior, Luiz Carlos; da Silva, Onilda Santos; Romão, Pedro Roosevelt Torres; Monteiro, Marta Chagas;	Aedes–Chikungunya Virus Interaction: Key Role of Vector Midguts Microbiota and Its Saliva in the Host Infection	Frontiers in microbiology	2019	Frontiers	4	1	Bti
Zhang, Si-Ming; Buddenborg, Sarah K; Adema, Coen M; Sullivan, John T; Loker, Eric S;	Altered gene expression in the schistosome-transmitting snail Biomphalaria glabrata following exposure to niclosamide, the active ingredient in the widely used molluscicide Bayluscide	PLoS Negl Trop Dis	2015	Public Library of Science	4	1	Bti
de Oliveira, Larissa Medeiros; Silva, Laiane S; Mar, Josiana M; Azevedo, Sidney G; Rabelo, Maxwaldo S; da Fonseca Filho, Henrique D; Lima, Suzan Xavier; Bezerra, Jaqueline de A; Machado, Marcos B; Campelo, Pedro H;	Alternative Biodefensive based on the Essential Oil from Allium sativum Encapsulated in PCL/Gelatin Nanoparticles	Journal of Food Engineering and Technology	2019		4	1	Bti
Marcombe, Sébastien; Chonephetsarath, Somsanith; Thammavong, Phoutmany; Brey, Paul T;	Alternative insecticides for larval control of the dengue vector Aedes aegypti in Lao PDR: insecticide resistance and semi-field trial study	Parasites & vectors	2018	BioMed Central	4	1	Bti
Mutero, Clifford Maina; Mbogo, Charles; Mwangangi, Joseph; Imbahale, Susan; Kibe, Lydia; Orindi, Benedict; Girma, Melaku; Njui, Annah; Lwande, Wilber; Affognon, Hippolyte;	An assessment of participatory integrated vector management for malaria control in Kenya	Environmental health perspectives	2015	National Institute of Environmental Health Sciences	4	1	Bti

Choi, Cheol June; Lee, Jin Yong; Woo, Ra Mi; Shin, Tae Young; Gwak, Won Seok; Woo, Soo Dong;	An effective entomopathogenic fungus Metarhizium anisopliae for the simultaneous control of Aedes albopictus and Culex pipiens mosquito adults	Journal of Asia-Pacific Entomology	2020	Elsevier	4	1	Bti
Hudman, Kalynn L;	An Experimental Study of the Direct and Indirect Effects of Red Imported Fire Ants (Solenopsis invicta) on Monarch Butterfly (Danaus plexippus) Eggs and Larvae and the Arthropod Community on Milkweed Plants (Asclepias viridis)		2018	Texas A&M University-Commerce	4	1	S-methoprene
Ameliora, Restky Sayety;	Analisis Indikator Kepadatan dan Status Kerentanan Nyamuk Aedes spp Vektor DBD di Nagari Pakandangan Kabupaten Padang Pariaman		2018	Universitas Andalas	4	1	Bti
Badal, S; Smith, KN; Rajnarayanan, R;	Analysis of natural product regulation of cannabinoid receptors in the treatment of human disease	Pharmacology & therapeutics	2017	Elsevier	4	1	S-methoprene
Ferdous, Zannatul; Fuchs, Silke; Behrends, Volker; Trasanidis, Nikolaos; Vlachou, Dina; Christophides, George K;	Anopheles coluzzii stearoyl-CoA desaturase is essential for adult female survival and reproduction upon blood feeding	bioRxiv	2020	Cold Spring Harbor Laboratory	4	1	Bti
Zhu, Shuangshuang; Wu, Guangjin; Gu, Lei; Sun, Yunfei; Zhang, Lu; Huang, Yuan; Lyu, Kai; Yang, Zhou;	Antidepressant sertraline impairs the induced morphological defense of Ceriodaphnia cornuta in response to Chaoborus larvae kairomone	Environmental Pollution	2020	Elsevier	4	1	S-methoprene
Maina, Githinji James; Timothy, Maitho; Muchunu, Mbaria James;	Antifleas Activity and Safety of Tithonia diversifolia and Senna didymobotrya Extracts	Journal of Pharmacy and Pharmacology Research	2018	Fortune Journals	4	1	S-methoprene
Kumar, Gaurav; Ojha, Vijay Prakash; Pasi, Shweta;	Applicability of Attractive Toxic Sugar Baits as a mosquito vector control tool in the context of India: a review	Pest Management Science	2020	Wiley Online Library	4	1	Bti
Liu, Xinzhi; Stechlinski, Peter;	Application of control strategies to a seasonal model of chikungunya disease	Applied Mathematical Modelling	2015	Elsevier	4	1	Bti
Teixeira, Leonardo SG; Lemos, Valfredo A; Coelho, Luciana Melo; Rocha, Fábio RP;	Applications of biosorbents in atomic spectrometry	Applied Spectroscopy Reviews	2016	Taylor & Francis	4	1	Bti
Lumpkin, Will Patrick;	Aquatic Community Interaction Diversity and Mosquito Larvae		2020		4	1	Bti
Cuthbert, Ross N; Vong, Gina YW; Paolacci, Simona; Dick, Jaimie TA; Callaghan, Amanda; Coughlan, Neil E;	Aquatic plant extracts and coverage mediate larval mosquito survivorship and development	Biological Control	2020	Elsevier	4	1	Bti
Diiro, Gracious M; Kassie, Menale; Muriithi, Beatrice W; Gathogo, Nancy G; Kidoido, Michael; Marubu, Rose; Bwire Ochola, John; Mutero, Clifford Maina;	Are Individuals Willing to Pay for Community-Based Eco-Friendly Malaria Vector Control Strategies? A Case of Mosquito Larviciding Using Plant-Based Biopesticides in Kenya	Sustainability	2020	Multidisciplinary Digital Publishing Institute	4	1	Bti
Levi, Laura I; Vignuzzi, Marco;	Arthritogenic alphaviruses: a worldwide emerging threat?	Microorganisms	2019	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
Baxter, Richard HG; Contet, Alicia; Krueger, Kathryn;	Arthropod innate immune systems and vector-borne diseases	Biochemistry	2017	ACS Publications	4	1	Bti
Otranto, Domenico;	Arthropod-borne pathogens of dogs and cats: from pathways and times of transmission to disease control	Veterinary parasitology	2018	Elsevier	4	1	S-methoprene
Bullivant, G; Martinou, AF;	Ascension Island: a survey to assess the presence of Zika virus vectors	BMJ Military Health	2017	British Medical Journal Publishing Group	4	1	Bti
Overgaard, Hans J; Pientong, Chamsai; Thaewnongiew, Kesorn; Bangs, Michael J; Ekalaksananan, Tipaya; Aromseree, Sirinart; Phanitchat, Thipruethai; Phanthanawiboon, Supranee; Fustec, Benedicte; Corbel, Vincent;	Assessing dengue transmission risk and a vector control intervention using entomological and immunological indices in Thailand: study protocol for a cluster-randomized controlled trial	Trials	2018	Springer	4	1	S-methoprene
Gonnabathula, Pavani Kumari;	Assessment of Emerging Contaminants–Multiple Pesticides and Hormonal Compounds in Water: Effects on Biomolecules and Application of Green Nanotechnology for Remediation		2020	Texas Southern University	4	1	Bti
Musa, Umar Kwami;	Assessment of House to House Inspection Manual in the Control of Sanitation Related Diseases in Gombe Metropolis		2018	Kwara State University (Nigeria)	4	1	Bti
Rydzanicz, Katarzyna; Jawień, Piotr; Lonc, Elżbieta; Modelska, Magdalena;	Assessment of productivity of Culex spp. larvae (Diptera: Culicidae) in urban storm water catch basin system in Wrocław (SW Poland)	Parasitology research	2016	Springer	4	1	Bti
Wenjere, Standreck;	Assessment of the efficacy of BTI Larvicide, VectoBac 12AS®(BTI AM65-52) against “nuisance” flies at water treatment plants in North West England		2017	University of Salford	4	1	Bti
Beugnet, Frédéric; Halos, Lénaïg; Liebenberg, Julian; Fourie, Josephus;	Assessment of the prophylactic speed of kill of Frontline Tri-Act® against ticks (Ixodes ricinus and Rhipicephalus sanguineus) on dogs	Parasite	2016	EDP Sciences	4	1	S-methoprene
Gookin, JL; Correa, MT; Peters, A; Malueg, A; Mathews, KG; Cullen, J; Seiler, G;	Association of gallbladder mucocele histologic diagnosis with selected drug use in dogs: a matched case-control study	Journal of veterinary internal medicine	2015	Wiley Online Library	4	1	S-methoprene
McKemey, Andy; Adey, Richard;	Autodissemination of insecticides for Mosquito control		2018		4	1	S-methoprene
Boost, Maureen V; Tung, Choi-yin; Ip, Claudia Hoi-Ki; Man, July Fung-oi; Hui, Toni Wing-tung; Leung, Candy Fung-yee; Mak, Maggie Yuen-wa; Yuen, Queeny; O’Donoghue, Margaret M;	Awareness of tick-borne disease and compliance with using tick preventive products of dog owners in Hong Kong	Preventive veterinary medicine	2017	Elsevier	4	1	S-methoprene
Derua, Yahya A; Kweka, Eliningaya J; Kisinza, William N; Githeko, Andrew K; Mosha, Franklin W;	Bacterial larvicides used for malaria vector control in sub-Saharan Africa: review of their effectiveness and operational feasibility	Parasites & vectors	2019	BioMed Central	4	1	Bti
Dhiman, Ramesh C; Singh, Poonam;	Basic Research for Decision Making in Control of Vectors of Malaria and Dengue in India	ON BASIC RESEARCH–IT’S ROLE IN NATIONAL DEVELOPMENT 87TH ANNUAL SESSION OF NASI 8TH-10TH DEC 2017	2018		4	1	Bti
Baker-Galloway, Maree; Hill, Rosie; Lloyd, Anderson; Queenstown, DX Box ZP95010;	Before a Special Tribunal		2018		4	1	S-methoprene
Junquera, Pablo; Hosking, Barry; Gameiro, Marta; Macdonald, Alicia;	Benzoylphenyl ureas as veterinary antiparasitics. An overview and outlook with emphasis on efficacy, usage and resistance	Parasite	2019	EDP Sciences	4	1	S-methoprene
Hammad, Mustafa Abdel-Rahman Mohammed;	Bioactivity of Some Botanical Extracts Against the Major Mosquito Disease Vectors in Sudan		2016	Sudan University of Science and Technology	4	1	Bti
Shoba, V;	BIOCHEMICAL STATUS AND HISTOLOGICAL CHANGES OF CATHARANTHUS ROSEUS ETHANOLIC LEAVES EXTRACT AGAINST MOSQUITO LARVAE AEDES AEGYPTI, ANOPHELES STEPHENSI AND CULEX QUINQUIFASCIATUS (DIPTERA: CULICIDAE)				4	1	Bti
Norris, Edmund J; Mullis, Adam S; Phanse, Yashdeep; Narasimhan, Balaji; Coats, Joel R; Bartholomay, Lyric C;	Biodistribution of degradable polyanhydride particles in Aedes aegypti tissues	PLOS Neglected Tropical Diseases	2020	Public Library of Science	4	1	S-methoprene
Lau, Koon Weng; Chen, Chee Dhang; Lee, Han Lim; Low, Van Lun; Sofian-Azirun, Mohd;	Bioefficacy of insect growth regulators against Aedes albopictus (Diptera: Culicidea) from Sarawak, Malaysia: a statewide survey	Journal of economic entomology	2018	Oxford University Press US	4	1	Bti
Kweka, Eliningaya J; Mahande, Aneth M; Msangi, Shandala; Sayumwe, Subira; Ouma, Johnson O; Temba, Violet; Lyaruu, Lucile J; Himeidan, Yousif E;	Biological Activity of Sumilarv 0.5 G against Anopheles gambiae sensu stricto and Anopheles arabiensis in Northern Tanzania	East Africa Science	2019		4	1	Bti
Dahmana, Handi; Sambou, Masse; Raoult, Didier; Fenollar, Florence; Mediannikov, Oleg;	Biological Control of Aedes albopictus: Obtained from the New Bacterial Candidates with Insecticidal Activity	Insects	2020	Multidisciplinary Digital Publishing Institute	4	1	Bti
Couret, Jannelle; Notarangelo, Marco; Veera, Sarashwathy; LeClaire-Conway, Noah; Ginsberg, Howard S; LeBrun, Roger L;	Biological control of Aedes mosquito larvae with carnivorous aquatic plant, Utricularia macrorhiza	Parasites & vectors	2020	Springer	4	1	Bti
Cuthbert, Ross Noel;	Biological control of Culex mosquitoes using multiple predators		2019	Queen's University Belfast. Faculty of Medicine, Health and Life Sciences …	4	1	Bti

Huang, Yan-Jang S; Higgs, Stephen; Vanlandingham, Dana L;	Biological control strategies for mosquito vectors of arboviruses	Insects	2017	Multidisciplinary Digital Publishing Institute	4	1	Bti
Sarwar, Muhammad;	Biology and ecology of some predaceous and herbivorous mites important from the agricultural perception	Pests Control and Acarology	2019	IntechOpen	4	1	S-methoprene
Keefer, Tony Christopher;	Biology, Diet Preferences, and Control of the Dark Rover Ant Brachymyrmex Patagonicus (Hymenoptera: Formicidae) in Texas		2016		4	1	S-methoprene
Ngesom, Mohd; Mohiddin, Ahmad;	Bionomic Of Aedes Species And The Susceptibility To Insecticides In Penang Island, Malaysia		2015		4	1	Bti
Sande, Shadreck;	Bionomics of malaria vectors in Mutare and Mutasa districts of Manicaland province, Zimbabwe		2016		4	1	Bti
OCHOLA, JOHN BWIRE;	BIOPROSPECTING FOR ANTI-MOSQUITO PHYTOCHEMICALS ASSOCIATED WITH OLFACTION AND LARVICIDAL ACTIVITIES FROM SELECTED KENYAN PLANTS		2020	KENYATTA UNIVERSITY	4	1	Bti
Okenicová, Lenka; Žemberyová, Mária; Procházková, Simona;	Biosorbents for solid-phase extraction of toxic elements in waters	Environmental Chemistry Letters	2016	Springer	4	1	Bti
Al-Saidi, HM;	Biosorption using chitosan thiourea polymer as an extraction and preconcentration technique for copper prior to its determination in environmental and food samples by flame atomic absorption spectrometry: Synthesis, characterization and analytical applications	International journal of biological macromolecules	2016	Elsevier	4	1	Bti
Ochieng, Ogola Edwin;	Blood-feeding pattern of malaria vector reveals malaria transmission dynamics in three islands of Lake Victoria in Kenya		2016	Egerton university	4	1	Bti
GoodA, Michael F; RitchieB, Scott A; McGinnC, Darryl; RussellD, Richard C;	Brian Herbert Kay 1944–2017		2018	CSIRO	4	1	S-methoprene
Horstick, Olaf; Boyce, Ross; Runge-Ranzinger, Silvia;	Building the evidence base for dengue vector control: searching for certainty in an uncertain world	Pathogens and global health	2018	Taylor & Francis	4	1	Bti
Andersson, Neil; Arostegui, Jorge; Nava-Aguilera, Elizabeth; Harris, Eva; Ledogar, Robert J;	Camino Verde (The Green Way): evidence-based community mobilisation for dengue control in Nicaragua and Mexico: feasibility study and study protocol for a randomised controlled trial	BMC public health	2017	Springer	4	1	Bti
Hensel, Patrick; Santoro, Domenico; Favrot, Claude; Hill, Peter; Griffin, Craig;	Canine atopic dermatitis: detailed guidelines for diagnosis and allergen identification	BMC veterinary research	2015	BioMed Central	4	1	S-methoprene
Saari, Seppo; Näreaho, Anu; Nikander, Sven;	Canine Parasites and Parasitic Diseases		2018	Academic Press	4	1	S-methoprene
Kumar, Amit; Premoli, Marika; Aria, Francesca; Bonini, Sara Anna; Maccarinelli, Giuseppina; Gianoncelli, Alessandra; Memo, Maurizio; Mastinu, Andrea;	Cannabimimetic plants: are they new cannabinoidergic modulators?	Planta	2019	Springer	4	1	S-methoprene
Sougoufara, Seynabou; Doucouré, Souleymane; Sembéne, Pape M Backé; Harry, Myriam; Sokhna, Cheikh;	Challenges for malaria vector control in sub-Saharan Africa: resistance and behavioral adaptations in Anopheles populations	Journal of vector borne diseases	2017	National Institute of Malaria Research (ICMR)	4	1	Bti
Martínez-García, Grecia; Santamaría-Espinosa, R Montserrat; Lira-Amaya, José J; Figueroa, Julio V;	Challenges in Tick-Borne Pathogen Detection: The Case for Babesia spp. Identification in the Tick Vector	Pathogens	2021	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
Han, Jung Soo; An, Chae Hui; Choi, Jun Kil; Lee, Hwang Goo;	Changes in benthic macroinvertebrates communities in response to biological mosquito larvae control techniques	Korean Journal of Environmental Biology	2019	Korean Society of Environmental Biology	4	1	Bti
Schrauth, Fabian Etienne; Wink, Michael;	Changes in species composition of birds and declining number of breeding territories over 40 years in a Nature Conservation Area in Southwest Germany	Diversity	2018	Multidisciplinary Digital Publishing Institute	4	1	Bti
Duarte, Ana Lúcia Miranda;	Changes in the feline gut microbiota associated to Toxocara cati infections		2018	Universidade de Lisboa, Faculdade de Medicina Veterinária	4	1	S-methoprene
Gowelo, Steven; Chirombo, James; Koenraadt, Constantianus JM; Mzilahowa, Themba; van den Berg, Henk; Takken, Willem; McCann, Robert S;	Characterisation of anopheline larval habitats in southern Malawi	Acta Tropica	2020	Elsevier	4	1	Bti
Das, Dipanwita; Chatterjee, Soumendranath; Dangar, Tushar Kanti;	Characterization and mosquitocidal potential of the soil bacteria Aneurinibacillus aneurinilyticus isolated from Burdwan, West Bengal, India	Proceedings of the National Academy of Sciences, India Section B: Biological Sciences	2016	Springer	4	1	Bti
Mysore, Keshava; Hapairai, Limb K; Sun, Longhua; Li, Ping; Wang, Chien-Wei; Scheel, Nicholas D; Lesnik, Alexandra; Igiede, Jessica; Scheel, Max P; Wei, Na;	Characterization of a dual-action adulticidal and larvicidal interfering RNA pesticide targeting the Shaker gene of multiple disease vector mosquitoes	PLoS neglected tropical diseases	2020	Public Library of Science San Francisco, CA USA	4	1	Bti
Kim, Il-Hwan;	Characterization of a mosquito larvicidal lipopeptide from the bacterium Xenorhabdus innexi		2015	The University of Wisconsin-Madison	4	1	Bti
Fun, Chai Pui; Rathinam, Xavier; Ghazali, Amir Hamzah; Subramaniam, Sreeramanan;	Characterization of a native Bacillus thuringiensis isolates from Malaysia that produces exosporium-enclosed parasporal inclusion	Emirates Journal of Food and Agriculture	2016		4	1	Bti
Lei, Fenfen; Zhao, Qiangzhong; Sun-Waterhouse, Dongxiao; Zhao, Mouming;	Characterization of a salt-tolerant aminopeptidase from marine Bacillus licheniformis SWJS33 that improves hydrolysis and debittering efficiency for soy protein isolate	Food chemistry	2017	Elsevier	4	1	Bti
Mysore, Keshava; Li, Ping; Wang, Chien-Wei; Hapairai, Limb K; Scheel, Nicholas D; Realey, Jacob S; Sun, Longhua; Roethele, Joseph B; Severson, David W; Wei, Na;	Characterization of a yeast interfering RNA larvicide with a target site conserved in the synaptotagmin gene of multiple disease vector mosquitoes	PLoS neglected tropical diseases	2019	Public Library of Science	4	1	Bti
Kakaley, Elizabeth Katharine Medlock;	Characterization of Early Events in the Activation of the Methyl Farnesoate Receptor		2016	North Carolina State University	4	1	S-methoprene
Kapfhammer, Patrick;	Chasing the tiger: a study on the spread and control of the asian tiger mosquito, Aedes Albopictus		2018	University of Pittsburgh	4	1	S-methoprene
Hu, Bo; Xu, Guangtao; Zheng, Yongxia; Tong, Fei; Qian, Ping; Pan, Xiaoyan; Zhou, Xinmei; Shen, Ruilin;	Chelerythrine attenuates renal ischemia/reperfusion-induced myocardial injury by activating CSE/H2S via PKC/NF-κB pathway in diabetic rats	Kidney and Blood Pressure Research	2017	Karger Publishers	4	1	S-methoprene
Naumenko, Anastasia Nikolayevna;	Chromosomal evolution in mosquitoes-vectors of diseases		2017	Virginia Tech	4	1	Bti
Hamburg, Mark Hahn;	City of Portage Municipal Services and Utilities Committee (This meeting will constitute a meeting of the Legislative and Regulatory Committee as a quorum of members will be present; but no business of this committee will be taken up.)				4	1	Bti
Butterworth, Melinda K;	Climate, Ecology, and the Socio-Political Dimensions of Mosquito-Borne Disease in the Southern United States		2015	The University of Arizona.	4	1	Bti
Satho, Tomomitsu; Dieng, Hamady; Ahmad, Muhammad Hishamuddin Itam; Ellias, Salbiah Binti; Hassan, Ahmad Abu; Abang, Fatimah; Abd Ghani, Idris; Miake, Fumio; Ahmad, Hamdan; Fukumitsu, Yuki;	Coffee and its waste repel gravid Aedes albopictus females and inhibit the development of their embryos	Parasites & vectors	2015	Springer	4	1	Bti
Corner, Assignment;	College News	Policy	2015		4	1	S-methoprene
Noskov, Yuriy A; Polenogova, Olga V; Yaroslavtseva, Olga N; Belevich, Olga E; Yurchenko, Yuriy A; Chertkova, Ekaterina A; Kryukova, Natalya A; Kryukov, Vadim Yu; Glupov, Viktor V;	Combined effect of the entomopathogenic fungus Metarhizium robertsii and avermectins on the survival and immune response of Aedes aegypti larvae	PeerJ	2019	PeerJ Inc.	4	1	Bti
Schorkopf, Dirk Louis P; Spanoudis, Christos G; Mboera, Leonard EG; Mafra-Neto, Agenor; Ignell, Rickard; Dekker, Teun;	Combining attractants and larvicides in biodegradable matrices for sustainable mosquito vector control	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	4	1	Bti
George, Leyanna; Lenhart, Audrey; Toledo, Joao; Lazaro, Adhara; Han, Wai Wai; Velayudhan, Raman; Ranzinger, Silvia Runge; Horstick, Olaf;	Community-effectiveness of temephos for dengue vector control: a systematic literature review	PLoS Negl Trop Dis	2015	Public Library of Science	4	1	Bti

Ohmes, Cameon M; Hostetler, Joe; Davis, Wendell L; Settje, Terry; McMinn, Amy; Everett, William R;	Comparative efficacy of an Imidacloprid/Flumethrin collar (Seresto®) and an oral fluralaner chewable tablet (Bravecto®) against tick (Dermacentor variabilis and Amblyomma americanum) infestations on dogs: a randomised controlled trial	Parasitology research	2015	Springer	4	1	S-methoprene
Jongejan, Frans; Crafford, Dionne; Erasmus, Heidi; Fourie, Josephus J; Schunack, Bettina;	Comparative efficacy of oral administrated afoxolaner (NexGard™) and fluralaner (Bravecto™) with topically applied permethrin/imidacloprid (Advantix®) against transmission of Ehrlichia canis by infected Rhipicephalus sanguineus ticks to dogs	Parasites & vectors	2016	BioMed Central	4	1	S-methoprene
Foxi, Cipriano; Delrio, Gavino; Luciano, Pietro; Mannu, Roberto; Ruiu, Luca;	Comparative laboratory and field study of biorational insecticides for Culicoides biting midge management in larval developmental sites	Acta tropica	2019	Elsevier	4	1	Bti
Amarasinghe, LD; Wickramarachchi, PASR; Aberathna, AAAU; Sithara, WS; De Silva, CR;	Comparative study on larvicidal activity of green synthesized silver nanoparticles and Annona glabra (Annonaceae) aqueous extract to control Aedes aegypti and Aedes albopictus (Diptera: Culicidae)	Heliyon	2020	Elsevier	4	1	Bti
Francis, Sheena; Crawford, Jervis; McKenzie, Sashell; Campbell, Towanna; Wright, Danisha; Hamilton, Trevann; Huntley-Jones, Sherine; Spence, Simone; Belemvire, Allison; Alavi, Kristen;	Comparative toxicity of larvicides and growth inhibitors on Aedes aegypti from select areas in Jamaica	Royal Society open science	2020	The Royal Society	4	1	Bti
Silva, Ana R; Grosso, Clara; Delerue-Matos, Cristina; Rocha, Joao M;	Comprehensive review on the interaction between natural compounds and brain receptors: Benefits and toxicity	European journal of medicinal chemistry	2019	Elsevier	4	1	S-methoprene
Henning, Bridget M; Hinz Jr, Leon C;	Conservation guidance for yellow-headed blackbird (Xanthocephalus xanthocephalus)		2017	Illinois Natural History Survey	4	1	Bti
Zogaris, Stamatis;	Conservation study of the Mediterranean Killifish Aphanius fasciatus in Akrotiri Marsh (Akrotiri SBA, Cyprus) Final Report				4	1	Bti
Barrera, Roberto;	Considerations for disrupting dengue virus transmission; ecology of Aedes aegypti and current (nongenetic) methods of control	Genetic control of malaria and dengue	2016	Elsevier	4	1	Bti
Nuamah, Linda A; Li, Yiping; Pu, Yashuai; Nwankwegu, Amechi S; Haikuo, Zhang; Norgbey, Eyram; Banahene, Patrick; Bofah-Buoh, Robert;	Constructed wetlands, status, progress, and challenges. The need for critical operational reassessment for a cleaner productive ecosystem	Journal of Cleaner Production	2020	Elsevier	4	1	Bti
Baldacchino, Frédéric; Caputo, Beniamino; Chandre, Fabrice; Drago, Andrea;	Control methods against invasive Aedes mosquitoes in Europe				4	1	Bti
Weeratunga, Praveen; Rodrigo, Chaturaka; Fernando, Sumadhya Deepika; Rajapakse, Senaka;	Control methods for Aedes albopictus and Aedes aegypti	The Cochrane Database of Systematic Reviews	2017	John Wiley and Sons, Inc. and the Cochrane Library	4	1	Bti
Weeratunga, P; Rodrigo, C; Fernando, SD; Rajapakse, S;	Control methods for and.	The Cochrane Database of Systematic Reviews	2017		4	1	Bti
Kalimuthu, Kandasamy; Panneerselvam, Chellasamy; Chou, Chi; Tseng, Li-Chun; Murugan, Kadarkarai; Tsai, Kun-Hsien; Alarfaj, Abdullah A; Higuchi, Akon; Canale, Angelo; Hwang, Jiang-Shiou;	Control of dengue and Zika virus vector Aedes aegypti using the predatory copepod Megacyclops formosanus: synergy with Hedychium coronarium-synthesized silver nanoparticles and related histological changes in targeted mosquitoes	Process Safety and Environmental Protection	2017	Elsevier	4	1	Bti
Annex, A;	Control of the mosquito Ae. aegypti				4	1	Bti
Capodaglio, AG;	Could EB irradiation be the simplest solution for removing emerging contaminants from water and wastewater?	Water Practice & Technology	2018	IWA Publishing	4	1	Bti
Mezzacappo, Natasha Ferreira; de Souza, Larissa Marila; Inada, Natália Mayumi; Dias, Lucas Danilo; Garbuio, Matheus; Venturini, Francine Perri; Corrêa, Thaila Quatrini; Moura, Lidia; Blanco, Kate Cristina; de Oliveira, Kleber Thiago;	Curcumin/d-mannitol as photolarvicide: induced delay in larval development time, changes in sex ratio and reduced longevity of Aedes aegypti	Pest Management Science	2021	Wiley Online Library	4	1	Bti
Caragata, Eric P; Tikhe, Chinmay V; Dimopoulos, George;	Curious entanglements: interactions between mosquitoes, their microbiota, and arboviruses	Current opinion in virology	2019	Elsevier	4	1	Bti
Christofferson, Rebecca C; Parker, Daniel M; Overgaard, Hans J; Hii, Jeffrey; Devine, Gregor; Wilcox, Bruce A; Nam, Vu Sinh; Abubakar, Sazaly; Boyer, Sebastien; Boonnak, Kobporn;	Current vector research challenges in the greater Mekong subregion for dengue, Malaria, and Other Vector-Borne Diseases: A report from a multisectoral workshop March 2019		2020	Public Library of Science San Francisco, CA USA	4	1	Bti
Dórea, Fernanda C; Swanenburg, Manon; van Roermund, HJW; Horigan, Verity; de Vos-de Jong, CJ; Gale, P; Lilja, T; Comin, Arianna; Bahuon, Céline; Zientara, Stephan;	Data collection for risk assessments on animal health (DACRAH)		2017	EFSA	4	1	S-methoprene
Telford, Sam R;	Deer reduction is a cornerstone of integrated deer tick management	Journal of Integrated Pest Management	2017	Oxford University Press	4	1	Bti
Chan, Onn Kei;	Degradation of phytic acid content in soy pulp by bacillus thuringiensis SP4 through solid-state fermentation		2018	UTAR	4	1	Bti
Falope, Oluyemisi; Hanson, Katheryn; Azizan, Azliyati;	Dengue and mosquito control programs: a comparative analysis	Journal of Applied Life Sciences International	2015		4	1	Bti
Runge-Ranzinger, Silvia; Kroeger, Axel; Olliaro, Piero; McCall, Philip J; Sánchez Tejeda, Gustavo; Lloyd, Linda S; Hakim, Lokman; Bowman, Leigh R; Horstick, Olaf; Coelho, Giovanini;	Dengue contingency planning: from research to policy and practice	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	4	1	Bti
Cheong, Yoon Ling;	Dengue disease in Malaysia		2015	Humboldt-Universität zu Berlin, Mathematisch-Naturwissenschaftliche Fakultät	4	1	Bti
Guldahl, Mari Kveberg;	Dengue fever: Occurence, causes, pathogenesis, diagnosis, treatment and prevention, with a special focus on Myanmar and Norway		2017		4	1	Bti
Hamer, Diana;	Dengue in Suriname: Implications for prevention, risk reduction and clinical trajectory		2015	Tulane University, School of Public Health and Tropical Medicine	4	1	Bti
Vythilingam, I; Wan-Yusoff, WS;	Dengue vector control in Malaysia: are we moving in the right direction	Trop. Biomed	2017		4	1	Bti
Vial, Thomas;	Dengue virus diverts the mosquito phospholipid metabolism for replication		2020	Université Paul Sabatier-Toulouse III	4	1	Bti
Londono-Renteria, Berlin; Troupin, Andrea; Conway, Michael J; Vesely, Diana; Ledizet, Michael; Roundy, Christopher M; Cloherty, Erin; Jameson, Samuel; Vanlandingham, Dana; Higgs, Stephen;	Dengue virus infection of Aedes aegypti requires a putative cysteine rich venom protein	PLoS pathogens	2015	Public Library of Science San Francisco, CA USA	4	1	Bti
Monteiro, Daniela Cristina Sensato; Souza, Natália Vasconcelos de; Amaral, Jane Cavalcante; Lima, Kaynan Bezerra de; Araújo, Fernanda Montenegro Carvalho de; Ramalho, Izabel Letícia Cavalcante; Martins, Victor Emanuel Pessoa; Colares, Jeová Keny Baima; Cavalcanti, Luciano Pamplona de Góes; Lima, Danielle Malta;	Dengue: 30 years of cases in an endemic area	Clinics	2019	SciELO Brasil	4	1	Bti
Smayda, Thomas Jon; Packard, Brenda L;	Design and management of constructed ponds: minimizing environmental hazards	Handbook of Integrated Pest Management for Turf and Ornamentals	2020	CRC Press	4	1	Bti
Ahedor, Believe;	Detection and characterization of mosquito-borne viruses circulating in mosquitoes of Morogoro Municipality, Tanzania		2016	Sokoine University of Agriculture	4	1	Bti

Atobiloye, Sekinat Oluwakemi;	Determination of Contaminants of Emerging Concern: Oxybenzone, Clofibrate, and Sulfamethoxazole in Water, Sediment, and Fish from the Galveston/Clear Creek Areas		2019	Texas Southern University	4	1	Bti
Hustedt, John;	Determining effectiveness of new approaches to dengue vector control in Cambodia		2020	London School of Hygiene & Tropical Medicine	4	1	Bti
Hustedt, John; Doum, Dyna; Keo, Vanney; Ly, Sokha; Sam, BunLeng; Chan, Vibol; Alexander, Neal; Bradley, John; Prasetyo, Didot Budi; Rachmat, Agus;	Determining the efficacy of guppies and pyriproxyfen (Sumilarv® 2MR) combined with community engagement on dengue vectors in Cambodia: study protocol for a randomized controlled trial	Trials	2017	BioMed Central	4	1	Bti
Tokash-Peters, Amanda G; Tokash, Ivan W; Campos, Alberto J; Woodhams, Douglas C;	Developing Effective Mosquito Control Strategies by Utilizing Vector Mosquito Life Histories and Ecology	Case Studies in the Environment	2019	University of California Press Journals	4	1	Bti
Peck, Robert; Banko, Paul; Pendleton, Frank;	Developing tools to eradicate ecologically destructive ants on Rose Atoll: effectiveness and attractiveness of formicidal baits		2016		4	1	S-methoprene
Ghosson, Hikmat;	Development of a novel universal proxy to assess the environmental fate and impact of complex (bio) pesticides by Mass Spectrometry-based Metabolomics		2020	Université de Perpignan	4	1	Bti
Nair, Kavita Murleedharan;	Development Of Bio-Insecticides Based On Local Qatari Bacillus Thuringiensis Strains For The Biological Control Of Harmful Dipteran Disease Vectors		2019		4	1	Bti
Atieh, Thérèse;	Développement du système universel de génétique inverse pour les arboviruses applicable dans les cellules mammifères et moustiques		2017	Aix-Marseille	4	1	Bti
Bloom, Paul; Livonia, MI;	Diagnosing and Managing Cutaneous Adverse Food Reactions				4	1	S-methoprene
Daaboub, Jabeur; Tabbabi, Ahmed; Laamari, Ali; Ben Cheikh, R; Feriani, Mohamed; Boubaker, Chokri; Ben Jha, I; Ben Cheikh, H;	Diagnosis and characterization of insensitive acetylcholinesterase and over-produced esterases associated with used organophosphate insecticide control in Culex pipiens pipiens (Diptera: Culicidae) from Tunisia	International Journal of Entomology Research	2017		4	1	Bti
Chen, Geng; Wang, Yanhui; Liu, Yanmin; Chen, Fajun; Han, Lanzhi;	Differences in midgut transcriptomes between resistant and susceptible strains of Chilo suppressalis to Cry1C toxin	BMC genomics	2020	BioMed Central	4	1	Bti
Alkhaibari, AM; Carolino, AT; Bull, JC; Samuels, RI; Butt, TM;	Differential pathogenicity of Metarhizium blastospores and conidia against larvae of three mosquito species	Journal of Medical Entomology	2017	Oxford University Press	4	1	Bti
Breuch, René; Klein, Daniel; Siefke, Eleni; Hebel, Martin; Herbert, Ulrike; Wickleder, Claudia; Kaul, Peter;	Differentiation of meat-related microorganisms using paper-based surface-enhanced Raman spectroscopy combined with multivariate statistical analysis	Talanta	2020	Elsevier	4	1	Bti
Gardner, Allison Mae;	Direct and indirect effects of native and invasive plants on mosquito ecology		2016	University of Illinois at Urbana-Champaign	4	1	Bti
Gardner, Allison M; Muturi, Ephantus J; Allan, Brian F;	Discovery and exploitation of a natural ecological trap for a mosquito disease vector	Proceedings of the Royal Society B	2018	The Royal Society	4	1	Bti
Larrea-Murrell, Jeny Adina; Rojas-Badia, Marcia Maria; García-Soto, Ivette; Romeu-Alvarez, Beatriz; Bacchetti, Tristano; Gillis, Annika; Boltes-Espinola, Ana Karina; Heydrich-Perez, Mayra; Lugo-Moya, Daysi; Mahillon, Jacques;	Diversity and enzymatic potentialities of Bacillus sp. strains isolated from a polluted freshwater ecosystem in Cuba	World Journal of Microbiology and Biotechnology	2018	Springer	4	1	Bti
Tagun, Rungnapa; Kunpradid, Tatporn;	Do Environmental Factors Influence the Distributions and Diversity of Tropical Macroinvertebrate Assemblages?: A Case Study of Mae Taeng River Basin, Northern Thailand	Naresuan University Journal: Science and Technology (NUJST)	2019		4	1	Bti
Cruz, Breno Cayeiro; Teixeira, Weslen Fabricio Pires; Gomes, Lucas Vinicius Costa; Maciel, Willian Giquelin; Felippelli, Gustavo; Buzzulini, Carolina; Ferreira, Lorena Lopes; Dos Santos, Thais Rabelo; Soares, Vando Edésio; Sakamoto, Claudio Alessandro Massamitsu;	Does bathing affect tick and flea burdens and ectoparasiticide effectiveness of a spot-on formulation (fipronil+(S)-methoprene) for dogs?	Veterinary Parasitology	2020	Elsevier	4	1	S-methoprene
Tennessen, Kenneth J;	Dragonfly nymphs of North America: an identification guide		2019	Springer	4	1	Bti
Buxton, Mmabaledi;	Dynamics of mosquito species (diptera: culicidae): implications on vector management and malaria prevalence under globalclimate change		2018	Botswana International University of Science and Technology	4	1	Bti
Varloud, Marie; Liebenberg, Julian; Fourie, Josephus;	Early Babesia canis transmission in dogs within 24 h and 8 h of infestation with infected pre-activated male Dermacentor reticulatus ticks	Parasites & vectors	2018	BioMed Central	4	1	S-methoprene
Kevan, Peter G; Shipp, Les; Smagghe, Guy;	Ecological Intensification: Managing Biocomplexity and Biodiversity in Agriculture Through Pollinators, Pollination and Deploying Biocontrol Agents against Crop and Pollinator Diseases, Pests and Parasites	Entomovectoring for Precision Biocontrol and Enhanced Pollination of Crops	2020	Springer	4	1	Bti
Hernandez Colina, Arturo;	Ecology of mosquito vectors in relation to avian malaria in zoological gardens in the United Kingdom		2019	University of Liverpool	4	1	Bti
Lundström, J; Schäfer, M; Kittayapong, P;	Ecology, behaviour and area-wide control of the floodwater mosquito Aedes sticticus, with potential of future integration of the sterile insect technique	Area-Wide Integrated Pest Management: Development and Field Application; CRC Press: Boca Raton, Florida, USA	2021		4	1	Bti
Bangert, Mathieu; Latheef, Aishath Thimna; Dev Pant, Shushil; Nishan Ahmed, Ibrahim; Saleem, Sana; Nazla Rafeeq, Fathimath; Abdulla, Moomina; Shamah, Fathimath; Jamsheed Mohamed, Ahmed; Fitzpatrick, Christopher;	Economic analysis of dengue prevention and case management in the Maldives	PLoS neglected tropical diseases	2018	Public Library of Science San Francisco, CA USA	4	1	Bti
Gross, Elisabeth; Garric, Jeanne;	Ecotoxicology: New Challenges and New Approaches		2019	Elsevier	4	1	Bti
Mehlhorn, Heinz;	Ectoparasites (Arthropods: Acari, Insecta, Crustacea)	Animal Parasites	2016	Springer	4	1	S-methoprene
Gubler, Duane J;	Edited by Nikos Vasilakis				4	1	Bti
LaLone, Carlie A; Villeneuve, Daniel L; Lyons, David; Helgen, Henry W; Robinson, Serina L; Swintek, Joseph A; Saari, Travis W; Ankley, Gerald T;	Editor's highlight: sequence alignment to predict across species susceptibility (SeqAPASS): a web-based tool for addressing the challenges of cross-species extrapolation of chemical toxicity	Toxicological Sciences	2016	Oxford University Press	4	1	S-methoprene
Ali, Zainelabdin Adam Mohmmed;	Effect of aqueous Extract of Some Plants on Mortality of the lesser grain borer, Rhyzopertha dominica (F.)(Coleoptera: Bostrichidae)		2017	Sudan University of Science and Technology	4	1	S-methoprene
Saliha, Benhissen; Wafa, Habbachi; Laid, Ouakid Mohamed;	Effect of Bacillus thuringiensis var krustaki on the mortality and development of Culex pipiens (Diptera; Cullicidae)	Int. J. Mosq. Res	2017		4	1	Bti
Sammani, Abeysinghe MP; Dissanayaka, Dissanayaka MSK; Wijayaratne, Leanage KW; Bamunuarachchige, Thushara C; Morrison, William R;	Effect of pheromones, plant volatiles and spinosad on mating, male attraction and burrowing of Cadra cautella (Walk.)(Lepidoptera: Pyralidae)	Insects	2020	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
Rajonhson, Dora Murielle; Miarinjara, A; Rahelinirina, S; Rajerison, M; Boyer, S;	Effectiveness of fipronil as a systemic control agent against Xenopsylla cheopis (Siphonaptera: Pulicidae) in Madagascar	Journal of Medical Entomology	2017	Oxford University Press	4	1	S-methoprene
Mpofu, Mulamuli;	Effectiveness of winter larviciding as a malaria vector control intervention in selected rural areas of Botswana and Zimbabwe		2018	University of Pretoria	4	1	Bti
Tay, JW; Lee, CY;	Effects of a juvenile hormone analogue pyriproxyfen on monogynous and polygynous colonies of the Pharaoh ant Monomorium pharaonis (Hymenoptera: Formicidae)	Trop. Biomed	2015		4	1	S-methoprene
Binckley, Christopher; Thomas, Sneha;	Effects of biopesticides on oviposition site selection in invasive and native mosquitoes in southeastern Pennsylvania	Journal of the Pennsylvania Academy of Science	2017	JSTOR	4	1	Bti

Shah, Sakhawat; Ma, Min; Ali, Asad; Kaya, Murat; Li, Xue-Gang; Wu, Gang; Yang, Feng-Lian;	Effects of diallyl trisulfide, an active substance from garlic essential oil, on structural chemistry of chitin in Sitotroga cerealella (Lepidoptera: Gelechiidae)	Pesticide Biochemistry and Physiology	2021	Elsevier	4	1	Bti
Van Tol, Sarah;	Effects of Entomopathogenic Chromobacterium (Csp_P) Exposure on the Microbiota and Fitness of Anopheles gambiae		2016	Johns Hopkins University	4	1	Bti
Gowelo, Steven; Chirombo, James; Spitzen, Jeroen; Koenraadt, Constantianus JM; Mzilahowa, Themba; Van Den Berg, Henk; Takken, Willem; McCann, Robert;	Effects of larval exposure to sublethal doses of Bacillus thuringiensis var. israelensis on body size, oviposition and survival of adult Anopheles coluzzii mosquitoes	Parasites & vectors	2020	Springer	4	1	Bti
Vantaux, Amélie; Ouattarra, Issiaka; Lefèvre, Thierry; Dabiré, Kounbobr Roch;	Effects of larvicidal and larval nutritional stresses on Anopheles gambiae development, survival and competence for Plasmodium falciparum	Parasites & vectors	2016	BioMed Central	4	1	Bti
Tuten, Holly C; Moosmann, Philipp; Mathis, Alexander; Schaffner, Francis;	Effects of pyriproxifen on Aedes japonicus development and Its auto-dissemination by gravid females in laboratory trials	Journal of the American Mosquito Control Association	2016	BioOne	4	1	S-methoprene
MLANGO, DIANA BADE;	EFFECTS OF SONCHUS (S. oleraceous) IN MAIZE AND COWPEA CROPPING SYSTEMS		2018	Pwani University	4	1	Bti
Dornelas, Aline SP; Sarmento, Renato A; Saraiva, Althiéris S; Barbosa, Rone S; Vieira, Mayane M; Gravato, Carlos; Soares, Amadeu MVM;	Effects of two biopesticides and salt on behaviour, regeneration and sexual reproduction of the freshwater planarian Girardia tigrina	Journal of Hazardous Materials	2021	Elsevier	4	1	Bti
White, Asa Benjamin;	Effects of watercress farming on fish populations		2020	University of Brighton	4	1	Bti
Han, WW; Lazaro, A; McCall, PJ; George, L; Runge-Ranzinger, S; Toledo, J; Velayudhan, R; Horstick, O;	Efficacy and community effectiveness of larvivorous fish for dengue vector control	Tropical Medicine & International Health	2015	Wiley Online Library	4	1	Bti
Bonneau, Stéphane; Reymond, Nadège; Gupta, Sandeep; Navarro, Christelle;	Efficacy of a fixed combination of permethrin 54.5% and fipronil 6.1%(Effitix®) in dogs experimentally infested with Ixodes ricinus	Parasites & vectors	2015	BioMed Central	4	1	S-methoprene
Goutam, C; Siddhartasankar, B; Kuntal, B; Soroj, C;	Efficacy of a Locally Isolated Strain of Bacillus cereus as Mosquito Larvicide	Molecular Entomology	2016		4	1	Bti
Carithers, Doug; Everett, William Russell; Gross, Sheila J; Solanki, Ruchika;	Efficacy of a proprietary formulation of fipronil/(S)-methoprene/cyphenothrin against Ixodes scapularis tick infestations on dogs	Parasites & vectors	2015	BioMed Central	4	1	S-methoprene
Zajac, AM; LaBranche, TP; Donoghue, AR;	Efficacy of fenbendazole in the treatment of experimental Giardia infection in dogs. Am J Vet Res., 59 (1), 61–63.	Drug Therapy for Infectious Diseases of the Dog and Cat		Wiley Online Library	4	1	S-methoprene
Addesso, KM; Oliver, JB; O'Neal, PA; Youssef, N;	Efficacy of nootka oil as a biopesticide for management of imported fire ants (Hymenoptera: Formicidae)	Journal of economic entomology	2017	Oxford University Press	4	1	S-methoprene
Lindholm, Joliene R;	Elucidating the Molecular Modes of Action of Insect Juvenile Hormone		2016	The University of Wisconsin-Madison	4	1	S-methoprene
Seixas, Gonçalo Filipe Rocha;	Emergence of Aedes aegypti in Madeira Island: origin, insecticide resistance and vector competence		2018	Instituto de Higiene e Medicina Tropical	4	1	Bti
Espinal, Marcos A; Andrus, Jon K; Jauregui, Barbara; Waterman, Stephen Hull; Morens, David Michael; Santos, Jose Ignacio; Horstick, Olaf; Francis, Lorraine Ayana; Olson, Daniel;	Emerging and reemerging Aedes-transmitted arbovirus infections in the region of the Americas: implications for health policy	American journal of public health	2019	American Public Health Association	4	1	Bti
Persons, Timothy M;	EMERGING INFECTIOUS DISEASES. Actions Needed to Address the Challenges of Responding to Zika Virus Disease Outbreaks		2017	GOVERNMENT ACCOUNTABILITY OFFICE WASHINGTON DC WASHINGTON DC United States	4	1	Bti
Goodman, Mark H;	Endosymbiotic bacteria in the bed bug, Cimex lectularius L.(Hemiptera: Cimicidae)		2016		4	1	S-methoprene
Lowe, Elizabeth C; Latty, Tanya; Webb, Cameron E; Whitehouse, Mary EA; Saunders, Manu E;	Engaging urban stakeholders in the sustainable management of arthropod pests	Journal of Pest Science	2019	Springer	4	1	S-methoprene
Elanga-Ndille, Emmanuel; Binyang, Achille; Ndo, Cyrille; Assatse, Tatiane; Nouage, Lynda; Tchouakui, Magellan; Tene-Fossog, Billy; Kekeunou, Sevilor; Wondji, Charles S;	Entomological indicators of malaria transmission and insecticide resistance profile of Anopheles gambiae at the early phase of irrigated rice farming in the forest area of central Cameroon	Wellcome Open Research	2020	F1000 Research Limited	4	1	Bti
Bara, Gracian T; Laing, Mark D;	Entomopathogens: potential to control thrips in avocado, with special reference to Beauveria bassiana	Horticultural Reviews	2020	Wiley Online Library	4	1	Bti
Brühl, Carsten; Frör, Oliver;	Entwicklung eines naturschutzkonformen Konzeptes zur Stechmückenbekämpfung am Oberrhein				4	1	Bti
Salvia, Marie-Virginie; Jrad, Amani Ben; Raviglione, Delphine; Zhou, Yuxiang; Bertrand, Cédric;	Environmental Metabolic Footprinting (EMF) vs. half-life: a new and integrative proxy for the discrimination between control and pesticides exposed sediments in order to further characterise pesticides' environmental impact	Environmental Science and Pollution Research	2018	Springer	4	1	Bti
Buhler, Claudia; Winkler, Volker; Runge-Ranzinger, Silvia; Boyce, Ross; Horstick, Olaf;	Environmental methods for dengue vector control–A systematic review and meta-analysis	PLoS neglected tropical diseases	2019	Public Library of Science San Francisco, CA USA	4	1	Bti
Koval, William T; Vazquez-Prokopec, Gonzalo M;	Environmental stochasticity and intraspecific competition influence the population dynamics of Culex quinquefasciatus (Diptera: Culicidae)	Parasites & vectors	2018	BioMed Central	4	1	Bti
PREPAREDNESS, I EPIDEMIC;	EPIDEMIC PREPAREDNESS AND RESPONSE	Reference Manual for Humanitarian Health Professionals		Springer	4	1	Bti
Guevara, Tatiana I Gardellini;	Epidemiological Analysis of Malaria Decrease in El Salvador from 1955 until 2017		2019	University of South Florida	4	1	Bti
Oppold, Ann-Marie; Müller, Ruth;	Epigenetics: a hidden target of insecticides	Advances in insect physiology	2017	Elsevier	4	1	Bti
Sirsi, Shashwat; Marsh, Madeleine J; Forstner, Michael RJ;	Evaluating the effects of red imported fire ants (Solenopsis invicta) on juvenile Houston Toads (Bufo [= Anaxyrus] houstonensis) in Colorado County, TX	PeerJ	2020	PeerJ Inc.	4	1	S-methoprene
Mutero, Clifford M; Okoyo, Collins; Girma, Melaku; Mwangangi, Joseph; Kibe, Lydia; Kussa, Dereje; Diiro, Gracious; Affognon, Hippolyte; Mbogo, Charles M;	Evaluating the impact of larviciding with Bti and community education and mobilization as supplementary integrated vector management interventions for malaria control in Kenya and Ethiopia	Malaria Journal	2020	BioMed Central	4	1	Bti
Nguyen, Chilinh; Gray, Meg; Burton, Timothy A; Foy, Soleil L; Foster, John R; Gendernalik, Alex Lazr; Rückert, Claudia; Alout, Haoues; Young, Michael C; Boze, Broox;	Evaluation of a novel West Nile virus transmission control strategy that targets Culex tarsalis with endectocide-containing blood meals	PLoS neglected tropical diseases	2019	Public Library of Science	4	1	Bti
Mangia, Carlo;	Evaluation of ABCB gene expression in an Ixodes ricinus cell line exposed to acaricides		2018	Università di Parma. Dipartimento di Scienze Medico-Veterinarie	4	1	S-methoprene
Volkan, Joshua K;	Evaluation of Bifenthrin and Deltamethrin Barrier Sprays for Mosquito Control in Eastern North Carolina		2016	East Carolina University	4	1	Bti
Colucci, Barbara;	Evaluation of laboratory and field methods for measuring mosquito repellent efficacy		2017	University_of_Basel	4	1	Bti
da Rocha Voris, Diego Gomes; dos Santos Dias, Luciana; Lima, Josélia Alencar; Lima, Keila dos Santos Cople; Lima, José Bento Pereira; dos Santos Lima, Antônio Luís;	Evaluation of larvicidal, adulticidal, and anticholinesterase activities of essential oils of Illicium verum Hook. f., Pimenta dioica (L.) Merr., and Myristica fragrans Houtt. against Zika virus vectors	Environmental Science and Pollution Research	2018	Springer	4	1	Bti
Salihu, Lukman; Adedayo, Adekunbi E; Olalekan, Babajide Jelili; Afolabi, Asani M; Mohammed, Idi Dansuleiman; Oke, Isaiah Adesola; Adewale, Obijole O;	Evaluation of Selected Reaeration Models for Water Quality Management	Effects of Emerging Chemical Contaminants on Water Resources and Environmental Health	2020	IGI Global	4	1	Bti
Hassandoust, Sahar; Moosa-Kazemi, Seyed Hassan; Vatandoost, Hassan; Sedaghat, Mohammad Mehdi; Akbarzadeh, Kamran;	Evaluation of Susceptibility of Aedes caspius (Diptera: Culicidae) to Insecticides in a potent arboviral-prone Area, Southern Iran	Journal of Arthropod-Borne Diseases	2020	Tehran University of Medical Sciences	4	1	Bti
Ramos, Amparo Gabriela Hernández;	Evaluation of the resistance to insecticides in Aedes aegypti, transmitter of dengue, in Latin America	Mexican Journal of Medical Research ICSA	2020		4	1	Bti

Andersson, Neil; Nava-Aguilera, Elizabeth; Arosteguí, Jorge; Morales-Perez, Arcadio; Suazo-Laguna, Harold; Legorreta-Soberanis, José; Hernandez-Alvarez, Carlos; Fernandez-Salas, Ildefonso; Paredes-Solís, Sergio; Balmaseda, Angel;	Evidence based community mobilization for dengue prevention in Nicaragua and Mexico (Camino Verde, the Green Way): cluster randomized controlled trial	Bmj	2015	British Medical Journal Publishing Group	4	1	Bti
McLaughlin, Lexua Grace;	Evidence of Skip Oviposition in Phlebotomus Papatasi Sand Flies		2020	The University of North Carolina at Greensboro	4	1	Bti
Wilson, Anne L; Boelaert, Marleen; Kleinschmidt, Immo; Pinder, Margaret; Scott, Thomas W; Tusting, Lucy S; Lindsay, Steve W;	Evidence-based vector control? Improving the quality of vector control trials	Trends in parasitology	2015	Elsevier	4	1	Bti
Maloof, Farah Zamira Vera;	Evolution of Mutations Associated with Pyrethroid Resistance and The Reversal of Resistance in Aedes aegypti		2019	Colorado State University	4	1	Bti
Silva Martins, Walter Fabricio;	Evolutionary genetics of insecticide resistance in Culex quinquefasciatus		2015	University of Liverpool	4	1	Bti
Goodman, Madeson C;	Experimental evidence that the non-native European fire ant alters invertebrate communities		2018		4	1	S-methoprene
Chanda, Emmanuel;	Exploiting the potential of integrated vector management for combating malaria in Africa		2016	IntechOpen	4	1	Bti
Alarcón, Jorge Antonio;	Exploring Relationships between Vector-Borne Diseases and Landscape Architecture: Aedes aegypti, Aedes albopictus and Landscape Architecture		2016		4	1	Bti
Traves, Renee Joycelyn;	Exploring the antigenic and immunostimulatory nature of dengue virus non-structural protein 1		2020		4	1	Bti
Dawson, Dan Eugene;	Exploring the effects of environmental characteristics and anthropogenic activities on mosquito populations: An experimental and spatially explicit model-based approach		2016		4	1	Bti
Lemieux, Valérie;	EXPOSITION DE L'HIRONDELLE BICOLORE (TACHYCINETA BICOLOR) AUX PESTICIDES AGRICOLES DANS LE SUD DU QUÉBEC				4	1	Bti
Devault, Damien A; Karolak, Sara; Lévi, Yves; Rousis, Nikolaos I; Zuccato, Ettore; Castiglioni, Sara;	Exposure of an urban population to pesticides assessed by wastewater-based epidemiology in a Caribbean island	Science of the total environment	2018	Elsevier	4	1	Bti
Fontaine, Albin; Filipović, Igor; Fansiri, Thanyalak; Hoffmann, Ary A; Cheng, Changde; Kirkpatrick, Mark; Rašić, Gordana; Lambrechts, Louis;	Extensive genetic differentiation between homomorphic sex chromosomes in the mosquito vector, Aedes aegypti	Genome biology and evolution	2017	Oxford University Press	4	1	Bti
Worthington, Amanda Jo;	Factors Associated with Behaviors in Response to Health-Related Messaging from Shawnee County Health Department: Results of a CASPER Survey		2017		4	1	Bti
Mbijiwe, Kenneth Koome;	Factors Influencing Use of Malaria Control Methods among the Residents of Nyando Sub-County, Kisumu County		2019	JKUAT-COHES	4	1	Bti
Traversa, D; Morelli, S; Di Cesare, A; Diakou, A;	Felid Cardiopulmonary Nematodes: Dilemmas Solved and New Questions Posed. Pathogens 2021, 10, 30		2021	s Note: MDPI stays neu-tral with regard to jurisdictional clai-ms in …	4	1	S-methoprene
Hustedt, John Christian; Doum, Dyna; Keo, Vanney; Ly, Sokha; Sam, BunLeng; Chan, Vibol; Alexander, Neal; Bradley, John; Liverani, Marco; Prasetyo, Didot Budi;	Field efficacy of guppies and pyriproxyfen (Sumilarv® 2MR) combined with community engagement on dengue vectors in Cambodia: a randomized controlled trial	bioRxiv	2020	Cold Spring Harbor Laboratory	4	1	Bti
Babu, Maya;	Field Testing the Attractancy and Toxicity of the Pro-Fragrance Compound, Okoumal, to Gravid Aedes Mosquitoes and Their Offspring Larvae		2020		4	1	Bti
LaPointe, Dennis A; Black, Theodore V; Riney, Michael; Brinck, Kevin W; Crampton, Lisa H; Hite, Justin;	Field trials to test new trap technologies for monitoring Culex populations and the efficacy of the biopesticide formulation VectoMax® FG for control of larval Culex quinquefasciatus in the Alaka'i Plateau, Kaua'i, Hawaii		2021		4	1	Bti
Teerlink, Jennifer; Hernandez, Jorge; Budd, Robert;	Fipronil washoff to municipal wastewater from dogs treated with spot-on products	Science of the Total Environment	2017	Elsevier	4	1	S-methoprene
Preet, Shabad; Sneha, A;	Fitness cost of malaria vector Anopheles stephensi induced with larvicidal and nutritional stress	Journal of Asia-Pacific Entomology	2018	Elsevier	4	1	Bti
Qi, Suzhen; Niu, Xinyue; hui Wang, Dong; Wang, Chen; Zhu, Lizhen; Xue, Xiaofeng; Zhang, Zhongyin; Wu, Liming;	Flumethrin at sublethal concentrations induces stresses in adult honey bees (Apis mellifera L.)	Science of the Total Environment	2020	Elsevier	4	1	S-methoprene
Борисова, ЕВ; Махутова, ОН; Гладышев, МИ; Сущик, НН;	Fluxes of biomass and essential polyunsaturated fatty acids from water to land through chironomid emergence from a mountain lake		2016		4	1	Bti
El-Bendary, Magda A; Moharam, Maysa E;	Formulation of spore toxin complex of Bacillus thuringiensis and Lysinibacillus sphaericus grown under solid state fermentation	Biological Control	2019	Elsevier	4	1	Bti
HEIKAL, MOHAMMED NASR RAGAB;	FRESHWATER CRUSTACEANS AS BIOLOGICAL CONTROL AGENTS OF MOSQUITO LARVAE IN EGYPT	CU Theses	2018		4	1	Bti
Edmunds, Cassandra;	Genetic Analysis of Tritrophic Interactions Between Entompathogenic Nematodes, Symbiotic Bacteria and Blood–Sucking Flies		2018	Liverpool John Moores University (United Kingdom)	4	1	Bti
Yang, Ting; Chen, Ming-Li; Wang, Jian-Hua;	Genetic and chemical modification of cells for selective separation and analysis of heavy metals of biological or environmental significance	TrAC Trends in Analytical Chemistry	2015	Elsevier	4	1	Bti
Qasim, Muhammad; Xiao, Huamei; He, Kang; Omar, Mohamed AA; Liu, Feiling; Ahmed, Sohail; Li, Fei;	Genetic engineering and bacterial pathogenesis against the vectorial capacity of mosquitoes	Microbial Pathogenesis	2020	Elsevier	4	1	Bti
Oyebola, KM;	Genome-wide Analysis and Diversity of Plasmodium Falciparum in Lagos and Ekiti States, South-West Nigeria		2015		4	1	Bti
Mafra-Neto, Agenor; Saroli, Jesse; da Silva, Rodrigo Oliveira; Mboera, Leonard E; White, Graham B; Foster, Woodbridge; Spencer, Kim Li; Ebrahimi, Babak; Sonenshine, Daniel E; Daniels, Thomas;	Getting them where they live—semiochemical-based strategies to address major gaps in vector control programs: Vectrax, SPLAT BAC, Trojan Cow, and SPLAT TK	Advances in the Biorational Control of Medical and Veterinary Pests	2018	ACS Publications	4	1	Bti
Quarles, William;	Global warming means more pathogens	IPM Practitioner	2017		4	1	Bti
Lwande, Olivia Wesula; Obanda, Vincent; Lindström, Anders; Ahlm, Clas; Evander, Magnus; Näslund, Jonas; Bucht, Göran;	Globe-trotting Aedes aegypti and Aedes albopictus: risk factors for arbovirus pandemics	Vector-Borne and Zoonotic Diseases	2020	Mary Ann Liebert, Inc., publishers 140 Huguenot Street, 3rd Floor New …	4	1	Bti
Govindarajan, Marimuthu;	Green synthesized silver nanoparticles: a potential new insecticide for mosquito control	Nanoparticles in the Fight Against Parasites	2016	Springer	4	1	Bti
Kratky, BA;	Growing direct-seeded watercress by two non-circulating hydroponic methods	College of Tropical Agriculture and Human Resources, Univ of Hawaii, VC-7	2015		4	1	Bti
Li, Shuzhong; Xu, Xiaoxia; De Mandal, Surajit; Shakeel, Muhammad; Hua, Yanyan; Shoukat, Rana Fartab; Fu, Dongran; Jin, Fengliang;	Gut microbiota mediate Plutella xylostella susceptibility to Bt Cry1Ac protoxin is associated with host immune response	Environmental Pollution	2021	Elsevier	4	1	Bti
Prakash, Jai; Chandra, Prem;	Halophilic microbes from plant growing under the hypersaline habitats and their application for plant growth and mitigation of salt stress	Plant Microbiomes for Sustainable Agriculture	2020	Springer	4	1	Bti
Githinji, James M;	Herbal medicine use in Murang'a county and antiflea activity and safety of Tithonia diversifolia and Senna didymobotrya extracts		2018	University of Nairobi	4	1	S-methoprene
TJOKROPRANOTO, RITA; ACMAD, TRI HANGGONO; SUTEDJA, ENDANG; TJAHJANI, SUSY;	Histological effect optimization combination of Bacillus sphaericus 2362 and Bacillus thuringiensis subsp. israelensis in midgut of Culex quinquefasciatus resistance	Asian J Pharm Clin Res	2016		4	1	Bti

Rodrigues-Alves, Marina Luiza; de Oliveira Melo-Júnior, Otoni Alves; Silveira, Patrícia; da Silveira Mariano, Reysla Maria; Leite, Jaqueline Costa; Santos, Thaiza Aline Pereira; Soares, Ingrid Santos; Lair, Daniel Ferreira; Melo, Marília Martins; Resende, Lucilene Aparecida;	Historical Perspective and Biotechnological Trends to Block Arboviruses Transmission by Controlling Aedes aegypti Mosquitos Using Different Approaches	Frontiers in Medicine	2020	Frontiers Media SA	4	1	Bti
Cifelli, Alyssa Nicole;	Horizontal and Vertical Transmission of a Pantoea Sp. in Culex Sp.		2015		4	1	Bti
Cozzer, Gilberto Dinis; de Souza Rezende, Renan; Lutinski, Junir Antônio; Junior, Walter Antônio Roman; Busato, Maria Assunta; Dal Magro, Jacir; Albeny-Simões, Daniel;	How long is long enough? Decreasing on plant extract lethal effects, over time, affecting Aedes aegypti larval mortality	bioRxiv	2019	Cold Spring Harbor Laboratory	4	1	Bti
World Health Organization;	How to design vector control efficacy trials: guidance on phase III vector control field trial design provided by the Vector Control Advisory Group		2017	World Health Organization	4	1	Bti
Nelder, Mark P; Russell, Curtis B; Sheehan, Nina Jain; Sander, Beate; Moore, Stephen; Li, Ye; Johnson, Steven; Patel, Samir N; Sider, Doug;	Human pathogens associated with the blacklegged tick Ixodes scapularis: a systematic review	Parasites & vectors	2016	BioMed Central	4	1	S-methoprene
Nasir, Idris Abdullahi; Dangana, Amos; Ahmad, Abdurrahman Elfulaty; Ojeamiren, Iduda; Emeribe, Anthony Uchenna;	Human Reemerging Arboviral Diseases of the Late 21st Century: From Ecological-Epidemiology to Control Strategies	Emerging and Reemerging Viral Pathogens	2020	Elsevier	4	1	Bti
Greenfield, Bethany PJ; Peace, Andy; Evans, Hugh; Dudley, Ed; Ansari, Minshad A; Butt, Tariq M;	Identification of Metarhizium strains highly efficacious against Aedes, Anopheles and Culex larvae	Biocontrol Science and Technology	2015	Taylor & Francis	4	1	Bti
Altmann, Mathias; Nahapetyan, Karen; Asghar, Humayun;	Identifying hotspots of viral haemorrhagic fevers in the Eastern Mediterranean Region: perspectives for the Emerging and Dangerous Pathogens Laboratory Network	overprescribing contributes to ANTIBIOTIC RESISTANCE	2018		4	1	S-methoprene
Velkova, Zdravka; Kirova, Gergana; Stoytcheva, Margarita; Kostadinova, Sonia; Todorova, Kostadinka; Gochev, Velizar;	Immobilized microbial biosorbents for heavy metals removal	Engineering in Life Sciences	2018	Wiley Online Library	4	1	Bti
Upadhyay, Hina; Mirza, Anis; Singh, Jatinder;	Impact of Biopesticides in Sustainable Agriculture	Advances in Plant Microbiome and Sustainable Agriculture	2020	Springer	4	1	Bti
Pott, Antonia; Otto, Mathias; Schulz, Ralf;	Impact of genetically modified organisms on aquatic environments: Review of available data for the risk assessment	Science of The Total Environment	2018	Elsevier	4	1	Bti
Hu, Xue Lei; Tang, Yuan Yuan; Kwok, Man Long; Chan, King Ming; Chu, Ka Hou;	Impact of juvenile hormone analogue insecticides on the water flea Moina macrocopa: Growth, reproduction and transgenerational effect	Aquatic Toxicology	2020	Elsevier	4	1	S-methoprene
Mashlawi, Abadi Mohammed H;	Impact of Mycolactone Produced by Mycobacterium ulcerans on Life-History Traits of Aedes aegypti aegypti (L.)(Diptera: Culicidae) and Resulting Habitat Selection for Oviposition		2017		4	1	Bti
Ahmed, Khaled Sayed; Mikhail, Wafai ZA; Sobhy, Hassan M; Radwan, Eman Mohamed Mostafa; Salaheldin, Taher A;	Impact of nanosilver-profenofos on cotton leafworm, Spodoptera littoralis (Boisd.) larvae	Bulletin of the National Research Centre	2019	Springer	4	1	S-methoprene
Redmond, Kelly Marie;	Impacts of Red Imported Fire Ants and Habitat Use of Gamebirds in the Coastal Prairie of Texas		2019	Texas A&M University-Kingsville	4	1	S-methoprene
Shafique, Muhammad; Lopes, Sergio; Doum, Dyna; Keo, Vanney; Sokha, Ly; Sam, BunLeng; Vibol, Chan; Alexander, Neal; Bradley, John; Liverani, Marco;	Implementation of guppy fish (Poecilia reticulata), and a novel larvicide (Pyriproxyfen) product (Sumilarv 2MR) for dengue control in Cambodia: A qualitative study of acceptability, sustainability and community engagement	PLoS neglected tropical diseases	2019	Public Library of Science	4	1	Bti
Antonio-Nkondjio, Christophe; Sandjo, Nino Ndjondo; Awono-Ambene, Parfait; Wondji, Charles S;	Implementing a larviciding efficacy or effectiveness control intervention against malaria vectors: key parameters for success	Parasites & vectors	2018	BioMed Central	4	1	Bti
Hottel, Benjamin Andrew;	Implications of surface topography on monitoring, detecting, and controlling bed bugs, Cimex lectularius l.(hemiptera: cimicidae)		2015	University of Florida	4	1	S-methoprene
Vidhu, VV; Evans, DA;	Importance of Formic Acid in Various Ethological States of Oecophylla smaragdina (Fabricius)	New Horizons in Insect Science: Towards Sustainable Pest Management	2015	Springer	4	1	Bti
Karki, Surendra;	Improved estimates of risk of exposure to pathogens transmitted by mosquitoes		2017	University of Illinois at Urbana-Champaign	4	1	Bti
Morrow, Michael E; Chester, Rebecca E; Lehnen, Sarah E; Drees, Bastiaan M; Toepfer, John E;	Indirect effects of red imported fire ants on Attwater's prairie-chicken brood survival	The Journal of wildlife management	2015	Wiley Online Library	4	1	S-methoprene
Lee, Sang Soo;	Influence of Hormonal State on Behavioral Plasticity in the Fruit Fly Drosophila melanogaster		2017	UC Riverside	4	1	S-methoprene
Abd Rabou, Abdel Fattah N; Yassin, Maged M; Sharif, Fadel A; Al-Agha, Mohammed R; Daher, Kamel S Abu; Ali, Abdel Karim S; Hamad, Dawi M;	Inhabitants Knowledge on Mosquito Proliferation and Control in the Wetland Ecosystem of Wadi Gaza, Gaza Strip, Palestine	IUG Journal of Natural Studies	2015		4	1	Bti
Knoll, Eva-Maria;	Inherited Without History? Maldive Fever and its Aftermath	Disease Dispersion and Impact in the Indian Ocean World	2020	Springer	4	1	Bti
CHATTOPADHYAY, PINAKI; CHATTOPADHYAY, PALLAVI; PALIT, DEBNATH;	Innovative Approach to Sustainable Development and Biodiversity Conservation	Environmental and Sustainable Development Through Forestry and Other Resources	2020	CRC Press	4	1	Bti
Phiri, John Damison;	Innovatively exploring the constraints and challenges faced by malaria patients in the prevention and control of malaria–Nkhata Bay Malawi		2015	THAMMASAT UNIVERSITY	4	1	S-methoprene
Inamke, Ritesh Suresh; Panpatte, Deepak; Parvez, Noushad; Pathak, Leena; Patel, Ankit; Khatri, Kuldeep; Jani, Janardan;	Insect conservation: a synthesis of management approaches	Arthropod Diversity and Conservation in the Tropics and Sub-tropics	2016	Springer	4	1	Bti
Mansour, Sameeh A; Aly, Amina R;	Insecticidal Activity of Plant Oils, Bacterial Endotoxins and their Combinations against Musca domestica L.	Journal of Biologically Active Products from Nature	2015	Taylor & Francis	4	1	Bti
Dahmana, Handi; Sambou, Masse; Raoult, Didier; Fenollar, Florence; Mediannikov, Oleg;	Insecticidal activity of the metabolites of sand soil bacteria in Northern Senegal		2020		4	1	Bti
Zulhussnain, Muhammad; Zahoor, Muhammad Kashif; Rizvi, Hina; Zahoor, Muhammad Asif; Rasul, Azhar; Ahmad, Aftab; Majeed, Humara Naz; Rasul, Amer; Ranian, Kanwal; Jabeen, Farhat;	Insecticidal and Genotoxic effects of some indigenous plant extracts in Culex quinquefasciatus Say Mosquitoes	Scientific reports	2020	Nature Publishing Group	4	1	Bti
Johnson, Brian J; Fonseca, Dina M;	Insecticide resistance alleles in wetland and residential populations of the West Nile virus vector Culex pipiens in New Jersey	Pest management science	2016	Wiley Online Library	4	1	Bti
ADEOGUN, ADEDAPO OLUFEMI;	INSECTICIDE RESISTANCE ASSOCIATED WITH 2La INVERSION AND MICROSATELLITE LOCI POLYMORPHISM IN Anopheles gambiae ss POPULATIONS FROM LAGOS AND OYO STATES, NIGERIA		2016		4	1	Bti
Calibeo, Dawn; Oi, Faith; Oi, David; Mannion, Catharine;	Insecticides for suppression of Nylanderia fulva	Insects	2017	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
New, Tim R;	Insects of Australia’s Inland Waters	Insect conservation and Australia’s Inland Waters	2020	Springer	4	1	Bti
Öhlund, Pontus; Lundén, Hanna; Blomström, Anne-Lie;	Insect-specific virus evolution and potential effects on vector competence	Virus genes	2019	Springer	4	1	Bti
Tetreau, Guillaume;	Interaction between insects, toxins, and bacteria: have we been wrong so far?	Toxins	2018	Multidisciplinary Digital Publishing Institute	4	1	Bti

Zhang, Bo; Zhang, Lei; He, Lujue; Yang, Xiaodong; Shi, Yali; Liao, Shaowei; Yang, Shan; Cheng, Jiagao; Ren, Tianrui;	Interactions of fipronil within fish and insects: Experimental and molecular modeling studies	Journal of agricultural and food chemistry	2018	ACS Publications	4	1	S-methoprene
Klimes, Petr; Okrouhlik, Jan;	Invasive ant Tapinoma melanocephalum (Hymenoptera: Formicidae): A rare guest or increasingly common indoor pest in Europe?	European Journal of Entomology	2015	Institute of Entomology	4	1	S-methoprene
Davis, JA; Harrington, SA; Pinder, AM;	Investigations into more effective control of nuisance chironomids (midges) in metropolitan wetlands, Perth, Western Australia		1988	Murdoch University	4	1	Bti
Ferrari, Marco;	Investigations on the detoxification mechanisms of the malaria vector Anopheles stephensi		2018	Università degli Studi di Milano	4	1	Bti
Nguyen, Chilinh;	Ivermectin-treated bird feed to control West Nile virus transmission		2018	Colorado State University	4	1	Bti
van den Hurk, Andrew F; Pyke, Alyssa T; Mackenzie, John S; Hall-Mendelin, Sonja; Ritchie, Scott A;	Japanese encephalitis virus in Australia: From known known to known unknown	Tropical medicine and infectious disease	2019	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
Wu, Zhongxia; He, Qiongjie; Zeng, Baojuan; Zhou, Haodan; Zhou, Shutang;	Juvenile hormone acts through FoxO to promote Cdc2 and Orc5 transcription for polyploidy-dependent vitellogenesis	Development	2020	Oxford University Press for The Company of Biologists Limited	4	1	S-methoprene
Spitzen, Jeroen; Takken, Willem;	Keeping track of mosquitoes: a review of tools to track, record and analyse mosquito flight	Parasites & vectors	2018	BioMed Central	4	1	Bti
Spitzen, Jeroen;	Keeping track of the enemy: Flight analyses of the host-seeking malaria mosquito Anopheles gambiae ss		2018	Wageningen University	4	1	Bti
Friederike, Reuss; Aljoscha, Kreß; Braun, Markus; Axel, Magdeburg; Pfenninger, Markus; Müller, Ruth; Mehring, Marion;	Knowledge on exotic mosquitoes in Germany, and public acceptance and effectiveness of Bti and two self-prepared insecticides against Aedes japonicus japonicus	Scientific Reports (Nature Publisher Group)	2020	Nature Publishing Group	4	1	Bti
Champion, Paul D;	Knowledge to action on aquatic invasive species: Island biosecurity–the New Zealand and South Pacific story	Management of Biological Invasions	2018	Regional Euro-Asian Biological Invasions Centre	4	1	Bti
Bawin, Thomas; Seye, Fawrou; Boukraa, Slimane; Zimmer, J-Y; Delvigne, Frank; Francis, Frédéric;	La lutte contre les moustiques (Diptera: Culicidae): diversité des approches et application du contrôle biologique	The Canadian Entomologist	2015	Cambridge University Press	4	1	Bti
Murphy, Martin; Cavalleri, Daniela; Seewald, Wolfgang; Drake, Jason; Nanchen, Steve;	Laboratory evaluation of the speed of kill of lotilaner (Credelio™) against Ixodes ricinus ticks on dogs	Parasites & vectors	2017	BioMed Central	4	1	S-methoprene
MacDonald, Michael;	Landscape of new vector control products	Baltimore: John Hopkins Center for Communication Programs	2015		4	1	Bti
Unlu, Isik; Rochlin, Ilia; Suman, Devi S; Wang, Yi; Chandel, Kshitij; Gaugler, Randy;	Large-scale operational pyriproxyfen autodissemination deployment to suppress the immature Asian tiger mosquito (Diptera: Culicidae) populations	Journal of medical entomology	2020	Oxford University Press US	4	1	Bti
Coolidge, Jessica Christine;	Larval Culex Mosquitoes Increase Primary Production and Decrease Bacterial Diversity in Aquatic Mesocosms		2017	UC Riverside	4	1	Bti
Moltini-Conclois, Isabelle; Stalinski, Renaud; Tetreau, Guillaume; Després, Laurence; Lambrechts, Louis;	Larval exposure to the bacterial insecticide Bti enhances dengue virus susceptibility of adult Aedes aegypti mosquitoes	Insects	2018	Multidisciplinary Digital Publishing Institute	4	1	Bti
Mukandiwa, Lillian; Eloff, Jacobus Nicolaas; Naidoo, Vinny;	Larvicidal activity of leaf extracts and seselin from Clausena anisata (Rutaceae) against Aedes aegypti	South African journal of botany	2015	Elsevier	4	1	Bti
Michaelakis, Antonios; Papachristos, Dimitrios P; Rumbos, Christos I; Benelli, Giovanni; Athanassiou, Christos G;	Larvicidal activity of spinosad and its impact on oviposition preferences of the West Nile vector Culex pipiens biotype molestus–A comparison with a chitin synthesis inhibitor	Parasitology international	2020	Elsevier	4	1	Bti
Targanski, Sabrina K; Sousa, Janaína R; de Pádua, Geilly MS; de Sousa, Jéssica M; Vieira, Lucas CC; Soares, Marcos A;	Larvicidal activity of substituted chalcones against Aedes aegypti (Diptera: Culicidae) and non-target organisms	Pest Management Science	2021	Wiley Online Library	4	1	Bti
Lin, Chia-Hsien; Schiøler, Karin Linda; Ekstrøm, Claus Thorn; Konradsen, Flemming;	Location, seasonal, and functional characteristics of water holding containers with juvenile and pupal Aedes aegypti in Southern Taiwan: A cross-sectional study using hurdle model analyses	PLoS neglected tropical diseases	2018	Public Library of Science San Francisco, CA USA	4	1	Bti
Zhou, Guofa; Lo, Eugenia; Githeko, Andrew K; Afrane, Yaw A; Yan, Guiyun;	Long-lasting microbial larvicides for controlling insecticide resistant and outdoor transmitting vectors: a cost-effective supplement for malaria interventions	Infectious Diseases of Poverty	2020	BioMed Central	4	1	Bti
Santos, Vanessa Santana Vieira; Pereira, Boscolli Barbosa;	Low toxicity and high efficacy in use of novel approaches to control Aedes aegypti	Journal of Toxicology and Environmental Health, Part B	2020	Taylor & Francis	4	1	Bti
Veronesi, Rodolfo; Carrieri, Marco; Maccagnani, Bettina; Maini, Stefano; Bellini, Romeo;	Macrocyclops albidus (Copepoda: Cyclopidae) for the biocontrol of Aedes albopictus and Culex pipiens in Italy	Journal of the American Mosquito Control Association	2015	BioOne	4	1	Bti
Grilo, ML; Vanstreels, RET; Wallace, R; García-Párraga, D; Braga, ÉM; Chitty, J; Catão-Dias, JL; Madeira de Carvalho, LM;	Malaria in penguins–current perceptions	Avian Pathology	2016	Taylor & Francis	4	1	Bti
ADUGNA, KELEM GETU;	MALARIA TRANSMISSION AND LONG-LASTING INSECTICIDAL NETS UTILIZATION IN QELO VILLAGE, DAWA CHEFA DISTRICT, OROMIYA ZONE: A RETROSPECTIVE AND PROSPECTIVE STUDY		2016		4	1	Bti
Ogunah, Joanne Atieno; Lalah, Joseph O; Schramm, Karl-Werner;	Malaria vector control strategies. What is appropriate towards sustainable global eradication?	Sustainable Chemistry and Pharmacy	2020	Elsevier	4	1	Bti
Frederick, Joseph; Saint Jean, Yvan; Lemoine, Jean Frantz; Dotson, Ellen M; Mace, Kimberly E; Chang, Michelle; Slutsker, Laurence; Le Menach, Arnaud; Beier, John C; Eisele, Thomas P;	Malaria vector research and control in Haiti: a systematic review	Malaria journal	2016	Springer	4	1	Bti
El-Bendary, Magda Abd El-Ghaffar; Moharam, Maysa El-sayed; Hamed, Shimaa Ragab; Mohamed, Sahar Saleh;	Malaysian Journal of Microbiology				4	1	Bti
Ginsberg, Howard S; Bargar, Timothy A; Hladik, Michelle L; Lubelczyk, Charles;	Management of arthropod pathogen vectors in North America: minimizing adverse effects on pollinators	Journal of medical entomology	2017	Oxford University Press US	4	1	Bti
Robbins, Paul; Butterworth, Melinda K; Landau, Katheryn; Morin, Cory W;	Managing mosquito spaces: Citizen self-governance of disease vectors in a desert landscape	Health & place	2017	Elsevier	4	1	Bti
Benelli, Giovanni;	Managing mosquitoes and ticks in a rapidly changing world–Facts and trends	Saudi journal of biological sciences	2019	Elsevier	4	1	Bti
Takken, Willem; van den Berg, H;	Manual on prevention of establishment and control of mosquitoes of public health importance in the WHO European Region	Copenhagen: World Health Organization	2019		4	1	Bti
Kurucz, Nina; Pettit, William J; Copley, Nadine; Barrett, S; Warchot, Allan; Wenham, Jaana;	Medical Entomology annual report 2013-14	Entomology annual report	2015	Medical Entomology, DoH	4	1	S-methoprene
Kurucz, Nina; Warchot, Allan; Pettit, WJ; Copley, Nadine; Hoskins, Megan; Okasaki, Tomoko; Roberts, Alexander;	Medical Entomology annual report 2015-6	Entomology Annual Report	2017	Medical Entomology, DoH	4	1	S-methoprene
Kurucz, Nina; Warchot, Allan; Pettit, WJ; Carter, Jane; Hoskins, Megan; Okazaki, Tomoko; Copley, Nadine;	Medical Entomology annual report 2016/17		2017	NT Health	4	1	S-methoprene
Kurucz, Nina;	Medical Entomology Annual Report 2018-19		2020	Top End Health Service, Northern Territory	4	1	S-methoprene
Alkhaibari, Abeer M; Carolino, Aline T; Yavasoglu, Sare I; Maffeis, Thierry; Mattoso, Thalles C; Bull, James C; Samuels, Richard I; Butt, Tariq M;	Metarhizium brunneum blastospore pathogenesis in Aedes aegypti larvae: attack on several fronts accelerates mortality	PLoS Pathogens	2016	Public Library of Science San Francisco, CA USA	4	1	Bti
Richardson, Elise A; Abruzzo, Nicole O; Taylor, Caitlin E; Stevens, Bruce R; Cuda, James P; Weeks, Emma NI;	Methionine as an effective mosquito larvicide in natural water sources	Florida Entomologist	2021	BioOne	4	1	Bti
Lacey, LA;	Microbial control of medically important mosquitoes in tropical climates	Microbial Control of Insect and Mite Pests	2017	Elsevier	4	1	Bti
Su, T;	Microbial control of pest and vector mosquitoes in North America north of Mexico	Microbial control of insect and mite pests	2017	Elsevier	4	1	Bti

Olmo, Carla; Marco, Amparo; Armengol, Xavier; Ortells, Raquel;	microcrustacean species isolated from field zooplankton communities		2016		4	1	Bti
Mohanty, Ajeet Kumar;	Midgut proteome analysis of female Anopheles stephensi Liston, a vector of malaria		2016	Goa University	4	1	Bti
Thomas, Jennifer E; Ohmes, Cameon M; Payton, Mark E; Hostetler, Joseph A; Reichard, Mason V;	Minimum transmission time of Cytauxzoon felis by Amblyomma americanum to domestic cats in relation to duration of infestation, and investigation of ingestion of infected ticks as a potential route of transmission	Journal of feline medicine and surgery	2018	Sage Publications Sage UK: London, England	4	1	S-methoprene
MOHAMMED, KONTO;	MOLECULAR DETECTION AND CHARACTERIZATION OF TICK-BORNE HEMOPATHOGENS IN STRAY DOGS IN MALAYSIA		2016		4	1	S-methoprene
Oliveira, Ana Cristina; Luz, Maria Francisca; Granada, Sara; Vilhena, Hugo; Nachum-Biala, Yaarit; Lopes, Ana Patrícia; Cardoso, Luís; Baneth, Gad;	Molecular detection of Anaplasma bovis, Ehrlichia canis and Hepatozoon felis in cats from Luanda, Angola	Parasites & vectors	2018	BioMed Central	4	1	S-methoprene
Thenmozhi, Palanisamy;	Molecular detection of dengue virus serotypes from clinical samples prevalent in and around Coimbatore		2018	PSG Institute of Medical Sciences and Research, Coimbatore	4	1	Bti
Marutescu, Luminita; Chifiriuc, Mariana Carmen;	Molecular mechanisms of pesticides toxicity	New Pesticides and Soil Sensors	2017	Elsevier	4	1	Bti
González-Álvarez, Vicente Homero; de Mera, Isabel G Fernández; Cabezas-Cruz, Alejandro; de la Fuente, José; Ortega-Morales, Aldo I; Almazán, Consuelo;	Molecular survey of Rickettsial organisms in ectoparasites from a dog shelter in Northern Mexico	Veterinary Parasitology: Regional Studies and Reports	2017	Elsevier	4	1	S-methoprene
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Masri, Reem Abed;	Monitoring pyrethroid resistance in the house mosquito, Culex pipiens, in Lebanon		2016		4	1	Bti
Boer, A;	Monitoring the spread of infected Dermacentor reticulatus ticks in the Netherlands.		2015		4	1	S-methoprene
Nocchi, Keity Jaqueline Chagas Vilela;	Monopolar Spindle 1 (Mps1) como alvo molecular para o controle do mosquito Aedes aegypti				4	1	Bti
Berger, Darren;	Moriello's Small Animal Dermatology Volume 1, Fundamental Cases and Concepts: Self-Assessment Color Review		2019	CRC Press	4	1	S-methoprene
Rodrílguez, Fredy Palacino; Sarmiento, Carlos E; González-Soriano, Enrique;	Morphological variability and evaluation of taxonomic characters in the genus Erythemis Hagen, 1861 (Odonata: Libellulidae: Sympetrinae).	Insecta mundi	2015		4	1	Bti
Theissinger, Kathrin; Röder, Nina; Allgeier, Stefanie; Beermann, Arne J; Brühl, Carsten A; Friedrich, Anna; Michiels, Susanne; Schwenk, Klaus;	Mosquito control actions affect chironomid diversity in temporary wetlands of the Upper Rhine Valley	Molecular ecology	2019	Wiley Online Library	4	1	Bti
Harriott, Nichelle;	Mosquito Control and Pollinator Health	Pesticides and You. Beyond Pesticides	2016		4	1	Bti
Becker, N; Lüthy, P;	Mosquito control with entomopathogenic bacteria in Europe	Microbial Control of Insect and Mite Pests	2017	Elsevier	4	1	Bti
Hess, Thomas M;	Mosquito Survey of Camp Gruber Training Center and Comparison with Other Oklahoma Military Bases		2019		4	1	Bti
Poulin, Brigitte; Lefebvre, Gaëtan; Muranyi-Kovacs, Camille; Hilaire, Samuel;	Mosquito traps: an innovative, environmentally friendly technique to control mosquitoes	International journal of environmental research and public health	2017	Multidisciplinary Digital Publishing Institute	4	1	Bti
Cohnstaedt, Lee W; Alfonso-Parra, Catalina; Fernandez-Salas, Ildefonso;	Mosquito Vector Biology and Control in Latin America—A 27th Symposium	Journal of the American Mosquito Control Association	2017	BioOne	4	1	S-methoprene
Chapman, Gail Elaine;	Mosquito-borne Arboviruses of Horses: Vector Presence, Competence and Disease Prevention in the UK.		2017	University of Liverpool	4	1	Bti
Saleem, Muhammad A; Lobanova, Iryna;	Mosquito-borne diseases	Dengue Virus Disease	2020	Elsevier	4	1	Bti
Dahmana, Handi; Mediannikov, Oleg;	Mosquito-borne diseases emergence/resurgence and how to effectively control it biologically	Pathogens	2020	Multidisciplinary Digital Publishing Institute	4	1	Bti
Suman, Devi Shankar; Chandel, Kshitij; Faraji, Ary; Gaugler, Randy; Chandra, Kailash;	Mosquito-Borne Diseases: Prevention Is the Cure for Dengue, Chikungunya and Zika Viruses	Mosquito-borne Diseases	2018	Springer	4	1	Bti
Ojala, Maria; Lidskog, Rolf;	Mosquitoes as a threat to humans and the community: the role of place identity, social norms, environmental concern and ecocentric values in public risk perception	Local Environment	2017	Taylor & Francis	4	1	Bti
Berube, David M;	Mosquitoes Bite: A Zika Story of Vector Management and Gene Drives	Synthetic Biology 2020: Frontiers in Risk Analysis and Governance	2020	Springer	4	1	Bti
Karungu, Samuel; Atoni, Evans; Ogalo, Joseph; Mwaliko, Caroline; Agwanda, Bernard; Yuan, Zhiming; Hu, Xiaomin;	Mosquitoes of etiological concern in Kenya and possible control strategies	Insects	2019	Multidisciplinary Digital Publishing Institute	4	1	Bti
Gouge, Dawn H; Li, Shujuan; Walker, Kathleen; Sumner, Chris; Nair, Shaku; Olson, Carl;	Mosquitoes: Biology and Integrated Mosquito Management		2016	College of Agriculture, University of Arizona (Tucson, AZ)	4	1	Bti
Becker, Norbert; Petrić, Dušan; Zgomba, Marija; Boase, Clive; Madon, Minoo B; Dahl, Christine; Kaiser, Achim;	Mosquitoes: identification, ecology and control		2020	Springer International Publishing	4	1	Bti
El-Bendary, Magda A; Moharam, Maysa E; Abdelraof, Mohamed; Allam, Mousa A; Roshdy, Amira M; Shaheen, Mohamed NF; Elmahdy, Elmahdy M; Elkomy, Gehan M;	Multi-bioactive silver nanoparticles synthesized using mosquitocidal Bacilli and their characterization	Archives of microbiology	2020	Springer	4	1	Bti
Delnat, Vienna;	Multistressor ecotoxicological study on Culex mosquitoes: from toxicity mechanisms to biotic interactions		2020		4	1	Bti
Lucia, Alejandro; Toloza, Ariel Ceferino; Fanucce, Micaela; Fernandez-Pena, Laura; Ortega, Francisco; Rubio, Ramon G; Coviella, Carlos; Guzman, Eduardo;	Nanoemulsions based on thymol-eugenol mixtures: Characterization, stability and larvicidal activity against Aedes aegypti	Bull. Insectology	2020		4	1	Bti
Naghdi, Mitra; Taheran, Mehrdad; Sarma, Saurabh Jyoti; Brar, Satinder Kaur; Ramirez, Antonio A; Verma, Mausam;	Nanotechnology to remove contaminants	Nanoscience in Food and Agriculture 1	2016	Springer	4	1	Bti
Paulraj, M Gabriel; Kumar, P Saravana; Ignacimuthu, S; Sukumaran, D;	Natural insecticides from actinomycetes and other microbes for vector mosquito control	Herbal Insecticides, Repellents and Biomedicines: Effectiveness and Commercialization	2016	Springer	4	1	Bti
Chen, Zhongyuan; Kearney, Christopher M;	Nectar protein content and attractiveness to Aedes aegypti and Culex pipiens in plants with nectar/insect associations	Acta tropica	2015	Elsevier	4	1	Bti
Kala, Smriti; Naik, SN; Patanjali, PK; Sogan, N;	Neem oil water dispersible tablet as effective larvicide, ovicide and oviposition deterrent against Anopheles culicifacies	South African Journal of Botany	2019	Elsevier	4	1	Bti
Chapman, Peter M;	Negatives and positives: contaminants and other stressors in aquatic ecosystems	Bulletin of environmental contamination and toxicology	2018	Springer	4	1	Bti
Peng, Donghai; Wan, Danfeng; Cheng, Chunsheng; Ye, Xiaobo; Sun, Ming;	Nematode-specific cadherin CDH-8 acts as a receptor for Cry5B toxin in Caenorhabditis elegans	Applied microbiology and biotechnology	2018	Springer	4	1	Bti
Burtis, James C; Poggi, Joseph D; McMillan, Joseph R; Crans, Scott C; Campbell, Scott R; Isenberg, Amy; Pulver, Janice; Casey, Patti; White, Kerry; Zondag, Craig;	NEVBD Pesticide Resistance Monitoring Network: Establishing a Centralized Network to Increase Regional Capacity for Pesticide Resistance Detection and Monitoring	Journal of Medical Entomology	2020		4	1	Bti

Goldson, SL; Bourdôt, GW; Brockerhoff, EG; Byrom, AE; Clout, MN; McGlone, MS; Nelson, WA; Popay, AJ; Suckling, DM; Templeton, MD;	New Zealand pest management: current and future challenges	Journal of the Royal Society of New Zealand	2015	Taylor & Francis	4	1	Bti
Serafini, Suélen; de Freitas Souza, Carine; Baldissera, Matheus Dellaméa; Baldisserotto, Bernardo; Da Silva, Aleksandro Schafer;	Nitric oxide levels in brain, liver, and gills of silver catfish (Rhamdia quelen) exposed to the antiparasitic eprinomectin	Fish Physiology and Biochemistry	2020	Springer	4	1	S-methoprene
Weeks, Emma NI; Kroll, Kevin J; Johnson, Timothy S; Colquhoun, Thomas; Cuda, James P; Denslow, Nancy D; Stevens, Bruce R;	Novel effective mosquito larvicide DL-methionine: Lack of toxicity to non-target aquatic organisms	Ecotoxicology and Environmental Safety	2021	Elsevier	4	1	Bti
Gómez-Vargas, Wilber; Valencia-Jiménez, Kelly; Correa-Londoño, Guillermo; Jaramillo-Yepes, Faiber;	Novel larvicide tablets of Bacillus thuringiensis var. israelensis: Assessment of larvicidal effect on Aedes aegypti (Diptera: Culicidae) in Colombia	Biomédica	2018	Instituto Nacional de Salud	4	1	Bti
Tennessen, Kenneth J;	Nymph Anatomy and Instar Determination	Dragonfly Nymphs of North America	2019	Springer	4	1	Bti
Bastos, Cynthia Molina; D'Avila, Otávio Pereira; Umpierre, Roberto Nunes; Gonçalves, Marcelo Rodrigues; Faccini, Lavínia Schuler; Harzheim, Erno;	O uso de larvicidas em água potável é seguro?		2016		4	1	Bti
Behnke, Robert; Walzer, Chris;	O. T2. 2 Health, Husbandry and Management of Eurasian lynx (Lynx lynx)				4	1	S-methoprene
Ali, Tagwa Salah Ahmed Mohammed;	Occurrence and distribution of phenotypic and genotypic resistant strain of Anopheles arabiensis to insecticides and Plasmodium sporozoites infection in Khartoum State, Sudan		2015	Sudan University of Science & Technology	4	1	Bti
Yeung, Katie WY; Giesy, John P; Zhou, Guang-Jie; Leung, Kenneth MY;	Occurrence, toxicity and ecological risk of larvicidal oil in the coastal marine ecosystem of Hong Kong	Marine Pollution Bulletin	2020	Elsevier	4	1	S-methoprene
Meek, Stephanie; Ryan, Maria M; Ogilvie, Madeleine; Lambert, Claire;	Online brand communities: The key to making them succeed		2016	Australian and New Zealand Marketing Academy Conference	4	1	Bti
Suresh, M; Jeevanandam, Jaison; San Chan, Yen; Danquah, Michael K; Kalaiarasi, JMV;	Opportunities for Metal Oxide Nanoparticles as a Potential Mosquitocide	BioNanoScience	2019	Springer	4	1	Bti
Foda, MS; Moharam, Maysa E; El-Bendary, Magda A;	Overproduction of mosquitocidal toxins of Bacillus thuringiensis serotype 14 on cost effective media	Biosciences Biotechnology Research Asia	2016		4	1	Bti
Scheff, Deanna Sue;	Packaging technologies for the control of stored-product insects		2016	Kansas State University	4	1	S-methoprene
Citarasu, Thavasimuthu;	Pandi Palanikumar, Dinamella Wahjuningrum, Paramachandran Abinaya, Mariavincent Michael Babu &				4	1	Bti
Shearer, David; Welle, Monika; Whitbread, Trevor;	Panel Discussion: Biopsies And Allergies-Is It Worth To Punch The Itch?	A message from the President			4	1	S-methoprene
Shukullari, Enstela;	Parasites and vector-borne diseases in client-owned dogs in Albania		2016	Imu	4	1	S-methoprene
Sing, Kong Wah;	Patterns of bee and butterfly diversity in Southeast and Southern East Asian megacities/Sing Kong Wah		2016	University of Malaya	4	1	Bti
Diallo, Mawlouth; Dia, Ibrahima; Diallo, Diawo; Diagne, Cheikh Tidiane; Ba, Yamar; Yactayo, Sergio;	Perspectives and challenges in entomological risk assessment and vector control of chikungunya	The Journal of infectious diseases	2016	Oxford University Press	4	1	Bti
Oliveira, Ana RS; Cohnstaedt, Lee W; Noronha, Leela E; Mitzel, Dana; McVey, D Scott; Cernicchiaro, Natalia;	Perspectives Regarding the Risk of Introduction of the Japanese Encephalitis Virus (JEV) in the United States	Frontiers in veterinary science	2020	Frontiers	4	1	Bti
Renkema, Justin; Devkota, Shashan; Nagle, Curtis;	Pesticide Options for Insect, Mite, and Mollusk Management in Commercial Strawberry Production in Florida1				4	1	S-methoprene
Arisov, Mikhail Vladimirovich; Indyuhova, Evgenia Nikolaevna; Arisova, Gulnara Bakitovna;	Pharmacokinetics of combination antiparasitic drug preparation for dogs and cats in the form of spot-on solution	Journal of advanced veterinary and animal research	2019	Network for the Veterinarians of Bangladesh	4	1	S-methoprene
Danforth, Mary E; Reisen, William K; Barker, Christopher M;	Phenotypic Stability in Extrinsic Incubation of West Nile Virus in Culex tarsalis (Diptera: Culicidae)	Proceedings and Papers	2015		4	1	Bti
DiSalvo, Andrew R; Reilly, Christopher M; Wiggans, K Tomo; Woods, Leslie W; Wack, Ray F; Clifford, Deana L;	Photoreceptor degeneration in a mountain lion cub (Puma Concolor)	Journal of Zoo and Wildlife Medicine	2016	BioOne	4	1	S-methoprene
Ayana, Negera Abdissa;	Phytochemical investigation of four asphodelaceae plants for antiplasmodial principles		2015	University of Nairobi	4	1	Bti
Dwyer, PG; Knight, JM; Dale, PER;	Planning development to reduce mosquito hazard in coastal peri-urban areas: case studies in NSW, Australia	Balanced urban development: options and strategies for liveable cities	2016	Springer, Cham	4	1	S-methoprene
Silvério, Maíra Rosato Silveiral; Espindola, Laila Salmen; Lopes, Norberto Peporine; Vieira, Paulo Cézar;	Plant natural products for the control of Aedes aegypti: The main vector of important arboviruses	Molecules	2020	Multidisciplinary Digital Publishing Institute	4	1	Bti
Ntalli, Nikoletta; Koliopoulos, George; Giatropoulos, Athanasios; Menkissoglu-Spiroudi, Urania;	Plant secondary metabolites against arthropods of medical importance	Phytochemistry Reviews	2019	Springer	4	1	Bti
Dobbins, Michael T; Holyoak, Marcel;	Population viability and management of the valley elderberry longhorn beetle	Biodiversity and Conservation		Springer	4	1	Bti
GAMBO, LAWAL SULEMAN;	POPULATION, ECONOMIC GROWTH AND ENVIRONMENTAL EMISSIONS IN NIGERIA		2017		4	1	Bti
Dvorak, Ana C; Solo-Gabriele, Helena M; Galletti, Andrea; Benzecry, Bernardo; Malone, Hannah; Boguszewski, Vicki; Bird, Jason;	Possible impacts of sea level rise on disease transmission and potential adaptation strategies, a review	Journal of environmental management	2018	Elsevier	4	1	Bti
Kendie, Fasil Adugna;	Potential biological control agents against mosquito vector in the case of larvae stage: A review	World News of Natural Sciences	2020	Scientific Publishing House „DARWIN”	4	1	Bti
Lees, Rosemary; Carvalho, DO; Bouyer, J;	Potential impact of integrating the sterile insect technique into the fight against disease-transmitting mosquitoes		2021	Routledge	4	1	Bti
Sun, Jiaqi; Bai, Yaoyu;	Predator-induced stress influences fall armyworm immune response to inoculating bacteria	Journal of invertebrate pathology	2020	Elsevier	4	1	Bti
Singh, Raj K; Dhama, Kuldeep; Khandia, Rekha; Munjal, Ashok; Karthik, Kumaragurubaran; Tiwari, Ruchi; Chakraborty, Sandip; Malik, Yashpal S; Bueno-Marí, Rubén;	Prevention and control strategies to counter Zika virus, a special focus on intervention approaches against vector mosquitoes—current updates	Frontiers in microbiology	2018	Frontiers	4	1	Bti
Nasir, SM Ibraheem; Amarasekara, Sachini; Wickremasinghe, Renu; Fernando, Deepika; Udagama, Preethi;	Prevention of re-establishment of malaria: historical perspective and future prospects	Malaria journal	2020	BioMed Central	4	1	Bti
Krämer, Friederike; Hüsken, Ricarda; Krüdewagen, Eva Maria; Deuster, Katrin; Blagburn, Byron; Straubinger, Reinhard K; Butler, Jamie; Fingerle, Volker; Charles, Sam; Settje, Terry;	Prevention of transmission of Borrelia burgdorferi sensu lato and Anaplasma phagocytophilum by Ixodes spp. ticks to dogs treated with the Seresto® collar (imidacloprid 10%+ flumethrin 4.5%)	Parasitology research	2020	Springer	4	1	S-methoprene
Ponnusamy, Suguna; Viswanathan, Saranya; Periyasamy, Abirami; Rajaiah, Shenbagarathai;	Production and characterization of PHB-HV copolymer by Bacillus thuringiensis isolated from Eisenia foetida	Biotechnology and applied biochemistry	2019	Wiley Online Library	4	1	Bti
World Health Organization;	Progress towards elimination in Malaysia		2015	World Health Organization	4	1	Bti
Ferreira, Taciano P; Haddi, Khalid; Corrêa, Roberto FT; Zapata, Viviana LB; Piau, Tathyana B; Souza, Luis FN; Santos, Swel-Marks G; Oliveira, Eugenio E; Jumbo, Luis OV; Ribeiro, Bergmann M;	Prolonged mosquitocidal activity of Siparuna guianensis essential oil encapsulated in chitosan nanoparticles	PLoS neglected tropical diseases	2019	Public Library of Science	4	1	Bti
Santos, Vanessa Santana Vieira; Pereira, Boscolli Barbosa;	Properties, toxicity and current applications of the biolarvicide spinosad	Journal of Toxicology and Environmental Health, Part B	2020	Taylor & Francis	4	1	Bti
Mah, HF; Nizam, S; Ismail, Saleh;	Prospect and efficiency of exotic fish as mosquito larvae biological control agent	International Journal of Medical Toxicology & Legal Medicine	2018	Medico Legal Society	4	1	Bti
Caragata, EP; Dong, S; Dong, Y; Simões, ML; Tikhe, CV; Dimopoulos, G;	Prospects and Pitfalls: Next-Generation Tools to Control Mosquito-Transmitted Disease	Annual review of microbiology	2020	Annual Reviews	4	1	Bti
Bouzid, Maha; Brainard, Julii; Hooper, Lee; Hunter, Paul R;	Public health interventions for Aedes control in the time of Zikavirus–a meta-review on effectiveness of vector control strategies	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	4	1	Bti

Hamzah, SN; Alias, Z;	Purification, expression and partial characterisation of glutathione s-transferases (GSTs) from three different strains of Aedes albopictus (Diptera: Culicidae)	Tropical Biomedicine	2016	Malaysian Society of Parasitology and Tropical Medicine	4	1	Bti
Currie-Jordan, Aislinn Rhiannon;	Quantitative Analysis of the Ecology and Feeding Behaviour of Aedes detritus		2019	The University of Liverpool (United Kingdom)	4	1	Bti
Huang, Tianpei; Yu, Xiaomin; Gelbič, Ivan; Guan, Xiong;	RAP-PCR fingerprinting reveals time-dependent expression of development-related genes following differentiation process of Bacillus thuringiensis	Canadian journal of microbiology	2015	NRC Research Press	4	1	Bti
Wylie, F Ross; Janssen-May, Sharon;	Red imported fire ant in Australia: what if we lose the war?	Ecological Management & Restoration	2017	Wiley Online Library	4	1	S-methoprene
World Health Organization;	Regional malaria action plan 2016–2020: towards a malaria-free Region		2017	World Health Organization. Regional Office for the Eastern Mediterranean	4	1	Bti
Kogan, Felix;	Remote Sensing for Malaria: Monitoring and Predicting Malaria from Operational Satellites		2020	Springer Nature	4	1	Bti
Asl, Eslam Moradi; Vatandoost, Hassan; Telmadarreiy, Zakie; Mohebali, Mehdi; Abai, Mohammad Reza;	Repellency effect of flumethrin pour-on formulation against vectors of Crimean–Congo haemorrhagic fever	EMHJ	2018		4	1	S-methoprene
Fankhauser, Becky; Dumont, Pascal; Hunter, James S; McCall, John W; Kaufmann, Christian; Mathis, Alexander; Young, David R; Carroll, Scott P; McCall, Scott; Chester, S Theodore;	Repellent and insecticidal efficacy of a new combination of fipronil and permethrin against three mosquito species (Aedes albopictus, Aedes aegypti and Culex pipiens) on dogs	Parasites & vectors	2015	Springer	4	1	S-methoprene
World Health Organization;	Report of the nineteenth WHOPES working group meeting: WHO		2016	World Health Organization	4	1	Bti
Paxton, Eben H; Laut, Megan; Vetter, John P; Kendall, Steve J;	Research and management priorities for Hawaiian forest birds	The Condor: Ornithological Applications	2018	Oxford University Press	4	1	Bti
Kress, Aljoscha;	Research into the Potential to Adapt and Establish of the invasive Asian Tiger Mosquito Aedes (Stegomyia) albopictus (SKUSE)	arXiv preprint arXiv:1611.10318	2016		4	1	Bti
Wang, Lanjiao;	Résistance aux insecticides: importance dans la transmission du virus chikungunya par les moustiques Aedes aegypti		2018	Université de Guyane	4	1	Bti
Wang, Lanjiao;	Résistance aux insecticides: importance dans la transmission du virus chikungunya par les moustiques Aedes aegyptial evolution		2018	Guyane	4	1	Bti
Boyer, Sébastien; Lopes, Sergio; Prasetyo, Didot; Hustedt, John; Sarady, Ay Sao; Doum, Dyna; Yean, Sony; Peng, Borin; Bunleng, Sam; Leang, Rithea;	Resistance of Aedes aegypti (Diptera: Culicidae) populations to deltamethrin, permethrin, and temephos in Cambodia	Asia Pacific Journal of Public Health	2018	SAGE Publications Sage CA: Los Angeles, CA	4	1	Bti
Silva-Filha, Maria Helena Neves Lobo;	Resistance of mosquitoes to entomopathogenic bacterial-based larvicides: current status and strategies for management	Bacillus thuringiensis and Lysinibacillus sphaericus	2017	Springer	4	1	Bti
Delnat, Vienna; Tran, Tam T; Janssens, Lizanne; Stoks, Robby;	Resistance to a chemical pesticide increases vulnerability to a biopesticide: Effects on direct mortality and mortality by predation	Aquatic Toxicology	2019	Elsevier	4	1	Bti
Shi, Yao; Sheng, Lianxi; Wang, Zhongqiang; Zhang, Xinyu; He, Nianpeng; Yu, Qiang;	Responses of soil enzyme activity and microbial community compositions to nitrogen addition in bulk and microaggregate soil in the temperate steppe of Inner Mongolia	Eurasian Soil Science	2016	Springer	4	1	Bti
Collantes, Francisco; Delacour, Sarah; Alarcón-Elbal, Pedro María; Ruiz-Arrondo, Ignacio; Delgado, Juan Antonio; Torrell-Sorio, Antonio; Bengoa, Mikel; Eritja, Roger; Miranda, Miguel Ángel; Molina, Ricardo;	Review of ten-years presence of Aedes albopictu s in Spain 2004–2014: known distribution and public health concerns	Parasites & vectors	2015	BioMed Central	4	1	Bti
Källqvist, Torsten; Dirven, Hubert; Gjøen, Tor; Tronsmo, Arne; Yazdankhah, Siamak Pour; Rivedal, Edgar; Borgå, Katrine; Eklo, Ole Martin; Grung, Merete; Lyche, Jan Ludvig;	Risk assessment of the biological plant protection product Turex 50 WG, with the organism Bacillus thuringiensis ssp. aizawai CG-91. Opinion of the Panel on Plant Protection Products of the Norwegian Scientific Committee for Food Safety	VKM Report	2016	Norwegian Scientific Committee for Food Safety (VKM)	4	1	Bti
EFSA Panel on Biological Hazards (BIOHAZ);	Risks for public health related to the presence of Bacillus cereus and other Bacillus spp. including Bacillus thuringiensis in foodstuffs	EFSA Journal	2016	Wiley Online Library	4	1	Bti
Sharma, Neelu; Singh, Veer; Shyma, KP;	Role of parasitic vaccines in integrated control of parasitic diseases in livestock	Veterinary world	2015	Veterinary World	4	1	Bti
Fabrick, Jeffrey A; Wu, Yidong;	Roles of insect midgut cadherin in Bt intoxication and resistance	Bt resistance: characterization and strategies for GM crops producing Bacillus thuringiensis toxins	2015	CABI Press	4	1	Bti
Devillers, James; Doucet-Panaye, Annick; Doucet, Jean-Pierre;	SAR and QSAR modeling of structurally diverse juvenoids active on mosquito larvae		2017	CRC Press, Boca Raton, FL	4	1	Bti
Coutinho, Mafalda Santos;	Screening of larvicidal activity of seaweed extracts against the mosquito Aedes aegypti		2017		4	1	Bti
Jupatanakul, Natapong; Pengon, Jutharat; Selisana, Shiela Marie Gines; Choksawangkarn, Waeowalee; Jaito, Nongluck; Saeung, Atiporn; Bunyong, Ratchanu; Posayapisit, Navaporn; Thammatinna, Khrongkhwan; Kalpongnukul, Nuttiya;	Serratia marcescens secretes proteases and chitinases with larvicidal activity against Anopheles dirus	Acta Tropica	2020	Elsevier	4	1	Bti
Sharma, Charu; Sadek, Bassem; Goyal, Sameer N; Sinha, Satyesh; Kamal, Mohammad Amjad; Ojha, Shreesh;	Small molecules from nature targeting G-protein coupled cannabinoid receptors: potential leads for drug discovery and development	Evidence-Based Complementary and Alternative Medicine	2015	Hindawi	4	1	S-methoprene
Chiotha, Sosten; Jamu, Daniel; Nagoli, Joseph; Likongwe, Patrick; Chanyenga, Tembo;	Socio-Ecological Resilience to Climate Change in a Fragile Ecosystem				4	1	Bti
Pfaff, Madeleine A;	Southern Illinois Ticks: An Ecological and Medical Overview		2015		4	1	S-methoprene
Chediak, Mateus; G Pimenta Jr, Fabiano; Coelho, Giovanini E; Braga, Ima A; Lima, José Bento P; Cavalcante, Karina Ribeiro LJ; de Sousa, Lindemberg C; de Melo-Santos, Maria Alice V; Macoris, Maria de Lourdes da G; Araújo, Ana Paula de;	Spatial and temporal country-wide survey of temephos resistance in Brazilian populations of Aedes aegypti	Memórias do Instituto Oswaldo Cruz	2016	SciELO Brasil	4	1	Bti
Wilson, Rebecca Cathleen;	Spatial distribution, habitat preference, and societal impact of the nuisance black fly, Simulium jenningsi		2018		4	1	Bti
Owusu-Asenso, CHRISTOPHER MFUM;	Spatio-Temporal Distribution and Insecticide Resistance Status of AEDES Mosquitoes in Ghana		2018	University Of Ghana	4	1	Bti
Morehart, Morgan;	Spatiotemporal Impacts of Invasive Species Removal and Reinvasion		2020		4	1	S-methoprene
Dufourd, Claire Chantal;	Spatio-temporal mathematical models of insect trapping: analysis, parameter estimation and applications to control		2016	University of Pretoria	4	1	Bti
Karikari, URIAH ARKO;	Species Diversity Of Bedbugs And Environmental Factors Influencing Their Survival		2016	University of Ghana	4	1	S-methoprene
Vinnersten, Thomas Z Persson; Halvarsson, Peter; Lundström, Jan O;	Specific detection of the floodwater mosquitoes Aedes sticticus and Aedes vexans DNA in predatory diving beetles	Insect science	2015	Wiley Online Library	4	1	Bti
Nwagu, Tochukwu Nwamaka;	Stabilization of Raw Starch Digesting Amylase from Aspergillus Carbonarius and Effects of Metal Ions on Enzyme Activity and Stability		2018		4	1	Bti
Bock, Friederike; Kuch, Ulrich; Pfenninger, Markus; Müller, Ruth;	Standardized laboratory feeding of larval Aedes japonicus japonicus (Diptera: Culicidae)	Journal of Insect Science	2015	Entomological Society of America	4	1	Bti
Oliva, Clélia F; Benedict, Mark Q; Collins, C; Baldet, Thierry; Bellini, Romeo; Bossin, Hervé; Bouyer, Jérémy; Corbel, Vincent; Facchinelli, Luca; Fouque, Florence;	Sterile Insect Technique (SIT) against Aedes Species Mosquitoes: A roadmap and good practice framework for designing, implementing and evaluating pilot field trials	Insects	2021	Multidisciplinary Digital Publishing Institute	4	1	Bti
Flacio, Eleonora; Engeler, Lukas; Tonolla, Mauro; Lüthy, Peter; Patocchi, Nicola;	Strategies of a thirteen year surveillance programme on Aedes albopictus (Stegomyia albopicta) in southern Switzerland	Parasites & vectors	2015	Springer	4	1	Bti

Rama, Aarti; Kumar, Vijay;	STRESS INVOLVED HOST-PARASITE INTERACTION-A REVIEW HYPOTHESIZING NOBLE APPROACH FOR CONTAINING PHLEBOTOMINE SAND FLIES	STRESS	2017		4	1	Bti
Salam, Kirankumar; Sylvia, Rajkumari; Bhopen, Salam;	Structural and Functional Aspects of Aedes Gut Microbiota and its Influence on the Host Physiology and the Environment	J. Commun. Dis	2015		4	1	Bti
Devillers, J; Doucet-Panaye, A; Doucet, JP;	Structure–activity relationship (SAR) modelling of mosquito larvicides	SAR and QSAR in Environmental Research	2015	Taylor & Francis	4	1	Bti
Ramlee, Siti Nurhafizah Saleeza;	Studies of breeding habitats and seasonal occurrence of mosquitoes in Putrajaya and Kuala Selangor, with laboratory experiments of guppies and dragonfly nymphs as potential biocontrol predators against mosquito larvae		2015	University of Malaya	4	1	Bti
Mohammed, Waheed Eldeen Elsideeg Dafalla;	Studies on Anopheles dthali Patton (Diptera: Culicidae) as a Malaria Vector in Jazan Region, Kingdom of Saudi Arabia (2014-2017)		2018	University of Gezira	4	1	Bti
Loach, Neha;	STUDY ON THE RELATIVE TOXICITY OF CERTAIN ENCAPSULATED NANOPARTICLES OF PLANT ORIGIN AGAINST SELECTED MOSQUITO LARVAE		2018	Agra	4	1	Bti
Bouchet, Diane;	Succession écologique et influence de la fauche dans des communautés végétales de talus routiers en région méditerranéenne française		2016	Université de Montpellier	4	1	Bti
Bateman, Melanie L; Day, Roger K; Luke, Belinda; Edgington, Steve; Kuhlmann, Ulrich; Cock, Matthew JW;	Supplementary Material Assessment of potential biopesticide options for managing fall armyworm (Spodoptera frugiperda) in Africa				4	1	S-methoprene
Piltch-Loeb, Rachael; Merdjanoff, Alexis A; Bhanja, Aditi; Abramson, David M;	Support for vector control strategies in the United States during the Zika outbreak in 2016: The role of risk perception, knowledge, and confidence in government	Preventive medicine	2019	Elsevier	4	1	Bti
Neves, Michelle; Lopes, Ana Patrícia; Martins, Carolina; Fino, Raquel; Paixão, Cláudia; Damil, Liliana; Lima, Clara; Alho, Ana Margarida; Schallig, Henk DFH; Dubey, Jitender P;	Survey of Dirofilaria immitis antigen and antibodies to Leishmania infantum and Toxoplasma gondii in cats from Madeira Island, Portugal	Parasites & vectors	2020	Springer	4	1	S-methoprene
Saeung, Manop; Ngoen-Klan, Ratchadawan; Thanispong, Kanutcharee; Muenworn, Vithee; Bangs, Michael J; Chareonviriyaphap, Theeraphap;	Susceptibility of Aedes aegypti and Aedes albopictus (Diptera: Culicidae) to Temephos in Thailand and Surrounding Countries	Journal of medical entomology	2020	Oxford University Press US	4	1	Bti
Ofori, ED;	Susceptibility of Human Bed Bugs (Cimex hemipterus) to Selected Insecticide Products in Three Educational Institutions in Accra Metropolis, Ghana		2019	University of Ghana	4	1	S-methoprene
DeLisi, Nicholas Alexander;	Susceptibility of the southern house mosquito, Culex quinquefasciatus, in East Baton Rouge Parish to larval insecticides		2017		4	1	Bti
Rocha, Hélio Daniel Ribeiro; Paiva, Marcelo Henrique Santos; Silva, Norma Machado; de Araújo, Ana Paula; da Moura, Aires Januário Fernandes; Gómez, Lara Ferrero; Ayres, Constância Flávia Junqueira; de Melo Santos, Maria Alice Varjal;	Susceptibility profile of Aedes aegypti from Santiago Island, Cabo Verde, to insecticides	Acta tropica	2015	Elsevier	4	1	Bti
Kanani, Khalil A; Katbeh-Bader, Ahmad; Al-Abdallat, Mohammed; Shadfan, Bassam;	Susceptibility Tests on Insecticides Used to Control Mosquitoes in Jordan	Biological	2015		4	1	Bti
Oberstadt, Moritz; Stieler, Jens; Simpong, David Larbi; Römuß, Ute; Urban, Nicole; Schaefer, Michael; Arendt, Thomas; Holzer, Max;	TDP-43 self-interaction is modulated by redox-active compounds Auranofin, Chelerythrine and Riluzole	Scientific reports	2018	Nature Publishing Group	4	1	S-methoprene
Runge-Ranzinger, Silvia;	Technical handbook for dengue surveillance, dengue outbreak prediction/detection and outbreak response (Model contingency plan)		2016	World Health Organization	4	1	Bti
World Health Organization;	Technical handbook for dengue surveillance, outbreak prediction/detection and outbreak response		2016	World Health Organization	4	1	Bti
Bassett, Mary T;	Technical Memorandum CEQR No. 00DOH002Y New York City Comprehensive Mosquito Surveillance and Control		2017		4	1	S-methoprene
de Souza Silva, Geovanna Cristine; Peltonen, Laura-Maria; Pruinelli, Lisiane; Shishido, Henrique Yoshikazu; Eler, Gabrielle Jacklin;	Technologies to Combat Aedes Mosquitoes: A Model Based on Smart City.	Nursing Informatics	2018		4	1	Bti
Safety, C;	THE BACILLUS SPHAERICUS TOXINS AND THEIR POTENTIAL FOR BIOTECHNOLOGICAL DEVELOPMENT				4	1	Bti
Rust, Michael K;	The biology and ecology of cat fleas and advancements in their pest management: a review	Insects	2017	Multidisciplinary Digital Publishing Institute	4	1	S-methoprene
Walker, Kathleen; Yaglom, Hayley; Gouge, Dawn H; Brophy, Maureen; Casal, Mariana; Encinas, Veronica Ortiz;	The brown dog tick and epidemic Rocky Mountain spotted fever in Arizona and northwestern Mexico	Univ. Az. Coop. Ext	2018		4	1	S-methoprene
Sinden, Robert E;	The challenge of disrupting vectorial capacity	Genetic Control of Malaria and Dengue	2016	Elsevier	4	1	Bti
Chong, Irene Yan Ling;	The characterization of isolated Bacillus Thuringiensis from blocks B, C, I and engineering workshop of Universiti Tunku Abdul Rahman, Kampar campus		2017	UTAR	4	1	Bti
André, L de A;	THE DEVELOPMENT BEHIND THE MULTI-PURPOSE MICROORGANISM	BACILLUS THURINGIENSIS			4	1	Bti
Adler, Peter H; Barzen, Jeb; Gray, Elmer; Lacy, Anne; Urbanek, Richard P; Converse, Sarah J;	The dilemma of pest suppression in the conservation of endangered species	Conservation Biology	2019	Wiley Online Library	4	1	Bti
Buczek, Alicja; Lachowska-Kotowska, Patrycja; Bartosik, Katarzyna;	The effect of synthetic pyrethroids on the attachment and host-feeding behaviour in Dermacentor reticulatus females (Ixodida: Amblyommidae)	Parasites & vectors	2015	Springer	4	1	S-methoprene
Mustapha, Obaidiyah;	The effect of terpenes on the life cycle of the malaria parasite		2017		4	1	Bti
Polwiang, Sittisede;	The effectiveness of dengue vaccine and vector control: Model study	Applied Science and Engineering Progress	2018		4	1	Bti
Skiff, Jeffrey J; Yee, Donald A;	The effects of protozoans on larval container mosquito performance	Annals of the Entomological Society of America	2015	Oxford University Press	4	1	Bti
Lamichhane, Ram Sharan; Neville, Peter J; Oosthuizen, Jacques; Clark, Kim; Mainali, Samir; Fatouros, Maria; Beatty, Shelley;	The highs and lows of making a bucket list—Quantifying potential mosquito breeding habitats in metropolitan backyards	Frontiers in public health	2017	Frontiers	4	1	S-methoprene
Wondwoson, Betelehem;	The Identification of cereal volatile compounds that attract gravid malaria mosquito, Anopheles arabiensis Patton (Diptera: Culicidae)		2016	Addis Ababa University	4	1	Bti
Buckham-Bonnett, Phillip;	The impact and spread of the invasive garden ant: an alien invasive species in the UK		2019	University of York	4	1	S-methoprene
Huancahuari, Marciano; Pensati, Fabrizio; Rongoni, Annarosa; Carrieri, Marco; Bellini, Romeo;	The introduction of Gambusia holbrooki in rice field for mosquito control can positively affect rice production	Bull. Insectol	2016		4	1	Bti
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Arsenović, Milica; Pezo, Lato; Vasić, Nebojša; Ćirić, Rodoljub; Stefanović, Milan;	The main factors influencing canine demodicosis treatment outcome and determination of optimal therapy	Parasitology research	2015	Springer	4	1	S-methoprene
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Schäfer, M; Wahlqvist, Pernilla; Lundström, Jan O;	The Nedre Dalälven River Landscape in Central Sweden—a hot-spot for mosquito (Diptera: Culicidae) diversity	J Eur Mosq Control Ass	2018		4	1	Bti
Desoky, ASS;	The pests caused diseases and strategy of their control	International Journal of Comprehensive Research in Biological Sciences	2015	Citeseer	4	1	Bti
Masetti, Antonio;	The potential use of essential oils against mosquito larvae: a short review	Bull. Insectol	2016		4	1	S-methoprene
Gross, Jonathon; Kearney, Christopher Michel;	The Presentation of Mosquitocidal Protein Toxin for Delivery in Yeast-Based Stations		2015		4	1	Bti
Heller, Charlotte;	The Public Perception of Urban Stormwater Ponds as Environmental Amenities		2020	Université d'Ottawa/University of Ottawa	4	1	Bti
Champion, Cody;	The Role Nadph Regeneration in Redox Homeostasis and Implications in Mosquito Longevity, Fecundity and Resistance to Insecticides		2018	New Mexico State University	4	1	S-methoprene
Pees, Barbara;	The role of C-type lectin-like domain genes in C. elegans immunity		2016		4	1	Bti
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Johnson, Brian J; Ritchie, Scott A; Fonseca, Dina M;	The state of the art of lethal oviposition trap-based mass interventions for arboviral control	Insects	2017	Multidisciplinary Digital Publishing Institute	4	1	Bti
Соболева, Евгения Сергеевна;	The study of inversion polymorphisms of malaria mosquitoes Anopheles beklemishevi in the natural populations of western Siberia: магистерская диссертация по направлению подготовки: 06.04. 01-Биология		2020	Томск:[б. и.]	4	1	Bti
Dambach, Peter;	The use of aquatic predators for larval control of mosquito disease vectors: Opportunities and limitations	Biological Control	2020	Elsevier	4	1	Bti
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Thakur, Neeraj; Chethan, GE; Akhilesh, Aishwarya Lekshman; Kumari, Priyanka; Shehzad, Munazah; Rajesh, JB; Mahendran, K; De, UK; Banerjee, PS;	Therapeutic management of Hepatozoon canis induced acute hepatitis in a dog	Hemoglobin (g/dl)	2018		4	1	S-methoprene
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World Health Organization;	Toolkit for Integrated Vector Management in Sub-Saharan Africa (A)		2016	World Health Organization	4	1	Bti
Sierras, Angela Juventina;	Toward a Liquid Bait Against Bed Bugs: Evaluation of Ingestible Insecticides.		2018		4	1	S-methoprene
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HAMPSHIRE, NEW;	TOWN OF RYE	Annual report of the town of Rye			4	1	Bti
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Bilbo, Thomas R;	Toxicological implications of the developmental environment in two Aedes sp. vector mosquitoes		2015		4	1	Bti
Ruchir, Fnu;	Transcriptomic Analyses of Drosophila Suzukii Responses to Pesticides and Anopheles Gambiae (ag55) Cell Line: A Model to Study Mosquito Physiology and Pathogen Interactions		2016	University of Georgia	4	1	Bti
Wilke, André BB; Beier, John C; Benelli, Giovanni;	Transgenic mosquitoes–fact or fiction?	Trends in parasitology	2018	Elsevier	4	1	Bti
Fourie, Josephus J; Evans, Alec; Labuschagne, Michel; Crafford, Dionne; Madder, Maxime; Pollmeier, Matthias; Schunack, Bettina;	Transmission of Anaplasma phagocytophilum (Foggie, 1949) by Ixodes ricinus (Linnaeus, 1758) ticks feeding on dogs and artificial membranes	Parasites & vectors	2019	Springer	4	1	S-methoprene
Regnault-Roger, Catherine;	Trends for Commercialization of Biocontrol Agents (Biopesticide)	Plant Defence: Biological Control	2020	Springer	4	1	Bti
Elston, Dirk M;	Tropical bites and stings	Tropical Dermatology E-Book	2016	Elsevier Health Sciences	4	1	S-methoprene
Dauda, Akeem Babatunde; Teh, Jun Chin; Kamarudin, Mohd Salleh; Romano, Nicholas;	Trypsin-modulating oostatic factor (TMOF) decreased the survival, growth and digestion enzymes of Macrobrachium rosenbergii	Journal of pesticide science	2016	Pesticide Science Society of Japan	4	1	Bti
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Elsheikha, Hany M; Schnyder, Manuela; Traversa, Donato; Di Cesare, Angela; Wright, Ian; Lacher, David W;	Updates on feline aelurostrongylosis and research priorities for the next decade	Parasites & vectors	2016	BioMed Central	4	1	S-methoprene
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Sarwar, Muhammad;	Usage spots of biological insecticides in consort with target insect pests or vectors and application in habitat	International Journal of Entomology and Nematology	2016		4	1	Bti
Caldwell, James William;	Use of extinguish plus to reduce red imported fire ants and increase northern bobwhite abundance		2015		4	1	S-methoprene
Tugwell, Laura A;	Using behavioural and immunological tools to study the seasonality of Culicoides biting midges in the UK.		2020	University of Surrey	4	1	Bti
Theissinger, Kathrin; Kästel, Anna; Elbrecht, Vasco; Makkonen, Jenny; Michiels, Susanne; Schmidt, Susanne I; Allgeier, Stefanie; Leese, Florian; Brühl, Carsten A;	Using DNA metabarcoding for assessing chironomid diversity and community change in mosquito controlled temporary wetlands		2018	Pensoft Publishers	4	1	Bti
Lupenza, Eliza T; Kihonda, Japhet; Limwagu, Alex J; Ngowo, Halfan S; Sumaye, Robert D; Lwetoijera, Dickson W;	Using pastoralist community knowledge to locate and treat dry-season mosquito breeding habitats with pyriproxyfen to control Anopheles gambiae sl and Anopheles funestus sl in rural Tanzania	Parasitology Research		Springer	4	1	Bti
Islam, Mohammed Alimul; Haque, Md Enamul; Sharif, Md Mohiuddin; Islam, Sumaiya; Amin, Mohammad Robed;	Vector borne viral diseases: An emerging threat and their control strategies in Bangladesh perspectives	Int. Res. J. Med. Med. Sci	2020		4	1	Bti
Coulibaly, Yaya Ibrahim;	Vector competence and filariasis transmission in Mali		2016	University of Liverpool	4	1	Bti
Schmidt, Monika; Hrabcova, Veronika; Jun, Daniel; Kuca, Kamil; Musilek, Kamil;	Vector control and insecticidal resistance in the African malaria mosquito Anopheles gambiae	Chemical research in toxicology	2018	ACS Publications	4	1	Bti

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Thompson, Sarah J; Pearce, John M; Ramey, Andrew M;	Vectors, hosts, and control measures for Zika virus in the Americas	EcoHealth	2017	Springer	4	1	Bti
Morin, Cory W;	Visualizations of mosquito risk: A political ecology approach to understanding the territorialization of hazard control		2015		4	1	Bti
DiGangi, Brian A;	Wellness and Preventive Care	Field Manual for Small Animal Medicine	2018	Wiley Online Library	4	1	S-methoprene
Johnson, Brian J; Manby, Russell; Devine, Gregor J;	What happens on islands, doesn't stay on islands: Patterns of synchronicity in mosquito nuisance and host-seeking activity between a mangrove island and adjacent coastal development	Urban Ecosystems	2020	Springer	4	1	Bti
Zaller, Johann G;	What Is the Problem? Pesticides in Our Everyday Life	Daily Poison	2020	Springer	4	1	Bti
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Carvalho, Fabiano Duarte; Moreira, Luciano Andrade;	Why is Aedes aegypti Linnaeus so Successful as a Species?	Neotropical entomology	2017	Springer	4	1	Bti
Mullens, Bradley A; Gerry, Alec C; Dhillon, Major S;	William E. Walton 1956–2020		2020	American Mosquito Control Association, Inc.	4	1	Bti
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Mollloy, Jennifer C;	Wolbachia-mosquito interactions and engineered female-specific lethality for Aedes-arbovirus control		2015	University of Oxford	4	1	Bti
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Workman, Michael J; Gomes, Bruno; Weng, Ju-Lin; Ista, Linnea K; Jesus, Camila P; David, Mariana R; Ramalho-Ortigao, Marcelo; Genta, Fernando A; Matthews, Scott K; Durvasula, Ravi;	Yeast-encapsulated essential oils: a new perspective as an environmentally friendly larvicide	Parasites & vectors	2020	Springer	4	1	Bti
Hasan, Shamimul; Saeed, Shazina; Panigrahi, Rajat; Choudhary, Priyadarshini;	Zika virus: A global public health menace: A comprehensive update	Journal of International Society of Preventive & Community Dentistry	2019	Wolters Kluwer--Medknow Publications	4	1	Bti
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Alto, Barry W; Lord, Cynthia C;	Transstadial effects of Bti on traits of Aedes aegypti and infection with dengue virus	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	1	3	Bti
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Wang, Yifan;	Aedes Mosquitoes in Alabama–Population Dynamics and Sensitivity to Insecticides		2018		4	3	Bti
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Zaller, Johann G;	What Is the Problem? Pesticides in Our Everyday Life	Daily Poison	2020	Springer	4	3	Bti
Zaller, Johann G;	Daily Poison: Pesticides-an Underestimated Danger		2020	Springer Nature	4	3	Bti
Zaller, Johann G;	Daily Poison			Springer	4	3	Bti
Baldet, Thierry; Carnevale, Pierre; Devillers, James; Dupé, Sandrine; Noël, Harold; Roiz Pereda, David;	Avis du 31/07/2018 révisé le 23/10/2018 de l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES) relatif à" l'analyse de la stratégie de lutte anti-vectorielle (LAV) mise en oeuvre à La Réunion depuis 2017".		2018	ANSES	5	3	Bti
Brühl, Carsten; Frör, Oliver;	Entwicklung eines naturschutzkonformen Konzeptes zur Stechmückenbekämpfung am Oberrhein				5	3	Bti
Kreß, Aljoscha;	Untersuchungen zum Anpassungs-und Etablierungspotential der invasiven Asiatischen Tigermücke Aedes (Stegomyia) albopictus (SKUSE)		2016	Verlag nicht ermittelbar	5	3	Bti
Pires, Vícinius Couto;	Avaliação do potencial larvicida do óleo essencial de melaleuca alternifólia e sua formulação em nanocápsulas poliméricas		2019	Instituto Gonçalo Moniz	5	3	Bti
SANTOS, Leilane Marina Morais dos;	Avaliação do potencial de óleo essencial de sementes de Syagrus coronata (Martius) Beccari (Arecaceae: Arecoideae) para controle do Aedes aegypti		2016	Universidade Federal de Pernambuco	5	3	Bti
Silva, William Ribeiro da;	Monitoramento da Resistência e dos Efeitos em Parâmetros Biológicos de Aedes aegypti Linnaeus, 1762 (Diptera: Culicidae) de Manaus, Amazonas, Exposto ao Biolarvicida Espinosade, em Condições de Laboratório		2019	Instituto Nacional de Pesquisas da Amazônia	5	3	Bti
Valtierra de Luis, Daniel;	Novel application of bioassays and functional importance of minor crystal components of Bacillus thuringiensis serovar israelensis for dipteran pests		2020		5	3	Bti
Hu, Xuelei;	Effects of Juvenile Hormone Analogue Insecticides, Fenoxycarb and Methoprene, on Neocaridina davidi and Moina macrocopa		2019	The Chinese University of Hong Kong (Hong Kong)	1	3	S-methoprene

Ramírez Villalobos, Jesica María;	Efecto sinérgico de distintos extractos vegetales y Bacillus thuringiensis var. israelensis para el control de Aedes aegypti (L.)(diptera, culicidae)		2020	Universidad Autónoma de Nuevo León	1	3	S-methoprene
Bakr, Reda; Tanani, Muhammad;	Toxicity And Physiological Activity of Methoprene, A Juvenile Hormone Analog, Against Development and Metamorphosis of The Grey Flesh Fly, Parasarcophaga argyrostoma (Robineau-Desvoidy)(Diptera: Sarcophagidae).	Egyptian Academic Journal of Biological Sciences. A, Entomology	2018	Egyptian Society of Biological Sciences	2	3	S-methoprene
Judd, Shiloh Dean;	The Effects of Juvenile Exposure to Sub-lethal Concentrations of Pesticides on the Adult Reproductive Biology of the Male Southern House Mosquitoe, Culex quinquefasciatus		2018		2	3	S-methoprene
Junges, Celina Maria; Maglianese, MI; Lajmanovich, Rafael Carlos; Peltzer, PM; Attademo, Andres Maximiliano;	Acute toxicity and etho-toxicity of three insecticides used for mosquito control on amphibian tadpoles	Water, Air, & Soil Pollution	2017	Springer	2	3	S-methoprene
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of Methoprene on Spermatogenesis of the Freshwater Crab Travancoriana schirnerae				2	3	S-methoprene
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of methoprene on oogenesis of the freshwater crab Travancoriana schirnerae Bott, 1969 (Decapoda: Gecarcinucidae)	Brazilian Journal of Biological Sciences	2017		2	3	S-methoprene
Recluse, Brown; Earworm, Corn; Fly, House; Marmorated, Brown; Bug, Bed; Bug, Tarnished Plant; Bug, Stink;	Insecticide Recommendations for Arkansas				2	3	S-methoprene
Richardson, Elise A; Abruzzo, Nicole O; Taylor, Caitlin E; Stevens, Bruce R; Cuda, James P; Weeks, Emma NI;	Combining DL-Methionine and Bacillus thuringiensis subspecies israelensis: Prospects for a Mosquito Larvicide	Insects	2020	Multidisciplinary Digital Publishing Institute	2	3	S-methoprene
Staples, Kerry;	Evaluation of a mosquito control intervention and recommendations for development of best practice protocols by the Shire of Kalamunda		2016		2	3	S-methoprene
Tamilselvan, S;	DEVELOPMENT AND EVALUATION OF FLY ASH BASED BACILLUS THURINGIENSIS VAR. ISRAELENSIS FORMULATIONS FOR MOSQUITO CONTROL		2015	Pondicherry	2	3	S-methoprene
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	2	3	S-methoprene
Ahmed, Ashraf M; El-Kersh, Talat A; Hussein, Hamdy I; Ayaad, Tahany H; El-Sadawy, Hanan A; Ibrahim, Mohamed S; Amoudi, Mikky A; Aseery, Ghaleb M;	Larvicidal activities of local Bacillus thuringiensis isolates and toxins from nematode bacterial symbionts against the Rift Valley fever vector, Aedes caspius (Diptera: Culicidae)	African Zoology	2021	Taylor & Francis	3	3	S-methoprene
Angelo, Elisangela Andrade; Vilas-Bôas, Gislayne Trindade; Castro-Gómez, Raúl Jorge Hernan; Lopes, José;	Utilisation of response surface methodology to optimise the culture medium for Bacillus thuringiensis subsp. israelensis	Biocontrol Science and Technology	2015	Taylor & Francis	3	3	S-methoprene
Brunk, Ingo; Sobczyk, Thomas; Roth, Mechthild;	Pest control in German forests: General patterns of biodiversity and possible impacts of Btk, diflubenzuron and lambda-Cyhalothrin on non-target arthropods, birds and bats–a literature review				3	3	S-methoprene
Nair, Kavita; Al-Thani, Roda; Ginibre, Carole; Chandre, Fabrice; Alsafran, Mohammed; Jaoua, Samir;	Bacillus thuringiensis strains isolated from Qatari soil, synthesizing δ-endotoxins highly active against the disease vector insect Aedes aegypti Bora Bora	Heliyon	2020	Elsevier	3	3	S-methoprene
Olmo, Carla; Marco, Amparo; Armengol, Xavier; Ortells, Raquel;	Effects of Bacillus thuringiensis var. israelensis on nonstandard microcrustacean species isolated from field zooplankton communities	Ecotoxicology	2016	Springer	3	3	S-methoprene
Olmo, Carla; Marco, Amparo; Armengol, Xavier; Ortells, Raquel;	microcrustacean species isolated from field zooplankton communities		2016		3	3	S-methoprene
Salama, Elham M; Ismail, IA; Khattab, Abeer A;	Combined Effect of a Chitinase Producing Bacteria and Bacillus thuringiensis Against Musca domestica (Diptera: Muscidae) Larvae.	Int J ChemTech Res	2016		3	3	S-methoprene
Ahmed, Khaled Sayed; Mikhail, Wafai ZA; Sobhy, Hassan M; Radwan, Eman Mohamed Mostafa; Salaheldin, Taher A;	Impact of nanosilver-profenofos on cotton leafworm, Spodoptera littoralis (Boisd.) larvae	Bulletin of the National Research Centre	2019	Springer	4	3	S-methoprene
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	4	3	S-methoprene
Bacci, L; Lupi, D; Savoldelli, S; Rossaro, B;	A review of Spinosyns, a derivative of biological acting substances as a class of insecticides with a broad range of action against many insect pests		2016	Pagepress	4	3	S-methoprene
Baker-Galloway, Maree; Hill, Rosie; Lloyd, Anderson; Queenstown, DX Box ZP95010;	Before a Special Tribunal		2018		4	3	S-methoprene
Bassett, Mary T;	Technical Memorandum CEQR No. 00DOH002Y New York City Comprehensive Mosquito Surveillance and Control		2017		4	3	S-methoprene
Bateman, Melanie L; Day, Roger K; Luke, Belinda; Edgington, Steve; Kuhlmann, Ulrich; Cock, Matthew JW;	Supplementary Material Assessment of potential biopesticide options for managing fall armyworm (Spodoptera frugiperda) in Africa				4	3	S-methoprene
Chong, Irene Yan Ling;	The characterization of isolated Bacillus Thuringiensis from blocks B, C, I and engineering workshop of Universiti Tunku Abdul Rahman, Kampar campus		2017	UTAR	4	3	S-methoprene
Cuthbert, Ross Noel;	Biological control of Culex mosquitoes using multiple predators		2019	Queen's University Belfast. Faculty of Medicine, Health and Life Sciences …	4	3	S-methoprene
Githinji, James M;	Herbal medicine use in Murang'a county and antiflea activity and safety of Tithonia diversifolia and Senna didymobotrya extracts		2018	University of Nairobi	4	3	S-methoprene
Gowelo, Steven A;	A participatory approach for malaria control in southern Malawi: Effects of the environment and community on larval source management		2020	Wageningen University	4	3	S-methoprene
Gross, Elisabeth; Garric, Jeanne;	Ecotoxicology: New Challenges and New Approaches		2019	Elsevier	4	3	S-methoprene
Gupta, Ramesh C; Anadón, Arturo;	Fipronil	Veterinary Toxicology	2018	Elsevier	4	3	S-methoprene

Hess, Thomas M;	Mosquito Survey of Camp Gruber Training Center and Comparison with Other Oklahoma Military Bases		2019		4	3	S-methoprene
Hustedt, John;	Determining effectiveness of new approaches to dengue vector control in Cambodia		2020	London School of Hygiene & Tropical Medicine	4	3	S-methoprene
Junquera, Pablo; Hosking, Barry; Gameiro, Marta; Macdonald, Alicia;	Benzoylphenyl ureas as veterinary antiparasitics. An overview and outlook with emphasis on efficacy, usage and resistance	Parasite	2019	EDP Sciences	4	3	S-methoprene
Kakaley, Elizabeth Katharine Medlock;	Characterization of Early Events in the Activation of the Methyl Farnesoate Receptor		2016	North Carolina State University	4	3	S-methoprene
Karikari, URIAH ARKO;	Species Diversity Of Bedbugs And Environmental Factors Influencing Their Survival		2016	University of Ghana	4	3	S-methoprene
Kress, Aljoscha;	Research into the Potential to Adapt and Establish of the invasive Asian Tiger Mosquito Aedes (Stegomyia) albopictus (SKUSE)	arXiv preprint arXiv:1611.10318	2016		4	3	S-methoprene
LaLone, Carlie A; Villeneuve, Daniel L; Lyons, David; Helgen, Henry W; Robinson, Serina L; Swintek, Joseph A; Saari, Travis W; Ankley, Gerald T;	Editor's highlight: sequence alignment to predict across species susceptibility (SeqAPASS): a web-based tool for addressing the challenges of cross-species extrapolation of chemical toxicity	Toxicological Sciences	2016	Oxford University Press	4	3	S-methoprene
Mahmood, Muhammad Asif; Khan, IA; Rana, MS; Hassan, SA;	Bio-efficacy and persistancy of Pyriproxyfen against Aedes aegypti: a control trial at district Lahore, Punjab, Pakistan.	Pakistan Journal of Public Health	2015	Health Services Academy	4	3	S-methoprene
Masetti, Antonio;	The potential use of essential oils against mosquito larvae: a short review	Bull. Insectol	2016		4	3	S-methoprene
Matthews, Graham A;	A history of pesticides		2018	CABI	4	3	S-methoprene
McKemey, Andy; Adey, Richard;	Autodissemination of insecticides for Mosquito control		2018		4	3	S-methoprene
Medlock Kakaley, Elizabeth Katharine;	Characterization of Early Events in the Activation of the Methyl Farnesoate Receptor.		2016		4	3	S-methoprene
Miller, Selpha Opisa;	Management of Spoladea recurvalis (Lepidoptera: Crambidae) on amaranths using biopesticides		2019	North-West University	4	3	S-methoprene
Nayak, Manoj K; Daglish, Gregory J; Phillips, Thomas W;	Managing resistance to chemical treatments in stored products pests	Stewart Postharvest Rev	2015		4	3	S-methoprene
Nguyen, Chilinh;	Ivermectin-treated bird feed to control West Nile virus transmission		2018	Colorado State University	4	3	S-methoprene
Nguyen, Tam Thi;	Genetics of phosphine resistance in the rice weevil Sitophilus oryzae (L.)(Coleoptera: Curculionidae)		2016		4	3	S-methoprene
Ogunah, Joanne Atieno; Lalah, Joseph O; Schramm, Karl-Werner;	Malaria vector control strategies. What is appropriate towards sustainable global eradication?	Sustainable Chemistry and Pharmacy	2020	Elsevier	4	3	S-methoprene
Omer, Sabah Abd Alla Birama;	The Lethal Impact of Ixora coccinea L. Extracts on Anopheles and culex Larvae and some of their Aquatic Predators		2017	University of Gezira	4	3	S-methoprene
Rizali, Akhmad;	Occurrence of Bacillus Thuringiensis in South Kalimantan. Indonesia		2020	lap-publishing	4	3	S-methoprene
Ruchir, Fnu;	Transcriptomic Analyses of Drosophila Suzukii Responses to Pesticides and Anopheles Gambiae (ag55) Cell Line: A Model to Study Mosquito Physiology and Pathogen Interactions		2016	University of Georgia	4	3	S-methoprene
Sánchez-Bayo, Francisco; Tennekes, Henk A;	Assessment of ecological risks of agrochemicals requires a new framework	Environmental Risk Assessment and Remediation	2017		4	3	S-methoprene
Sarwar, Muhammad;	Biology and ecology of some predaceous and herbivorous mites important from the agricultural perception	Pests Control and Acarology	2019	IntechOpen	4	3	S-methoprene
Sharma, Charu; Sadek, Bassem; Goyal, Sameer N; Sinha, Satyesh; Kamal, Mohammad Amjad; Ojha, Shreesh;	Small molecules from nature targeting G-protein coupled cannabinoid receptors: potential leads for drug discovery and development	Evidence-Based Complementary and Alternative Medicine	2015	Hindawi	4	3	S-methoprene
Stone Lakes, NWR;	Compatibility Determination for Mosquito Control on the Stone Lakes National Wildlife Refuge				4	3	S-methoprene
Valtierra de Luis, Daniel;	Novel application of bioassays and functional importance of minor crystal components of Bacillus thuringiensis serovar israelensis for dipteran pests		2020		4	3	S-methoprene
van Leeuwenhoeklaan, A; Marinković, M; Montforts, M;	1. Mosquito control products				4	3	S-methoprene
Vieira Santos, Vanessa Santana; Caixeta, Evelyn Siqueira; Campos Júnior, Edimar Olegário de; Pereira, Boscolli Barbosa;	Ecotoxicological effects of larvicide used in the control of Aedes aegypti on nontarget organisms: Redefining the use of pyriproxyfen	Journal of Toxicology and Environmental Health, Part A	2017	Taylor & Francis	4	3	S-methoprene
Wylie, F Ross; Janssen-May, Sharon;	Red imported fire ant in Australia: what if we lose the war?	Ecological Management & Restoration	2017	Wiley Online Library	4	3	S-methoprene
Zaller, Johann G;	What Is the Problem? Pesticides in Our Everyday Life	Daily Poison	2020	Springer	4	3	S-methoprene
Baldet, Thierry; Carnevale, Pierre; Devillers, James; Dupé, Sandrine; Noël, Harold; Roiz Pereda, David;	Avis du 31/07/2018 révisé le 23/10/2018 de l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES) relatif à" l'analyse de la stratégie de lutte anti-vectorielle (LAV) mise en oeuvre à La Réunion depuis 2017".		2018	ANSES	5	3	S-methoprene
Brühl, Carsten; Frör, Oliver;	Entwicklung eines naturschutzkonformen Konzeptes zur Stechmückenbekämpfung am Oberrhein				5	3	S-methoprene
Hamza, Amany; Hamza, Amal;	Toxicity and combined action of some insecticides and clove oil against Rhyzopertha dominica in wheat grain	Journal of Plant Protection Research	2018	Committee of Plant Protection PAS	5	3	S-methoprene
Kreß, Aljoscha;	Untersuchungen zum Anpassungs-und Etablierungspotential der invasiven Asiatischen Tigermücke Aedes (Stegomyia) albopictus (SKUSE)		2016	Verlag nicht ermittelbar	5	3	S-methoprene
NARAYANAN, S;	EFFECT OF COMBINATION OF YOGA WITH RESISTANCE AND YOGA WITH PLYOMETRIC TRAINING AND SELECTED PHYSIOLOGICAL, PSYCHOLOGICAL AND SKILL PERFORMANCE VARIABLES AMONG VOLLEYBALL PLAYERS		2015		5	3	S-methoprene
Oliveira Filho, Jaires Gomes de;	Uso de compostos repelentes produzidos por cães resistentes ao Rhipicephalus sanguineus sensu lato para o seu controle em cães susceptiveis		2018	Universidade Federal de Goiás	5	3	S-methoprene
SANTOS, Leilane Marina Morais dos;	Avaliação do potencial de óleo essencial de sementes de Syagrus coronata (Martius) Beccari (Arecaceae: Arecoideae) para controle do Aedes aegypti		2016	Universidade Federal de Pernambuco	5	3	S-methoprene
Van Tuat NGUYEN, VAAS;	DEVENIR DES TOXINES Cry DE BACILLUS THURINGIENSIS DANS LE SOL		2015	Huazhong Agricultural University	5	3	S-methoprene
이석희;	Identification and Characterization of Novel Juvenile Hormone-related Insect Growth Regulators		2018	서울대학교 대학원	5	3	S-methoprene
谷静; **席**贻龙; **胡**晓燕; **江慧**;	**不同斜生**栅藻密度下布洛芬浓度对多刺裸腹溞生命表统计学参数的影响.	Yingyong Shengtai Xuebao	2018		5	3	S-methoprene

Authors	Title	Publication	Year	Publisher	Clasification	Question	Product
Bordalo, MD; Gravato, C; Beleza, S; Campos, D; Lopes, I; Pestana, JLT;	Lethal and sublethal toxicity assessment of Bacillus thuringiensis var. israelensis and Beauveria bassiana based bioinsecticides to the aquatic insect Chironomus riparius	Science of The Total Environment	2020	Elsevier	2	4	Bti
ADEOGUN, ADEDAPO OLUFEMI;	INSECTICIDE RESISTANCE ASSOCIATED WITH 2La INVERSION AND MICROSATELLITE LOCI POLYMORPHISM IN Anopheles gambiae ss POPULATIONS FROM LAGOS AND OYO STATES, NIGERIA		2016		4	4	Bti
Amarasinghe, LD; Wickramarachchi, PASR; Aberathna, AAAU; Sithara, WS; De Silva, CR;	Comparative study on larvicidal activity of green synthesized silver nanoparticles and Annona glabra (Annonaceae) aqueous extract to control Aedes aegypti and Aedes albopictus (Diptera: Culicidae)	Heliyon	2020	Elsevier	4	4	Bti
Amiard-Triquet, Claude;	Pollution tolerance in aquatic animals: From fundamental biological mechanisms to ecological consequences	Ecotoxicology	2019	Elsevier	4	4	Bti
André, L de A;	THE DEVELOPMENT BEHIND THE MULTI-PURPOSE MICROORGANISM	BACILLUS THURINGIENSIS			4	4	Bti
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	4	4	Bti
Bhaskar, C; Chandrasekar, S;	A comparative spectral and biological studies of trimethyl (chloro)(4-N, N-dimethylamino pyridine) tin (IV) complex.				4	4	Bti
CHATTOPADHYAY, PINAKI; CHATTOPADHYAY, PALLAVI; PALIT, DEBNATH;	Innovative Approach to Sustainable Development and Biodiversity Conservation	Environmental and Sustainable Development Through Forestry and Other Resources	2020	CRC Press	4	4	Bti
Dyck, VA; Hendrichs, J; Robinson, AS;	POTENTIAL IMPACT OF INTEGRATING THE STERILE INSECT TECHNIQUE INTO THE FIGHT AGAINST DISEASE-TRANSMITTING MOSQUITOES	Sterile Insect			4	4	Bti
Goldson, SL; Bourdôt, GW; Brockerhoff, EG; Byrom, AE; Clout, MN; McGlone, MS; Nelson, WA; Popay, AJ; Suckling, DM; Templeton, MD;	New Zealand pest management: current and future challenges	Journal of the Royal Society of New Zealand	2015	Taylor & Francis	4	4	Bti
Gonnabathula, Pavani Kumari;	Assessment of Emerging Contaminants–Multiple Pesticides and Hormonal Compounds in Water: Effects on Biomolecules and Application of Green Nanotechnology for Remediation		2020	Texas Southern University	4	4	Bti
Govindarajan, Marimuthu;	Green synthesized silver nanoparticles: a potential new insecticide for mosquito control	Nanoparticles in the Fight Against Parasites	2016	Springer	4	4	Bti
Gross, Elisabeth; Garric, Jeanne;	Ecotoxicology: New Challenges and New Approaches		2019	Elsevier	4	4	Bti
New, Tim R;	Insects of Australia's Inland Waters	Insect conservation and Australia's Inland Waters	2020	Springer	4	4	Bti
Pignotti, Emanuela;	Contaminants of Emerging Concern: occurrence and distribution in aquatic environments		2018	alma	4	4	Bti
Sánchez-Bayo, Francisco; Tennekes, Henk A;	Assessment of ecological risks of agrochemicals requires a new framework	Environmental Risk Assessment and Remediation	2017		4	4	Bti
Singh, Raj K; Dhama, Kuldeep; Khandia, Rekha; Munjal, Ashok; Karthik, Kumaragurubaran; Tiwari, Ruchi; Chakraborty, Sandip; Malik, Yashpal S; Bueno-Marí, Rubén;	Prevention and control strategies to counter Zika virus, a special focus on intervention approaches against vector mosquitoes—current updates	Frontiers in microbiology	2018	Frontiers	4	4	Bti
Sukkanon, Chutipong; Yaicharoen, Rapeeporn; Ngrenngarmlert, Warunee;	Comparative effectiveness of monomolecular surface film on Aedes aegypti (L.) and Anopheles minimus (Theobald)(Diptera: Culicidae)	Agriculture and Natural Resources	2016	Elsevier	4	4	Bti
TE, TH;	ENT R		2018		4	4	Bti
Tillekaratne, Aashani;	Guest Articles	THE NEW NORMAL	2020		4	4	Bti
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	4	4	Bti
van Leeuwenhoeklaan, A; Marinković, M; Montforts, M;	1. Mosquito control products				4	4	Bti
Wickramarachchi, SR; Amarasinghe, LD;	Annona glabra Leaf Extract as a Dengue Mosquito Larvicide				4	4	Bti
Zaller, Johann G;	What Is the Problem? Pesticides in Our Everyday Life	Daily Poison	2020	Springer	4	4	Bti
Zaller, Johann G;	Daily Poison: Pesticides-an Underestimated Danger		2020	Springer Nature	4	4	Bti
Zaller, Johann G;	Daily Poison			Springer	4	4	Bti
Chagas, Juliana Macêdo;	Avaliação do potencial inseticida de extratos salinos de sementes de seis espécies de plantas (família Fabaceae) contra Aedes (Stegomyia) aegypti (Diptera: Culicidae) L. em diferentes estágios do ciclo biológico		2016	Brasil	5	4	Bti
Coelho, Sónia Dias;	Human exposure pathways to environmental contaminants		2016	Universidade de Aveiro (Portugal)	5	4	Bti

Hifni, Hifziah Ahmad;	Penyerapan Pb dan Cd menggunakan jerami padi dan aspergillus niger yang diiradiasi gamma pada rumput gajah dan kembang bulan		2016	Jakarta: Fakultas Sains dan Teknologi UIN Syarif Hidayatullah	5	4	Bti
Iyaloo, Diana Pillay; Bouyer, Jeremy; Facknath, Sunita; Bheecarry, Ambicadutt;	Pilot Suppression trial of Aedes albopictus mosquitoes through an Integrated Vector Management strategy including the Sterile Insect Technique in Mauritius	bioRxiv	2020	Cold Spring Harbor Laboratory	5	4	Bti
Lemieux, Valérie;	EXPOSITION DE L'HIRONDELLE BICOLORE (TACHYCINETA BICOLOR) AUX PESTICIDES AGRICOLES DANS LE SUD DU QUÉBEC				5	4	Bti
Mollloy, Jennifer C;	Wolbachia-mosquito interactions and engineered female-specific lethality for Aedes-arbovirus control		2015	University of Oxford		4	Bti
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of methoprene on oogenesis of the freshwater crab Travancoriana schirnerae Bott, 1969 (Decapoda: Gecarcinucidae)	Brazilian Journal of Biological Sciences	2017		1	4	S-methoprene
Sánchez-Bayo, Francisco;	Current-use Pesticides	Bioremediation of Agricultural Soils	2019	CRC Press	2	4	S-methoprene
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	2	4	S-methoprene
Baker-Galloway, Maree; Hill, Rosie; Lloyd, Anderson; Queenstown, DX Box ZP95010;	Before a Special Tribunal		2018		4	4	S-methoprene
Bassett, Mary T;	Technical Memorandum CEQR No. 00DOH002Y New York City Comprehensive Mosquito Surveillance and Control		2017		4	4	S-methoprene
Bateman, Melanie L; Day, Roger K; Luke, Belinda; Edgington, Steve; Kuhlmann, Ulrich; Cock, Matthew JW;	Assessment of potential biopesticide options for managing fall armyworm (Spodoptera frugiperda) in Africa	Journal of Applied Entomology	2018	Wiley Online Library	4	4	S-methoprene
Bateman, Melanie L; Day, Roger K; Luke, Belinda; Edgington, Steve; Kuhlmann, Ulrich; Cock, Matthew JW;	Supplementary Material Assessment of potential biopesticide options for managing fall armyworm (Spodoptera frugiperda) in Africa				4	4	S-methoprene
Chen, Chong; Zou, Wenbing; Cui, Guolu; Tian, Jichen; Wang, Yuncai; Ma, Limin;	Ecological risk assessment of current-use pesticides in an aquatic system of Shanghai, China	Chemosphere	2020	Elsevier	4	4	S-methoprene
Githinji, James M;	Herbal medicine use in Murang'a county and antiflea activity and safety of Tithonia diversifolia and Senna didymobotrya extracts		2018	University of Nairobi	4	4	S-methoprene
Ningombam, Arati; Seileshkumar, Th; Santhalembi, L; Singh, IM; Prakash, N;	Strategies and management practices for stored grain pest	INTEGRATED FARMING SYSTEM FOR SUSTAINABLE HILL AGRICULTURE: AN OPTION FOR CLIMATE SMART AGRICULTURE & NATURAL RESOURCE MANAGEMENT	2017		4	4	S-methoprene
Rodríguez, Silvia Marta;	Evaluación del efecto insecticida de Picrasma crenata (Vell.) Engl.-Simaroubaceae-sobre coleópteros plaga de granos almacenados		2015	Universidad Nacional de La Plata	4	4	S-methoprene
Wieck, Stefanie;	Biozide Wirkstoffe im Haushalt: Anwendungsmuster und Einträge in das Abwasser		2018	Universitätsbibliothek der Leuphana Universität Lüneburg	4	4	S-methoprene
Wieck, Stefanie; Olsson, Oliver; Kümmerer, Klaus;	Possible underestimations of risks for the environment due to unregulated emissions of biocides from households to wastewater	Environment international	2016	Elsevier	4	4	S-methoprene
World Health Organization;	Meeting on the Global Vector Control Response 2017-2030, Nadi, Fiji, 1-2 August 2018: meeting report		2018	Manila: WHO Regional Office for the Western Pacific	4	4	S-methoprene
Yeung, Katie WY; Giesy, John P; Zhou, Guang-Jie; Leung, Kenneth MY;	Occurrence, toxicity and ecological risk of larvicidal oil in the coastal marine ecosystem of Hong Kong	Marine Pollution Bulletin	2020	Elsevier	4	4	S-methoprene
Zortéa, Talyta; da Silva, Aleksandro Schafer; Dos Reis, Tamires Rodrigues; Segat, Julia Corá; Paulino, Alexandre Tadeu; Sousa, José Paulo; Baretta, Dilmar;	Ecotoxicological effects of fipronil, neem cake and neem extract in edaphic organisms from tropical soil	Ecotoxicology and environmental safety	2018	Elsevier	4	4	S-methoprene

Authors	Title	Publication	Year	Publisher	Clasification	Question	Product
Bordalo, MD; Gravato, C; Beleza, S; Campos, D; Lopes, I; Pestana, JLT;	Lethal and sublethal toxicity assessment of Bacillus thuringiensis var. israelensis and Beauveria bassiana based bioinsecticides to the aquatic insect Chironomus riparius	Science of The Total Environment	2020	Elsevier	2	5	Bti
Junges, Celina Maria; Maglianese, MI; Lajmanovich, Rafael Carlos; Peltzer, PM; Attademo, Andres Maximiliano;	Acute toxicity and etho-toxicity of three insecticides used for mosquito control on amphibian tadpoles	Water, Air, & Soil Pollution	2017	Springer	2	5	Bti
Lagadic, Laurent; Schäfer, Ralf B; Roucaute, Marc; Szöcs, Eduard; Chouin, Sébastien; de Maupeou, Jérôme; Duchet, Claire; Franquet, Evelyne; Le Hunsec, Benoit; Bertrand, Céline;	No association between the use of Bti for mosquito control and the dynamics of non-target aquatic invertebrates in French coastal and continental wetlands	Science of the Total Environment	2016	Elsevier	2	5	Bti
Lawler, Sharon P;	Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control	Ecotoxicology and environmental safety	2017	Elsevier	2	5	Bti
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	2	5	Bti
Alto, Barry W; Lord, Cynthia C;	Transstadial effects of Bti on traits of Aedes aegypti and infection with dengue virus	PLoS neglected tropical diseases	2016	Public Library of Science San Francisco, CA USA	4	5	Bti
Amiard-Triquet, Claude;	Pollution tolerance in aquatic animals: From fundamental biological mechanisms to ecological consequences	Ecotoxicology	2019	Elsevier	4	5	Bti
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	4	5	Bti
Coelho, Sónia Dias;	Human exposure pathways to environmental contaminants		2016	Universidade de Aveiro (Portugal)	4	5	Bti
Dhama, Kuldeep; Karthik, Kumaragurubaran; Tiwari, Ruchi; Khandia, Rekha; Munjal, Ashok; Chakraborty, Sandip; Yadav, Jay Prakash; Kumar, Deepak; Latheef, Shyma K; Saminathan, Mani;	Zika virus/Zika fever: a comprehensive update	J Exp Biol Agric Sci	2018		4	5	Bti
Foster, Woodbridge A; Walker, Edward D;	mosquitoes (Culicidae)	Medical and veterinary entomology	2019	Elsevier	4	5	Bti
Goldson, SL; Bourdôt, GW; Brockerhoff, EG; Byrom, AE; Clout, MN; McGlone, MS; Nelson, WA; Popay, AJ; Suckling, DM; Templeton, MD;	New Zealand pest management: current and future challenges	Journal of the Royal Society of New Zealand	2015	Taylor & Francis	4	5	Bti
Gonnabathula, Pavani Kumari;	Assessment of Emerging Contaminants–Multiple Pesticides and Hormonal Compounds in Water: Effects on Biomolecules and Application of Green Nanotechnology for Remediation		2020	Texas Southern University	4	5	Bti
Gross, Elisabeth; Garric, Jeanne;	Ecotoxicology: New Challenges and New Approaches		2019	Elsevier	4	5	Bti
Judd, Shiloh Dean;	The Effects of Juvenile Exposure to Sub-lethal Concentrations of Pesticides on the Adult Reproductive Biology of the Male Southern House Mosquitoe, Culex quinquefasciatus		2018		4	5	Bti
Maletz, Sibylle; Wollenweber, Marc; Kubiak, Katharina; Müller, Annett; Schmitz, Stefan; Maier, Dieter; Hecker, Markus; Hollert, Henner;	Investigation of potential endocrine disrupting effects of mosquito larvicidal Bacillus thuringiensis israelensis (Bti) formulations	Science of the Total Environment	2015	Elsevier	4	5	Bti
Matthews, Graham A;	A history of pesticides		2018	CABI	4	5	Bti
Nakazawa, Mitsue Maia; Araújo, Ana Paula; Melo-Santos, Maria Alice Varjal; Oliveira, Cláudia Maria Fontes; Silva-Filha, Maria Helena Neves Lobo;	Efficacy and persistence of Bacillus thuringiensis svar. israelensis (Bti) and pyriproxyfen-based products in artificial breeding sites colonized with susceptible or Bti-exposed Aedes aegypti larvae	Biological Control	2020	Elsevier	4	5	Bti
New, Tim R;	Insects of Australia's Inland Waters	Insect conservation and Australia's Inland Waters	2020	Springer	4	5	Bti
Pignotti, Emanuela;	Contaminants of Emerging Concern: occurrence and distribution in aquatic environments		2018	alma	4	5	Bti
Rama, Aarti; Kumar, Vijay;	STRESS INVOLVED HOST-PARASITE INTERACTION-A REVIEW HYPOTHESIZING NOBLE APPROACH FOR CONTAINING PHLEBOTOMINE SAND FLIES	STRESS	2017		4	5	Bti
Regnault-Roger, Catherine;	Trends for Commercialization of Biocontrol Agents (Biopesticide)	Plant Defence: Biological Control	2020	Springer	4	5	Bti
Riaz, Bushra; Zahoor, Muhammad Kashif; Zahoor, Muhammad Asif; Majeed, Humara Naz; Javed, Irum; Ahmad, Aftab; Jabeen, Farhat; Zulhussnain, Muhammad; Sultana, Kishwar;	Toxicity, phytochemical composition, and enzyme inhibitory activities of some indigenous weed plant extracts in fruit fly, Drosophila melanogaster	Evidence-Based Complementary and Alternative Medicine	2018	Hindawi	4	5	Bti
Ruchir, Fnu;	Transcriptomic Analyses of Drosophila Suzukii Responses to Pesticides and Anopheles Gambiae (ag55) Cell Line: A Model to Study Mosquito Physiology and Pathogen Interactions		2016	University of Georgia	4	5	Bti
Salihu, Lukman; Adedayo, Adekunbi E; Olalekan, Babajide Jelili; Afolabi, Asani M; Mohammed, Idi Dansuleiman; Oke, Isaiah Adesola; Adewale, Obijole O;	Evaluation of Selected Reaeration Models for Water Quality Management	Effects of Emerging Chemical Contaminants on Water Resources and Environmental Health	2020	IGI Global	4	5	Bti

Sánchez-Bayo, Francisco; Tennekes, Henk A;	Assessment of ecological risks of agrochemicals requires a new framework	Environmental Risk Assessment and Remediation	2017		4	5	Bti
Singh, Raj K; Dhama, Kuldeep; Khandia, Rekha; Munjal, Ashok; Karthik, Kumaragurubaran; Tiwari, Ruchi; Chakraborty, Sandip; Malik, Yashpal S; Bueno-Marí, Rubén;	Prevention and control strategies to counter Zika virus, a special focus on intervention approaches against vector mosquitoes—current updates	Frontiers in microbiology	2018	Frontiers	4	5	Bti
Suman, Devi Shankar; Chandel, Kshitij; Faraji, Ary; Gaugler, Randy; Chandra, Kailash;	Mosquito-Borne Diseases: Prevention Is the Cure for Dengue, Chikungunya and Zika Viruses	Mosquito-borne Diseases	2018	Springer	4	5	Bti
Suresh, M; Jeevanandam, Jaison; San Chan, Yen; Danquah, Michael K; Kalaiarasi, JMV;	Opportunities for Metal Oxide Nanoparticles as a Potential Mosquitocide	BioNanoScience	2019	Springer	4	5	Bti
Tamilselvan, S;	DEVELOPMENT AND EVALUATION OF FLY ASH BASED BACILLUS THURINGIENSIS VAR. ISRAELENSIS FORMULATIONS FOR MOSQUITO CONTROL		2015	Pondicherry	4	5	Bti
Thompson, Sarah J; Pearce, John M; Ramey, Andrew M;	Vectors, hosts, and control measures for Zika virus in the Americas	EcoHealth	2017	Springer	4	5	Bti
Wang, Yifan;	Aedes Mosquitoes in Alabama–Population Dynamics and Sensitivity to Insecticides		2018		4	5	Bti
Webb, Cameron; Doggett, Stephen; Russell, Richard;	A guide to mosquitoes of Australia		2016	Csiro Publishing	4	5	Bti
Williams, Trevor; Farfán, Juan L; Mercado, Gabriel; Valle, Javier; Abella, Antonio; Marina, Carlos F;	Efficacy of spinosad granules and lambda-cyhalothrin contrasts with reduced performance of temephos for control of Aedes spp. in vehicle tires in Veracruz, Mexico	Insects	2019	Multidisciplinary Digital Publishing Institute	4	5	Bti
Zaller, Johann G;	What Is the Problem? Pesticides in Our Everyday Life	Daily Poison	2020	Springer	4	5	Bti
Zaller, Johann G;	Daily Poison: Pesticides-an Underestimated Danger		2020	Springer Nature	4	5	Bti
FLORÊNCIO, Sloana Giesta Lemos;	Potencial de uso de machos esterilizados por radiação gama (^{60}CO) para o controle populacional de Aedes aegypti (Diptera-Culicidae): um caminho biotecnológico do laboratório para o campo		2017	Universidade Federal de Pernambuco	5	5	Bti
Lemieux, Valérie;	EXPOSITION DE L'HIRONDELLE BICOLORE (TACHYCINETA BICOLOR) AUX PESTICIDES AGRICOLES DANS LE SUD DU QUÉBEC				5	5	Bti
Adnan, Saleh Mohammad; Mendez, Vivian; Morelli, Renata; Akter, Humayra; Farhana, Iffat; Taylor, Phillip W;	Dietary methoprene supplement promotes early sexual maturation of male Queensland fruit fly Bactrocera tryoni	Journal of Pest Science	2018	Springer	1	5	S-methoprene
Bakr, Reda; Tanani, Muhammad;	Toxicity And Physiological Activity of Methoprene, A Juvenile Hormone Analog, Against Development and Metamorphosis of The Grey Flesh Fly, Parasarcophaga argyrostoma (Robineau-Desvoidy)(Diptera: Sarcophagidae).	Egyptian Academic Journal of Biological Sciences. A, Entomology	2018	Egyptian Society of Biological Sciences	2	5	S-methoprene
Ghoneim, K; Al-Keridis, LA;	Disruptive effectiveness of methoprene (a juvenile hormone analogue) on adult performance and natality of the grey flesh fly Parasarcophaga argyrostoma (Diptera: Sarcophagidae)	African Entomology	2019	BioOne	2	5	S-methoprene
Lawler, Sharon P;	Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control	Ecotoxicology and environmental safety	2017	Elsevier	2	5	S-methoprene
Sánchez-Bayo, Francisco;	Current-use Pesticides	Bioremediation of Agricultural Soils	2019	CRC Press	2	5	S-methoprene
Subramanian, Sabtharishi; Shankarganesh, K;	Insect hormones (as pesticides)	Ecofriendly Pest Management for Food Security	2016	Elsevier	2	5	S-methoprene
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	2	5	S-methoprene
Wijayaratne, LKW; Arthur, FH; Whyard, S;	Methoprene and control of stored-product insects	Journal of Stored Products Research	2018	Elsevier	2	5	S-methoprene
Yeeles, Peter; Strain, Angela; Lenancker, Pauline; Lach, Lori;	Low reduction of invasive ant colony productivity with an insect growth regulator	Pest Management Science	2020	Wiley Online Library	2	5	S-methoprene
Albanese, Francesco;	Cytology of Canine and Feline Non-neoplastic Skin Diseases	Canine and Feline Skin Cytology	2017	Springer	4	5	S-methoprene
Barreto, Natalia M Vega;	Human exposure to permethrin and pyriproxyfen from dogs treated with Vetguard Plus™		2016	Murray State University	4	5	S-methoprene
Bassett, Mary T;	Technical Memorandum CEQR No. 00DOH002Y New York City Comprehensive Mosquito Surveillance and Control		2017		4	5	S-methoprene
Bateman, Melanie L; Day, Roger K; Luke, Belinda; Edgington, Steve; Kuhlmann, Ulrich; Cock, Matthew JW;	Supplementary Material Assessment of potential biopesticide options for managing fall armyworm (Spodoptera frugiperda) in Africa				4	5	S-methoprene
Berger, Darren;	Moriello's Small Animal Dermatology Volume 1, Fundamental Cases and Concepts: Self-Assessment Color Review		2019	CRC Press	4	5	S-methoprene
Bloom, Paul; Livonia, MI;	Diagnosing and Managing Cutaneous Adverse Food Reactions				4	5	S-methoprene
Budgin, Jeanne;	Beyond Steroids: Therapy of Immune-Mediated Skin Disease				4	5	S-methoprene
Cases, Fundamental;	Moriello's Small Animal Dermatology				4	5	S-methoprene
European Food Safety Authority;	Scientific support for preparing an EU position in the 49th Session of the Codex Committee on Pesticide Residues (CCPR)	EFSA Journal	2017	Wiley Online Library	4	5	S-methoprene

Fosset, Fabrice TJ;	Drug allergy in veterinary medicine awareness, incidence, and clinical characteristics		2015		4	5	S-methoprene
Githinji, James M;	Herbal medicine use in Murang'a county and antiflea activity and safety of Tithonia diversifolia and Senna didymobotrya extracts		2018	University of Nairobi	4	5	S-methoprene
Greco, Deborah S; Davidson, Autumn P;	Blackwell's Five-Minute Veterinary Consult Clinical Companion: Small Animal Endocrinology and Reproduction		2017	John Wiley & Sons	4	5	S-methoprene
Gupta, Ramesh C; Doss, Robin B; Srivastava, Ajay; Lall, Rajiv; Sinha, Anita;	Nutraceuticals for Control of Ticks, Fleas, and Other Ectoparasites	Nutraceuticals in Veterinary Medicine	2019	Springer	4	5	S-methoprene
HAMADAH, KHALID SH;	IMPAIRED SURVIVAL AND DEVELOPMENT OF THE FALSE STABLE FLY, MUSCINA STABULANS (FALLEN)(DIPTERA: MUSCIDAE) BY PYRIPROXYFEN (A JUVENILE HORMONE ANALOGUE)	Journal of the Egyptian Society of Parasitology	2018	The Egyptian Society of Parasitology	4	5	S-methoprene
Judd, Shiloh Dean;	The Effects of Juvenile Exposure to Sub-lethal Concentrations of Pesticides on the Adult Reproductive Biology of the Male Southern House Mosquitoe, Culex quinquefasciatus		2018		4	5	S-methoprene
Kakaley, Elizabeth Katharine Medlock;	Characterization of Early Events in the Activation of the Methyl Farnesoate Receptor		2016	North Carolina State University	4	5	S-methoprene
LaLone, Carlie A; Villeneuve, Daniel L; Lyons, David; Helgen, Henry W; Robinson, Serina L; Swintek, Joseph A; Saari, Travis W; Ankley, Gerald T;	Editor's highlight: sequence alignment to predict across species susceptibility (SeqAPASS): a web-based tool for addressing the challenges of cross-species extrapolation of chemical toxicity	Toxicological Sciences	2016	Oxford University Press	4	5	S-methoprene
Litchfield, Hailey; Gupta, Ramesh C; Doss, Robin B; Bland, Stephanie D; Canerdy, Terry D;	Safety evaluation of permethrin and indoxacarb in dogs topically exposed to Activyl® tick plus	Veterinary Science & Technology	2015	OMICS Publishing Group	4	5	S-methoprene
Mangia, Carlo;	Evaluation of ABCB gene expression in an Ixodes ricinus cell line exposed to acaricides		2018	Università di Parma. Dipartimento di Scienze Medico-Veterinarie	4	5	S-methoprene
Medlock Kakaley, Elizabeth Katharine;	Characterization of Early Events in the Activation of the Methyl Farnesoate Receptor.		2016		4	5	S-methoprene
Padmanabhan, Latha Nadkandi; Raghavan, Sudha Devi Arath; Ayanath, Aswani;	Impact of methoprene on oogenesis of the freshwater crab Travancoriana schirnerae Bott, 1969 (Decapoda: Gecarcinucidae)	Brazilian Journal of Biological Sciences	2017		4	5	S-methoprene
Peck, Robert; Banko, Paul; Cappadonna, Justin; Snook, Kirsten; Euaparadorn, Melody;	Distribution of invasive ants and methods for their control in Hawaii Volcanoes National Park.		2016		4	5	S-methoprene
Ramsey, Ian;	BSAVA Small Animal				4	5	S-methoprene
Sakka, Maria K; Riga, Maria; Ioannidis, Panagiotis; Baliota, Georgia V; Tselika, Martha; Jagadeesan, Rajeswaran; Nayak, Manoj K; Vontas, John; Athanassiou, Christos G;	Transcriptomic analysis of s-methoprene resistance in the lesser grain borer, Rhyzopertha dominica, and evaluation of piperonyl butoxide as a resistance breaker	BMC genomics	2021	Springer	4	5	S-methoprene
Sharma, Charu; Sadek, Bassem; Goyal, Sameer N; Sinha, Satyesh; Kamal, Mohammad Amjad; Ojha, Shreesh;	Small molecules from nature targeting G-protein coupled cannabinoid receptors: potential leads for drug discovery and development	Evidence-Based Complementary and Alternative Medicine	2015	Hindawi	4	5	S-methoprene
Shearer, David; Welle, Monika; Whitbread, Trevor;	Panel Discussion: Biopsies And Allergies-Is It Worth To Punch The Itch?	A message from the President			4	5	S-methoprene
Silva, Ana R; Grosso, Clara; Delerue-Matos, Cristina; Rocha, Joao M;	Comprehensive review on the interaction between natural compounds and brain receptors: Benefits and toxicity	European journal of medicinal chemistry	2019	Elsevier	4	5	S-methoprene
Thompson, Sarah J; Pearce, John M; Ramey, Andrew M;	Vectors, hosts, and control measures for Zika virus in the Americas	EcoHealth	2017	Springer	4	5	S-methoprene
Webb, Cameron; Doggett, Stephen; Russell, Richard;	A guide to mosquitoes of Australia		2016	Csiro Publishing	4	5	S-methoprene

Authors	Title	Publication	Year	Publisher	Clasification	Question	Product
Bordalo, Maria D; Machado, Ana L; Campos, Diana; Coelho, Sónia D; Rodrigues, Andreia CM; Lopes, Isabel; Pestana, João LT;	Responses of benthic macroinvertebrate communities to a Bti-based insecticide in artificial microcosm streams	Environmental Pollution	2021	Elsevier	1	6	Bti
Tonjes, David J; McElroy, Anne E; Barnes-Pohjonen, Robin K; Ninivaggi, Dominick V; Dawydiak, Walter; Greene, Gregory T; Brownawell, Bruce J;	Fate of methoprene in temperate salt marsh ditches following aerial applications	Science of the total environment	2018	Elsevier	1	6	Bti
Dara, Surendra K; Goble, Tarryn A; Shapiro-Ilan, David I;	Leveraging the ecology of invertebrate pathogens in microbial control	Ecology of invertebrate diseases	2018	John Wiley & Sons	2	6	Bti
Lawler, Sharon P;	Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control	Ecotoxicology and environmental safety	2017	Elsevier	2	6	Bti
Maletz, Sibylle; Wollenweber, Marc; Kubiak, Katharina; Müller, Annett; Schmitz, Stefan; Maier, Dieter; Hecker, Markus; Hollert, Henner;	Investigation of potential endocrine disrupting effects of mosquito larvicidal Bacillus thuringiensis israelensis (Bti) formulations	Science of the Total Environment	2015	Elsevier	2	6	Bti
Pignotti, Emanuela;	Contaminants of Emerging Concern: occurrence and distribution in aquatic environments		2018	alma	2	6	Bti
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	4	6	Bti
Babu, Maya;	Field Testing the Attractancy and Toxicity of the Pro-Fragrance Compound, Okoumal, to Gravid Aedes Mosquitoes and Their Offspring Larvae		2020		4	6	Bti
Bacci, L; Lupi, D; Savoldelli, S; Rossaro, B;	A review of Spinosyns, a derivative of biological acting substances as a class of insecticides with a broad range of action against many insect pests		2016	Pagepress	4	6	Bti
Chong, Irene Yan Ling;	The characterization of isolated Bacillus Thuringiensis from blocks B, C, I and engineering workshop of Universiti Tunku Abdul Rahman, Kampar campus		2017	UTAR	4	6	Bti
Cifelli, Alyssa Nicole;	Horizontal and Vertical Transmission of a Pantoea Sp. in Culex Sp.		2015		4	6	Bti
Coelho, Sónia Dias;	Human exposure pathways to environmental contaminants		2016	Universidade de Aveiro (Portugal)	4	6	Bti
Gonnabathula, Pavani Kumari;	Assessment of Emerging Contaminants–Multiple Pesticides and Hormonal Compounds in Water: Effects on Biomolecules and Application of Green Nanotechnology for Remediation		2020	Texas Southern University	4	6	Bti
Gross, Elisabeth; Garric, Jeanne;	Ecotoxicology: New Challenges and New Approaches		2019	Elsevier	4	6	Bti
Laurance, Robin;	Coconut: How the Shy Fruit Shaped our World		2019	The History Press	4	6	Bti
Maramorosch, Karl;	Biotechnology for Biological Control of				4	6	Bti
Ntalli, Nikoletta; Koliopoulos, George; Giatropoulos, Athanasios; Menkissoglu-Spiroudi, Urania;	Plant secondary metabolites against arthropods of medical importance	Phytochemistry Reviews	2019	Springer	4	6	Bti
Nuamah, Linda A; Li, Yiping; Pu, Yashuai; Nwankwegu, Amechi S; Haikuo, Zhang; Norgbey, Eyram; Banahene, Patrick; Bofah-Buoh, Robert;	Constructed wetlands, status, progress, and challenges. The need for critical operational reassessment for a cleaner productive ecosystem	Journal of Cleaner Production	2020	Elsevier	4	6	Bti
Ogunah, Joanne Atieno; Lalah, Joseph O; Schramm, Karl-Werner;	Malaria vector control strategies. What is appropriate towards sustainable global eradication?	Sustainable Chemistry and Pharmacy	2020	Elsevier	4	6	Bti
Regnault-Roger, Catherine;	Trends for Commercialization of Biocontrol Agents (Biopesticide)	Plant Defence: Biological Control	2020	Springer	4	6	Bti
Sachdev, Swati; Singh, Rana Pratap;	Current challenges, constraints and future strategies for development of successful market for biopesticides	Clim Change Environ Sustain	2016		4	6	Bti
Salihu, Lukman; Adedayo, Adekunbi E; Olalekan, Babajide Jelili; Afolabi, Asani M; Mohammed, Idi Dansuleiman; Oke, Isaiah Adesola; Adewale, Obijole O;	Evaluation of Selected Reaeration Models for Water Quality Management	Effects of Emerging Chemical Contaminants on Water Resources and Environmental Health	2020	IGI Global	4	6	Bti
Stone Lakes, NWR;	Compatibility Determination for Mosquito Control on the Stone Lakes National Wildlife Refuge				4	6	Bti
Suresh, M; Jeevanandam, Jaison; San Chan, Yen; Danquah, Michael K; Kalaiarasi, JMV;	Opportunities for Metal Oxide Nanoparticles as a Potential Mosquitocide	BioNanoScience	2019	Springer	4	6	Bti
Thompson, Sarah J; Pearce, John M; Ramey, Andrew M;	Vectors, hosts, and control measures for Zika virus in the Americas	EcoHealth	2017	Springer	4	6	Bti
Van Tol, S; Dimopoulos, George;	Influences of the mosquito microbiota on vector competence	Advances in insect physiology	2016	Elsevier	4	6	Bti
Varani, Alessandro; He, Susu; Siguier, Patricia; Ross, Karen; Chandler, Michael;	The IS 6 family, a clinically important group of insertion sequences including IS 26	Mobile DNA	2021	Springer	4	6	Bti
Vincent, Kim; Abbott, Tyler; Team, Wyoming Toad Recovery;	Revised Recovery Plan 2015		2015		4	6	Bti

Wani, Javaid Ahmad; Wali, Adil Farooq; Majid, Sabhiya; Rasool, Saiema; Rehman, Muneeb U; Rashid, Shahzada Mudasir; Ali, Shafat; Farooq, Sanah; Rasool, Shabhat; Ahmad, Ajaz;	Bio-Pesticides: Application and Possible Mechanism of Action	Bioremediation and Biotechnology, Vol 2	2020	Springer	4	6	Bti
Yadav, Kamlesh Kumar; Chandel, Kshitij; Bhagyawant, Sameer S; Veer, Vijay;	14 Midgut Bacterial Microbiota of Important Mosquito Disease Vectors and Its Role in Control of Parasite Transmission	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	6	Bti
Yadav, Kamlesh Kumar; Chandel, Kshitij; Bhagyawant, Sameer S; Veer, Vijay;	14 Midgut Bacterial	Microbial Control of Vector-Borne Diseases	2018	CRC Press	4	6	Bti
Lemieux, Valérie;	EXPOSITION DE L'HIRONDELLE BICOLORE (TACHYCINETA BICOLOR) AUX PESTICIDES AGRICOLES DANS LE SUD DU QUÉBEC				5	6	Bti
Van Tuat NGUYEN, VAAS;	DEVENIR DES TOXINES Cry DE BACILLUS THURINGIENSIS DANS LE SOL		2015	Huazhong Agricultural University	5	6	Bti
André, L de A;	THE DEVELOPMENT BEHIND THE MULTI-PURPOSE MICROORGANISM	BACILLUS THURINGIENSIS			1 and 2	6	Bti
Bruehl, Carsten A; Despres, Laurence; Frör, Oliver; Patil, Chandrashekhar D; Poulin, Brigitte; Tetreau, Guillaume; Allgeier, Stefanie;	Environmental and socioeconomic effects of mosquito control in Europe using the biocide Bacillus thuringiensis subsp. israelensis (Bti)	Science of the Total Environment	2020	Elsevier	1 and 2	6	Bti
Sánchez-Bayo, Francisco;	Current-use Pesticides	Bioremediation of Agricultural Soils	2019	CRC Press	2	6	S-methoprene
Arora, Sumitra;	Pesticide Risk Assessment		2019	CABI	4	6	S-methoprene
Bassett, Mary T;	Technical Memorandum CEQR No. 00DOH002Y New York City Comprehensive Mosquito Surveillance and Control		2017		4	6	S-methoprene
Butcherine, Peter; Benkendorff, Kirsten; Kelaher, Brendan; Barkla, Bronwyn J;	The risk of neonicotinoid exposure to shrimp aquaculture	Chemosphere	2019	Elsevier	4	6	S-methoprene
da Cunha, Virgínia Filipa Pereira Monteiro;	Chemosensitisation assessment of emergent and organic pollutants using zebrafish (Danio rerio) embryo tests		2016		4	6	S-methoprene
Tudi, Muyesaier; Daniel Ruan, Huada; Wang, Li; Lyu, Jia; Sadler, Ross; Connell, Des; Chu, Cordia; Phung, Dung Tri;	Agriculture Development, Pesticide Application and Its Impact on the Environment	International Journal of Environmental Research and Public Health	2021	Multidisciplinary Digital Publishing Institute	4	6	S-methoprene

Classification	Definition
1	Relevant and key term provided
2	Relevant but key term not provided
3	Relevant for another question
4	Not relevant
5	Not accessible (e.g. not in English)

Appendix C

Question 2 – sources and outcomes

Table C1 Grey literature summary

Database source / request type	Title - reference	Summary of key points	Eligibility
DAWE – Referrals list	2016 - City of Busselton/Water Management and Use/Layman Road, Busselton, WA/Western Australia/Aerial application of mosquito larvicides to Vasse Wonnerup Wetlands, WA – 2016/7780	Aerial application of mosquito larvicides (S-methoprene and Bacillus thuringienses var isaaelensis) to the Vasse-Wonnerup Ramsar site. Small area (approx. 740 ha) and short duration (3 year program) with a maximum of 4 applications per year. Decision – action is not a controlled action. As described in the referral including further information. Relevant MNES – Wetland of international importance and, and listed migratory species The referral application acknowledged and applied measures from previous referral process. The referral provides detail regarding the project area, project description and nature of impacts on MNES. It is supported by at least four studies of wetland bird observations during helicopter activity and seven studies of the potential of larvicide application to aquatic invertebrate prey species (Paice 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016). The referral also refers to current literature at the time regarding the effects of using the larvicide on aquatic invertebrates from other countries. Key documents include in the literature review: Paice, R (2016) Assessment of mosquito larvicide impacts on aquatic invertebrates in the Vasse-Wonnerup Wetland System 2009 – 2015. Report to the City of Busselton. Paice, R (2009-2016) Impact of aerial larvicide for mosquito control on aquatic invertebrates in the Vasse-Wonnerup Wetland System: results of sampling. Report to the City of Busselton. Lagadic, L. et al. (2016) 'No association between the use of Bti for mosquito control and the dynamics of non-target aquatic invertebrates in French coastal and continental wetlands', Science of the Total Environment, 553, pp. 486–494. Marina CF, JG Bond, J Muñoz, J Valle, R Novelo-Gutiérrez and T Williams (2014) Efficacy and non-target impact of spinosad, Bti and temephos larvicides for control of Anopheles spp. in an endemic malaria region of southern Mexico. Parasites & Vectors 2014, 7:55. Butler M, HS Ginsberg, RA LeBrun, and A Gettman (2010) Evaluation of nontarget effects of methoprene applied to catch basins for mosquito control. Journal of Vector Ecology 35 (2): 372-384.	1 and 2
	2006 - Shire of Capel/Tourism, recreation and conservation management/Capel/WA/larviciding of potential mosquito breeding wetlands – 2006/2601	Undertake mosquito larviciding within Forrest Beach/ Peppermint Grove wetlands, Shire of Capel, WA using ProLink ProSand. Small area (approx. 300 ha) and short duration period (3 years) with a maximum of 4 applications per year. The referral provides detail regarding the project area, project description and nature of impacts on MNES. Decision – action is not a controlled action. As described in the referral including further information. The referral was supported by a study of wetland bird observations during helicopter activity, however no studies undertaken linking direct or indirect impacts of larvicide products to MNES or general terms. Although reviewed this information was not included in the literature review.	2
	2005 - Shire of Busselton/Agriculture and forestry/Busselton/WA/Aerial Mosquito Spraying Vasse-Wonnerup System – 2005/1952	Application of synthetic hormone (S-methoprene) to mosquito breeding sites in the Vasse-Wonnerup Ramsar site. Small area (approx. 740 ha) and short duration (3 year program) with a maximum of 4 applications per year. Relevant MNES – Wetland of international importance and, and listed migratory species Decision – action is not a controlled action provided it is undertaken in a particular manner. A list of 7 conditions determine the manner in which the action is to be undertaken The referral was supported by a study of wetland bird observations during helicopter activity, however no studies undertaken linking direct or indirect impacts of larvicide products to MNES or general terms.	2 and 3

Database source / request type	Title - reference	Summary of key points	Eligibility
	2001 - East Gippsland Shire/Agriculture and Forestry/East Gippsland/Victoria/Gippsland Lakes Mosquito Control Aerial /Hovercraft Spraying – 2001/491	Referral application withdrawn, therefore no additional information available.	4
Google search - Search term combinations for mosquito control programs in local government areas across Australia	List of local government websites reviewed for information Victorian – Surfcoast shire, Wellington shire, Campaspe shire, Bellarine Shire, Gannawarra shire, Mornington Peninsula, Moira shire, Moyne shire, Greater Shepparton City Council, Mildura Rural City Council, City of Casey, Swan Hill Rural City Council, QLD- Noosa shire, Flinders shire, Banana shire, Burdekin shire, Exmouth shire, Balonne shire, Hinchinbrook shire, Moreton Bay shire WA - Shire of Harvey, Shire of Dardanup, Shire of Broome, Shire of Dandaragan, Shire of York, Shire of Waroona, Shire of Ashburton, Shire of Kalamunda, Shire of Capel, Shire of Busselton, Shire of Westonia, Shire of Katanning, Shire of Yalgoo, City of Mandurah, Shire of Mingenew, Shire of Augusta/Margaret River, City of Joondalup, City of Rockingham, City of Swan, City of Karratha NSW- Byron shire, Sydney Olympic Park Authority, Albury City SA – Murray Bridge Council, Berri Barmera Council	Council websites were searched for the following: – Mosquito control program/strategy report – Types of products used and application rates – Impacts of products used, indirect/direct effects on MNES or other ecological values including invertebrates, birds, reptiles, mammals, amphibians Summary of results: All organisation websites provided details regarding the mosquito control activities, public awareness and mosquito prevention guidance. Most organisation websites provided a document detailing a current or historical mosquito control program/strategy however none contained any detail regarding the potential impacts/effects of the use of the products on the receiving environment. No organisation mentioned/discussed indirect / direct effects of product use to an MNES Two organisations (Byron Shire and Sydney Olympic Park Authority) discussed potential environmental impacts of product use to ecological values, however the information provided was very broad. No supporting information/ documentation was provided.	4
GHD requested information from the City (18/2/2021)	One document - NSW Health, 2019 *New approaches to managing mosquitoes and mosquito-borne disease; building on the current mosquito management strategies of City of Greater Geelong, Borough of Queenscliffe, and surf Coast shire, Victoria*. A Report Prepared for the City of Greater Geelong, Geelong Victoria	Relevant extract p 58 – NSW Health noted that the need to be aware of potential direct and indirect non-target and ecological impacts of mosquito control activities in environmentally sensitive coastal wetlands requires consideration of many aspects of the local environment. A recent review of the scientific literature associated with non-target invertebrates in the local region (GHD 2017) concluded that the mosquito control products used in the area do not have a significant impact on the non-target invertebrates within the local habitats. These invertebrates may represent an important food source for threatened avian species (e.g. migratory birds) present in the local area. In addition, a further report, combined with field observations, investigated the potential impact of the aerial mosquito control activities on bird behaviour in the Swan Bay and Conneware RAMSAR sites during the 207-2018 mosquito control program (GHD 2019). With these assessments, together with previous monitoring seasons of bird activity, there is no evidence that the existing mosquito control program is directly or indirectly adversely impacting the local ecosystem based on current scientific knowledge. The evidence from the City of Greater Geelong program supports conclusions from elsewhere in Australia where no significant direct or indirect non-target impacts have been reported to any aspect of coastal wetland ecosystems. Given that many regions of Australia where estuarine mosquitoes (including Aedes vigilax, a mosquito that shares a similar ecological niche to Aedes camptorhychus but is found in coastal wetlands of Australia north of the Victoria/NSW boarder) are the focus of pest and public health concerns, mosquito control is required in habitats shared with wildlife, including migratory shorebirds. On such location where mosquito management and migratory shorebird conservation is balanced is at Sydney	1

Database source / request type	Title - reference	Summary of key points	Eligibility
		Olympic Park, NSW. A mosquito control program in this area has been undertaken for over 20 years and includes aerial (via helicopter) and ground based applications of Bacillus thuringiensis israelensis to the mangroves and saltmarsh (an Endangered Ecological Community under the NSW Biodiversity Conservation Act 2016). This site is routinely surveyed for bird activity and there have been no reports of local or migratory birds significantly impacted by the use of a helicopter across the site undertaking mosquito control. The City submitted an information request to the lead author Associate Professor Cameron Webb (NSW Health) and to the Sydney Olympic Park Authority (SOPA) (20/09/2021) for supporting background documents, particularly regarding the migratory bird surveys. Associate Professor Webb and the SOPA responded stating that a formal assessment of the potential impacts from the application of larvicide on migratory shorebirds has not been completed, rather an informal assessment noting that no obvious declines in migratory bird numbers were noted for the period of the bird monitoring.	
Google search Search term combinations for literature review - S-methoprene OR bacillus thuringiensis israelensis	Articles considered in the literature review: Allgeier, S. (2019) Mosquito control based on Bacillus thuringiensis israelensis (Bti) - Ecological effects on wetland food chains and public acceptance of control alternatives. Accepted dissertation thesis for the partial fulfillment of the requirements for a Doctor of Natural Sciences Faculty 7: Natural and environmental sciences, University of Koblenz-Landau – Germany. Land, M., Miljand, M., (2014): Biological control of mosquitoes using Bacillus thuringiensis israelensis: a pilot study of effects on target organisms, non-target organisms and humans. Mistra EviEM Pilot Study PS4 (www.eviem.se) Glare,T. & O'Callaghan, M. (2005). A Review and Update of the Report "Environmental and health impacts of the insect juvenile hormone analogue, S-methoprene" 1999. Report for New Zealand Ministry of Health. Russell T, L (2006). Biologically-based insecticides for mosquito control and environmental conservation in south-east Queensland. PhD Thesis, School of Population Health / School of Integrative Biology, The University of Queensland. Available at: https://espace.library.uq.edu.au/data/UQ. Staples, K. (2016). Evaluation of a mosquito control intervention and recommendations for development of best practice protocols by the Shire of Kalamunda. https://ro.ecu.edu.au/theses/1800	16 articles of which 5 are considered relevant however none contained reference to MNES. A summary of the relevant articles is provided below: Allgeier 2019 – Rhine Valley, Germany. This thesis aims at investigating direct and indirect effects of Bti-based mosquito control on non-target organisms within wetland food chains. Effects were examined in studies with increasing eco (toxico) logical complexity, ranging from laboratory over microcosm to field approaches with a focus on the non-biting Chironomidae and amphibian larvae (Rana temporaria, Lissotriton sp.). In addition, public acceptance of environmentally less invasive alternative mosquito control methods was evaluated within surveys among the local population. Chironomids were the most severely affected non-target aquatic invertebrates. Bti substantially reduced larval and adult chironomid abundances and modified their species composition. Repeated exposures to commonly used Bti formulations induced sublethal alterations of enzymatic biomarkers activity in frog tadpoles. Bti-induced reductions of chironomid prey availability indirectly decreased body size of newts at metamorphosis and increased predation on newt larvae in microcosm experiments. Indirect effects of severe reductions in midge biomass might equally be passed through aquatic but also terrestrial food chains influencing predators of higher trophic levels. As Bti-based mosquito control can adversely affect wetland ecosystems, its large-scale applications, including nature conservation areas, should be considered more carefully to avoid harmful consequences for the environment at the Upper Rhine Valley. This thesis emphasizes the importance to reconsider the current practice of mosquito control and encourage research on alternative mosquito control concepts that are endorsed by the local population. In the context of the ongoing amphibian and insect declines further human induced effects on wetlands should be avoided to preserve biodiversity in functioning ecosystems. Land et al 2014 - The Swedish Environmental Protection Agency evaluated various effects of using VectoBac G to control the abundance of mosquitoes in flooded areas. VectoBac G is a granular formulation of the bacterium Bacillus thuringiensis subsp. israelensis (Bti). The efficacy of Bti treatment on target organisms has been thoroughly studied and shown to be very high. Direct effects on non-target species have been studied quite extensively, and the largest non-target group susceptible to Bti is chironomids. Due to its mode of action, Bti is considered to be safe for fish, birds and mammals, including livestock and pets. Despite a fairly large number of studies, no occurrence of resistance to Bti in the field has been reported. Effects on eutrophication of water bodies and indirect effects on non-target species related to changes in the food web have rarely been studied. Nuisance-related effects of the presence of mosquitoes on human well-being, recreational activities, tourism and home prices are poorly studied too. There are a fairly large number of studies on the effectiveness of Bti treatment in terms of mosquito abundance, although the results have varied. It may thus be feasible to conduct a systematic review in that area. The same is probably true also for the persistence of Bti in the environment.	1 and 2

Database source / request type	Title - reference	Summary of key points	Eligibility
		With the exception of certain species within the suborder Nematocera, non-target organisms are not susceptible to Bti (Lacey, 2007) because they generally do not possess (i) the alkaline gut needed to dissolve the crystals, (ii) the enzymes needed to activate the protoxines, and (iii) the cell membrane receptors needed for binding the toxins. However, there may be indirect effects related to changes in the food web, although rather few studies have investigated them. Changes in insect density and richness have been observed in wetlands in Minnesota, USA (Hershey et al., 1998; Niemi et al., 1999), although no differences between treated and untreated areas were observed in later studies of the same wetlands (Balcer et al., 1999). Effects on insectivorous birds through multitrophic interactions have been reported from the Camargue area in France, where clutch size and fledging success of house martins (Delichon urbicum) were significantly smaller at treated sites relative to control sites (Poulin, 2012; Poulin et al., 2010). Other studies, where black flies were the main target, have failed to indicate any indirect effects on non-target species (Boisvert and Boisvert, 2000; Jackson et al., 2002), but no long-term studies are available. Glare et al 2005 - A report was developed by Glare and O'Callaghan (1999) for the Ministry of Health on the environmental and health impacts associated with the use of S-methoprene for control and eradication of mosquitoes in New Zealand. This report along with a companion report on Bacillus thuringiensis israelensis (Glare and O'Callaghan 1998), were developed because of recent introductions of non-indigenous mosquito species that can serve as vectors for disease in humans. These pesticides were not registered for use as mosquito control agents in New Zealand and were thought at the time to be the best choices for control and/or eradication programmes in the country. Both assessments were extremely well-done and covered the known literature of the time. The general conclusions of this report were, although methoprene is toxic to 12 orders of insects and may have effects on other nontarget organisms, particularly other nontarget arthropods, methoprene is one of the least environmentally damaging mosquito control agents and poses little risk to human and animal health. In fact, the concentrations of methoprene necessary to control mosquites (1 part per billion) are often much lower than the concentrations necessary to cause damage to populations of many nontarget organisms. Methoprene has a short half-life in the environment making it unlikely to accumulate in various environmental compartments. Although new literature has been published showing declines in insect biomass due to long-term use of methoprene and Bti in freshwater wetlands in Minnosota, USA, no evidence for permanent damage to ecosystem function has been found. Additionally, a concern discussed in the original assessment was the possibility that methoprene may be the cause of limb malformations being detected in frogs in the USA. Even though it has been six years since the last assessment, the causal agent(s) of frog deformities in the USA has still not been clearly elucidated. Some scientists believe that these deformities are caused primarily by a parasitic trematode, not methoprene. Others believe that a combination of several factors, such as trematodes, UV radiation and chemicals may be working synergistically to cause the observed malformations. It is my opinion that the conclusions reached by Glare and O'Callaghan in 1999 are still valid today and I would recommend that methoprene be the first choice for control and eradication of introduced mosquito species in New Zealand. The justification for this recommendation is that the alternative control agents, other than Bacillus sphaericus and Bti are organophorous insecticides like temephos that are very broad-spectrum neurotoxins that pose a much more serious risk to the environment, human and animal health than methoprene. New pesticides, such as spinosad (a natural product) and fipronil (a synthetic neurotoxin) have shown promise as controls for mosquitoes, but the potential impacts of these products on human health and nontarget organisms is not presently known because they haven't been used in wide-scale mosquito control/eradication programmes to date. Russell 2016 - The results of this thesis found that Bti can be used to effectively control mosquito immatures under different field conditions. Applications of Bti and S-methoprene did not decrease the diversity or abundance of non-target arthropods in south-east Queensland. As such, future applications of Bti and S-methoprene are supported in preference to organophosphate alternatives; this is based on a	

Database source / request type	Title - reference	Summary of key points	Eligibility
		comparison with previously published literature that has demonstrated organophosphate insecticides to be directly toxic to non-target arthropods. Considering that the appropriate use of Bti and S-methoprene can reduce the incidence of arbovirus transmission among the local human population, the future application of these products is supported. The use of insecticides should be integrated with public education, biological control, physical habitat modification and early detection systems. Staples 2016 – The theses assessed the mosquito control program implemented by the Shire of Kalamunda Environmental Health Service. Mosquito species and abundance has been evaluated along with an assessment on the current level of pesticide resistance and downstream S-methoprene levels post-treatment. The rate of Ross River virus transmission within the Shire has also been considered, along with the relationship between local species and virus transmission. Application of S‐methoprene has been encouraged to protect of public health; however, there is an increasing level of community concern about the use of any chemical or pesticide by local and state authorities, and an increasing expectation that any possible impacts on the environment have been assessed. S‐methoprene can have negative impacts on other insect larvae, amphibians, crustaceans and fish (Kuo et al., 2010). Local area studies are required as the effectiveness of S‐methoprene is influenced by local environmental factors such as; sediment components, water volume and depth, temperature, exposure to ultraviolet light, microbial degradation, frequency of gully cleaning programs, and target species (Baker and Yan, 2011; Butler, Lebrun, Ginsberg & Gettman, 2006). S‐methoprene is not released from briquets at a consistent rate, so multiple samples should be taken. Sampling directly for its presence can also be difficult. Rainfall can cause re‐suspension of S‐methoprene, and concentrations are higher in upper layers unless mixing occurs (Des Lauriers et al., 2006). Sampling for effects of non‐target organisms may be a useful indicator, but is outside of the scope of this study.	

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Appendix G

Likelihood of occurrence assessment

Appendix G Table notes

Species listing status

EPBC Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

FFG Victorian *Flora and Fauna Guarantee Act 1988*

Records sourced from DELWP Victorian Biodiversity Atlas (VBA 2021) and Commonwealth Atlas of Living Australia (ALA, 2021) - number of records within 10 km of the proposed action area from the VBA database. For species that have been listed as threatened under the EPBC Act since the original referral variation (2020), information was sourced from the VBA (VBA 2024). *Count of records* = represents the number of dates that a species was observed. *Number of records/ date range* = total number of individuals recorded for that species regardless of location or date within the date range (oldest – most recent record). Note: Absence of records indicates species is predicted by PMST only.

Most recent All dates are representative of the most recent record of that species within 10 km of the proposed action area from the VBA database.

Status of species under EPBC Act and FFG Act

CR/cr Critically Endangered

EN/en Endangered

VU/vu Vulnerable

Species group (birds)

Migratory species (terrestrial, marine, wetland) - All species on the list of migratory species are matters of national environmental significance under the EPBC Act. Listed migratory species include any native species identified in an international (CAMBA, JAMBA, ROKAMBA) or national agreement approved by the Minister.

Shorebird - There are 37 shorebird species protected as MNES (listed migratory species) under the EPBC Act that migrate to and from Australia each year (DoE, 2015). Sixteen of the 37 species are also listed as vulnerable, endangered or critically endangered under the EPBC Act. Migratory shorebirds are birds that inhabit the shorelines of coasts and inland water bodies during most of their life cycles. The majority of these birds are from two taxonomic families, the Sandpipers (Scolopacidae) and the Plovers (Charadriidae) (DotE, 2015).

Likelihood of occurrence

The likelihood of occurrence within the proposed action area was evaluated for each species using the information from the literature review and online databases to inform the following rationale:

PRESENT – Species known to occur within or in close proximity to the treatment sites based on findings from the literature review and database search.

POSSIBLE – Potentially suitable habitat occurs within a treatment site(s) and species' known range encompasses the proposed action area. Species recorded historically within 10 km of the proposed action area, and generally within the last 10 years.

UNLIKELY – Species' known range encompasses the proposed action area, but suitable habitat does not occur within treatment sites, or occurs within proposed action area but may be marginal (e.g. very small extent) or of low quality. Species recorded historically within 10 km of the proposed action area, but generally not within the last 10 years.

HIGHLY UNLIKELY – No historical records of the species within 10 km of the proposed action area and/or no suitable habitat within proposed action area.

References

Department of the Environment (DotE) (2015) EPBC Act Policy Statement 3.21—Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species, Commonwealth of Australia 2015'

Table G1 Likelihood of occurrence – EPBC Act listed threatened flora species

Scientific Name	Common Name	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in action area	Assessment of significance required
Amphibromus fluitans	*River Swamp Wallaby-grass*	VU	-	-	-	Possible	No –habitat removal or modification will not occur
Caladenia pumila	*Dwarf Spider-orchid*	VU	cr	4	4, 1916-2012	Unlikely	No –habitat removal or modification will not occur
Dianella amoena	*Matted Flax-lily*	EN	cr	1	1, 2012	Unlikely	No –habitat removal or modification will not occur
Diuris basaltica	*Small Golden Moths Orchid*	EN	cr	-	-	Unlikely	No –habitat removal or modification will not occur
Dodonaea procumbens	*Trailing Hop-bush*	VU	-	-	-	Unlikely	No –habitat removal or modification will not occur
Glycine latrobeana	*Clover Glycine*	VU	vu	-	-	Unlikely	No –habitat removal or modification will not occur
Ixodia achillaeoides subsp. arenicola	*Sand Ixodia*	VU	-	1	1, 1926	Possible	No –habitat removal or modification will not occur
Lachnagrostis adamsonii	*Adamson's Blown-grass*	EN	en	-	2626, 1995-2002	Possible	No –habitat removal or modification will not occur
Lepidium aschersonii	*Spiny Pepper-cress*	VU	en	6	20, 1996-2019	Possible	No –habitat removal or modification will not occur
Lepidium hyssopifolium	*Basalt Pepper-cress*	EN	-	-	-	Unlikely	No –habitat removal or modification will not occur
Leucochrysum albicans var. tricolor	*Hoary Sunray*	EN	en	-	-	Unlikely	No –habitat removal or modification will not occur
Pimelea spinescens subsp. spinescens	*Plains Rice-flower*	CR	cr	5	1, 1984-2013	Possible	No –habitat removal or modification will not occur
Prasophyllum frenchii	*Maroon Leek-orchid*	EN	en	1	1, 1930	Possible	No –habitat removal or modification will not occur
Prasophyllum spicatum	*Dense Leek-orchid*	VU	cr	-	-	Unlikely	No –habitat removal or modification will not occur
Pterostylis chlorogramma	*Green-striped Greenhood*	VU	en	6	17, 1991-2013	Possible	No –habitat removal or modification will not occur

Scientific Name	Common Name	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in action area	Assessment of significance required
Pterostylis cucullata	*Leafy Greenhood*	VU	-	2	2, 1894-2004	Possible	No –habitat removal or modification will not occur
Rutidosis leptorrhynchoides	*Button Wrinklewort*	EN	en	8	15, 1921-2010	Possible	No –habitat removal or modification will not occur
Senecio macrocarpus	*Large-fruit Fireweed*	VU	cr	27	546, 1853-2016	Possible	No –habitat removal or modification will not occur
Senecio psilocarpus	*Swamp Fireweed*	VU	-	-	-	Unlikely	No –habitat removal or modification will not occur
Thelymitra epipactoides	*Metallic Sun-orchid*	EN	en	2	2, 1897-1923	Possible	No –habitat removal or modification will not occur
Thelymitra matthewsii	*Spiral Sun-orchid*	VU	en	-	-	Unlikely	No –habitat removal or modification will not occur
Xerochrysum palustre	*Swamp Everlasting*	VU	cr	1	1, 1995	Present – located adjacent treatment site but not within a treatment site	No –habitat removal or modification will not occur

Table G2 Likelihood of occurrence EPBC Act listed threatened and migratory species

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
MAMMALS								
Grey-headed Flying-fox	*Pteropus poliocephalus*	Terrestrial mammal	VU	vu	34	849, 1884-2019	Present (species is known from Eastern Park /Botanical Gardens roost area and is regularly observed foraging across the proposed action area)	No – Known and potential habitat for this species will not be removed or modified. This species is primarily nocturnal (active during the night) and is therefore unlikely to occur at aerial treatment sites or move through the proposed action area during daytime treatments.
Long-nosed Potoroo	*Potorous tridactylus*	Terrestrial mammal	VU	-	0	0	Highly unlikely	No – Highly unlikely to occur. Potential habitat for this species will not be removed or modified
Spot-tailed Quoll	*Dasyurus maculatus maculatus*	Terrestrial mammal	EN	en	0	0	Highly unlikely	No – Highly unlikely to occur. Potential habitat for this species will not be removed or modified
Swamp Antechinus	*Antechinus minimus maritimus*	Terrestrial mammal	VU	-	1	2, 1982	Unlikely	No – Unlikely to occur. Potential habitat for this species will not be removed or modified
Southern Brown Bandicoot	*Isoodon obesulus obesulus*	Terrestrial mammal	EN	-	12	12, 1961-1981	Possible (recent anecdotal records exist in the proposed action area)	No – Known and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Yellow-bellied Glider (south-eastern)	*Petaurus australis australis*	Terrestrial mammal	VU	en	0	0	Highly unlikely	No – No records of this forest species occur on the Bellarine Peninsula. The project will not affect potentially suitable eucalypt forest habitat.
BIRDS								
Australasian Bittern	*Botaurus poiciloptilus*	Terrestrial bird	EN	en	90 (vba only)	120, 1901-2020	Present	Yes –refer section 4
Australian Painted Snipe	*Rostratula australis*	Marine and terrestrial bird	EN	cr	10	15, 1860-2013	Possible	Yes –refer section 4

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Australian Fairy Tern	*Sternula nereis nereis*	Marine bird	VU	en	1073	11393, 1800-2020	Present	Yes –refer section 4
Antipodean Albatross	*Diomedea antipodensis*	Migratory marine bird	VU	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Bar-tailed Godwit (Western Alaskan)	*Limosa lapponica bauera*	Migratory wetland bird//shorebird	EN, Mi	-	5	5, 1988-2002	Present	Yes –refer section 4
Black-browed Albatross	*Thalassarche melanophris*	Migratory marine bird	VU	vu	320	801, 1919-2020	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Black-tailed Godwit	*Limosa limosa*	Migratory wetland bird/shorebird	EN, Mi	cr	29	105, 2000-2019	Present	Yes –refer section 4
Blue Petrel	*Halobaena caerulea*	Marine bird	VU	-	6	8, 1980-2014	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Blue-winged Parrot	*Neophema chrysostoma*	Terrestrial bird	VU	-	137	2594, 1994 - 2016	Present	Yes –refer section 4
Brown Treecreeper (south-eastern)	*Climacteris picumnus victoriae*	Terrestrial bird	VU	-	3	3, 1896 - 1951	Unlikely	No – Species habitat will not be removed or modified. Species dependent on woodland habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Buller's Albatross	*Thalassarche bulleri*	Migratory marine bird	VU	en	2	2, 2012	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Campbell Albatross	*Thalassarche impavida*	Migratory marine bird	VU	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Common Greenshank	*Tringa nebularia*	Migratory wetland bird/shorebird	EN, Mi	en	246	2477, 1959-2019	Present	Yes –refer section 4
Curlew Sandpiper	*Calidris ferruginea*	Migratory wetland bird/shorebird	CR, Mi	cr	2113	14763, 1860-2020	Present	Yes –refer section 4
Diamond Firetail	*Stagonopleura guttata*	Terrestrial bird	VU	vu	6	6, 1989 - 1973	Unlikely	No – Species habitat will not be removed or modified. Species favours grassy woodland habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Eastern Hooded Plover	*Thinornis cucullatus cucullattus*	Terrestrial bird/shorebird	VU	vu	798	2729, 1902-2020	Present	
Eastern Curlew	*Numenius madagascariensis*	Migratory wetland bird/shorebird	CR, Mi	cr	618	309, 1860-2020	Present	Yes –refer section 4
Fairy Prion (southern)	*Pachyptila turtur subantarctica*	Marine bird	VU	-	0	0	Unlikely	
Gang-gang Cockatoo	*Callocephalon fimbriatum*	Terrestrial bird	EN	en	40	1913, 1906 - 2021	Unlikely	No – Species habitat will not be removed or modified. Species dependent on woodland and forest habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Gould’s Petrel	*Pterodroma leucoptera leucoptera*	Migratory marine bird	EN	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Great Knot	*Calidris tenuirostris*	Migratory wetland bird/shorebird	VU, Mi	cr	294	6168, 1950-2020	Present	Yes –refer section 4
Greater Sand Plover	*Charadrius leschenaultii*	Migratory wetland bird/shorebird	VU, Mi	vu	77	70, 1963-2019	Present	Yes –refer section 4
Grey Falcon	*Falco hypoleucos*	Terrestrial bird	VU	vu	0	0	Unlikely	No – Species habitat will not be removed or modified. Species favours drier woodland habitats. It is very rare in Victoria, and therefore is highly unlikely to regularly occupy or visit habitats within the treatment sites.
Grey Plover	*Pluvialis squatarola*	Migratory wetland bird/shorebird	VU, Mi	vu	4	27, 1986-2013	Present	Yes –refer section 4
Grey-headed Albatross	*Thalassarche chrysostoma*	Migratory marine bird	EN	en	3	7, 1950-197	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Hooded Robin (south-eastern)	*Melanodryas cucullata cucullata*	Terrestrial bird	EN	vu	6	6, 1860 - 1978	Unlikely	No – Species habitat will not be removed or modified. Species dependent on woodland habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Latham's Snipe	*Gallinago hardwickii*	Migratory wetland bird	VU, Mi	-	1146	6684, 1860-2020	Present	Yes –refer section 4
Lesser Sand Plover	*Charadrius mongolus*	Migratory wetland bird/shorebird	EN. Mi	en	226	631, 1941-2017	Present	Yes –refer section 4
Northern Buller's Albatross	*Thalassarche bulleri platei*	Migratory marine bird	VU	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Northern Royal Albatross	*Diomedea sanfordi*	Migratory marine bird	EN	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Northern Giant-Petrel	*Macronectes halli*	Migratory marine bird	VU	en	32	15, 1975-2016	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Orange-bellied Parrot	*Neophema chrysogaster*	Migratory marine bird	CR	cr	20 (vba only)	6170, 1857-2008 (vba and ala)	Present	Yes –refer section 4
Plains-wanderer	*Pedionomus torquatus*	Terrestrial bird	CR	cr	1	1, 1896	Unlikely	No – Known and potential habitat for this species will not be removed or modified. It is unlikely that this species would occupy the habitats of the aerial treatment sites (e.g. wetland habitats).
Painted Honeyeater	*Grantiella picta*	Terrestrial bird	VU	vu	10	29, 1994-1995	Highly unlikely	No – Unlikely to occur. Potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Red Knot	*Calidris canutus*	Migratory wetland bird/shorebird	VU, Mi	en	608	20381, 1860-2020	Present	Yes –refer section 4
Regent Honeyeater	*Anthochaera (Xanthomyza) phrygia*	Terrestrial bird	CR	cr	4	4, 1860-2004	Highly unlikely	No – Unlikely to occur. Potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Royal Albatross	*Diomedea epomophora*	Migratory marine bird	VU	vu	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Ruddy Turnstone	*Arenaria interpres*	Migratory wetland bird/shorebird	VU, Mi	en	18	109, 1988-2017	Present	Yes –refer section 4
Sharp-tailed Sandpiper	*Calidris acuminata*	Migratory wetland bird/shorebird	VU, Mi	-	208	12161, 1961-2021	Present	Yes –refer section 4
Shy Albatross	*Thalassarche cauta*	Migratory marine bird	EN	en	429	1306, 1860-2020	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Southern Giant-Petrel	*Macronectes giganteus*	Migratory marine bird	EN	en	81	77, 1860-2012	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Soft-plumaged Petrel	*Pterodroma mollis*	Migratory marine bird	VU	-	1	1, 2018	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Salvin's Albatross	*Thalassarche salvini*	Migratory marine bird	VU		3	2, 2010-2012	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Sooty Albatross	*Phoebetria fusca*	Migratory marine bird	VU	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Sooty Shearwater	*Ardenna grisea*	Marine bird	VU, Mi	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
Southern Royal Albatross	*Diomedea epomophora*	Migratory marine bird	VU	vu	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Southern Whiteface	*Aphelocephala leucopsis*	Terrestrial bird	VU	-	4	4, 1860 - 1971	Unlikely	No – Species habitat will not be removed or modified. Species favours grassy woodland habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
Swift Parrot	*Lathamus discolor*	Migratory marine bird	CR	cr	328	2320, 1995-2020	Present	No - Known and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Terek Sandpiper	*Xenus cinereus*	Migratory wetland bird/shorebird	VU, Mi	en	2	2, 2014	Possible	Yes –refer section 4
Wandering Albatross	*Diomedea exulans*	Migratory marine bird	VU	cr	46	7, 1860-1984	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
White-capped Albatross	*Thalassarche cauta steadi*	Migratory marine bird	VU	-	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.
White-throated Needletail	*Hirundapus caudacutus*	Migratory terrestrial bird	VU, Mi	vu	272	2897, 1800-2020	Present	No - Known and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Yellow-nosed Albatross	*Thalassarche chlororhynchos*	Migratory marine bird	VU	vu	0	0	Unlikely	No – Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
REPTILES								
Victorian Grassland Earless Dragon	*Tympanocryptis pinguicolla*	Terrestrial reptile	CR	en	0	0	Highly unlikely	No – Species most likely local extinct. Potential habitat for this species will not be removed or modified. It is highly unlikely that this species would occupy the habitats of the aerial treatment sites (e.g. wetland habitats).
Striped Legless Lizard	*Delma impar*	Terrestrial reptile	VU	en	1	5 (no year)	Unlikely	No – Potential habitat for this species will not be removed or modified. It is unlikely that this species would occupy the habitats of the aerial treatment sites (e.g. wetland habitats).
Swamp Skink	*Lissolepis coventryi*	Terrestrial reptile	EN	en	2	1989	Unlikely	No – There are two VBA records of this species in the project area, both on Swan Island from 1989. This species required vegetative cover to avoid predation, and is considered unlikely to occur within the treatment area.
FROG								
Growling Grass Frog	*Litoria raniformis*	frog	VU	vu	658	3289, 1788-2020	Present (more recent anecdotal records known from Reedy Lake and Lake Connewarre areas)	Yes –refer section 4
FISH								
Australian Grayling	*Prototroctes maraena*	fish	VU	en	56	356, 1873-2013	Possible	Yes –refer section 4
Eastern Dwarf Galaxias	*Galaxiella pusilla*	fish	EN	en	0	0	Unlikely	No – Unlikely to occur and potential habitat for this species will not be removed or modified.
Yarra Pygmy Perch	*Nannoperca obscura*	fish	EN	vu	142	848, 1876-2014	Present	Yes –refer section 4

Common name	Scientific Name	Species Group	EPBC	FFG	Count of records	Number of records/ date range	Likelihood of occurrence in Proposed action area	Assessment of significance required
INSECT								
Golden Sun Moth	*Synemon plana*	insect	VU	en	0	0	Unlikely	No – Unlikely to occur and potential habitat for this species will not be removed or modified.

Table G3 Likelihood of occurrence EPBC Act listed migratory bird species (excluding species also listed as threatened)

Common name	Scientific Name	Species Group	EPBC	FFG	Count of survey	VBA records	Likelihood of occurrence in Proposed action area	Assessment of significance required
Migratory marine/ shorebirds								
Wilson's Storm-Petrel	*Oceanites oceanicus*	Migratory marine bird	Mi	-	15	10, 1860-2008	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species reliant on marine, offshore island and coastal habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Sooty Shearwater	*Puffinus griseus*	Migratory marine bird	Mi, VU	-	6	26, 1957-1980	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species reliant on marine, offshore island and coastal habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Short-tailed Shearwater	*Puffinus tenuirostris*	Migratory marine bird	Mi	-	14	14, 1951-2005	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species reliant on marine, offshore island and coastal habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Flesh-footed Shearwater	*Puffinus carneipes*	Migratory marine bird	Mi	-	0	0	Highly unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites
White-winged Black Tern	*Chlidonias leucopterus*	Migratory marine bird	Mi	-	198	579, 1972-2020	Possible	Yes –refer section 4
Gull-billed Tern	*Sterna nilotica*	Migratory marine bird	Mi	en	35	48, 1860-2008	Present	Yes –refer section 4
Caspian Tern	*Sterna caspia*	Migratory marine bird	Mi	vu	1334	4457, 1860-2019	Present	Yes –refer section 4
Crested Tern	*Sterna bergii*	Migratory marine bird	Mi		2489	104199,1860-2021	Present	Yes –refer section 4

Common name	Scientific Name	Species Group	EPBC	FFG	Count of survey	VBA records	Likelihood of occurrence in Proposed action area	Assessment of significance required
Little Tern	*Sternula albifrons*	Migratory marine bird	Mi	vu	456	274, 1860-2020	Present	Yes –refer section 4
Common Tern	*Sterna hirundo*	Migratory marine bird	Mi	-	189	1362, 1964-2020	Present	Yes –refer section 4
Common Noddy	*Anous stolidus*	Migratory marine bird	Mi	-	1	1, 1978	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Arctic Jaeger	*Stercorarius parasiticus*	Migratory marine bird	Mi	-	270	360, 1860-2020	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Pomarine Jaeger	*Stercorarius pomarinus*	Migratory marine bird	Mi	-	36	19, 1965-2017	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified. Species highly reliant on marine habitats and therefore unlikely to regularly occupy habitats within the treatment sites
Long-toed Stint	*Calidris subminuta*	Migratory marine bird/shorebird	Mi	-	75	67, 1966-2020	Possible	Yes –refer section 4
Little Stint	*Calidris minuta*	Migratory marine bird/shorebird	Mi	-	31	46, 1977-2019	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified.
Little Ringed Plover	*Charadrius dubius*	Migratory marine bird/shorebird	Mi	-	1	1, 1987	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified.
Wood Sandpiper	*Tringa glareola*	Migratory marine bird/shorebird	Mi	en	92	102, 1941-2020	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of survey	VBA records	Likelihood of occurrence in Proposed action area	Assessment of significance required
Ruff	*Philomachus pugnax*	Migratory marine bird/shorebird	Mi	-	6	4, 2001-2014	Present	Yes –refer section 4
Fork-tailed Swift	*Apus pacificus*	Migratory marine bird	Mi	-	210	20155, 1860-2020	Present	No – Unlikely to occur and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Migratory wetland/shorebirds								
Ruddy Turnstone	*Arenaria interpres*	Migratory wetland bird/shorebird	Mi, VU	en	738	5725, 1770-2021	Present	Yes –refer section 4
Grey Plover	*Pluvialis squatarola*	Migratory wetland bird/shorebird	Mi, VU	vu	415	5910, 1860-2020	Present	Yes –refer section 4
Pacific Golden Plover	*Pluvialis fulva*	Migratory wetland bird/shorebird	Mi	vu	531	4622, 1860-2020	Present	Yes –refer section 4
Double-banded Plover	*Charadrius bicinctus*	Migratory wetland bird/shorebird	Mi	-	1244	31210, 1860-2021	Present	Yes –refer section 4
Little Curlew	*Numenius minutus*	Migratory wetland bird/shorebird	Mi	-	17	14, 1891-2019	Possible	Yes –refer section 4
Whimbrel	*Numenius phaeopus*	Migratory wetland bird/shorebird	Mi	en	87	130, 1905-2017	Present	Yes –refer section 4
Black-tailed Godwit	*Limosa limosa*	Migratory wetland bird/shorebird	Mi, EN	cr	234	634, 1905-2020	Present	Yes –refer section 4
Grey-tailed Tattler	*Heteroscelus brevipes*	Migratory wetland bird/shorebird	Mi	cr	172	350, 1933-2020	Present	Yes –refer section 4

Common name	Scientific Name	Species Group	EPBC	FFG	Count of survey	VBA records	Likelihood of occurrence in Proposed action area	Assessment of significance required
Common Sandpiper	*Actitis hypoleucos*	Migratory wetland bird/shorebird	Mi	vu	145	69, 1931-2020	Present	Yes –refer section 4
Common Greenshank	*Tringa nebularia*	Migratory wetland bird/shorebird	Mi, EN	en	2552	21637, 1860-2021	Present	Yes –refer section 4
Marsh Sandpiper	*Tringa stagnatilis*	Migratory wetland bird/shorebird	Mi	en	844	10468, 1948-2020	Present	Yes –refer section 4
Terek Sandpiper	*Xenus cinereus*	Migratory wetland bird/shorebird	Mi, VU	en	39	28, 1959-2020	Present	Yes –refer section 4
Red-necked Stint	*Calidris ruficollis*	Migratory wetland bird/shorebird	Mi	-	5092	813424, 1897-2021	Present	Yes –refer section 4
Sharp-tailed Sandpiper	*Calidris acuminata*	Migratory wetland bird/shorebird	Mi, VU	-	3779	359923, 1881-2020	Present	Yes –refer section 4
Sanderling	*Calidris alba*	Migratory wetland bird/shorebird	Mi	-	135	256, 1970-2020	Present	Yes –refer section 4
Broad-billed Sandpiper	*Limicola falcinellus*	Migratory wetland bird	Mi	-	33	19, 1977-2016	Possible	Yes –refer section 4
Pectoral Sandpiper	*Calidris melanotos*	Migratory wetland bird/shorebird	Mi	-	108	98, 1952-2021	Present	Yes –refer section 4
Red-necked Phalarope	*Phalaropus lobatus*	Migratory wetland bird/shorebird	Mi	-	41	30, 1981-2017	Present	Yes –refer section 4
Latham's Snipe	*Gallinago hardwickii*	Migratory wetland bird/shorebird	Mi, VU	-	1146	6684, 1860-2020	Present	Yes –refer section 4
Swinhoe's Snipe	*Gallinago megala*	Migratory wetland bird/shorebird	Mi	-	0	0	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified.

Common name	Scientific Name	Species Group	EPBC	FFG	Count of survey	VBA records	Likelihood of occurrence in Proposed action area	Assessment of significance required
Pin-tailed Snipe	*Gallinago stenura*	Migratory wetland bird//shorebird	Mi	-	0	0	Unlikely	No – Unlikely to occur. Species habitat will not be removed or modified.
Osprey	*Pandion haliaetus*	Migratory wetland bird	Mi	-	51	56, 2007-2019	Possible	Yes –refer section 4
Migratory terrestrial								
Rufous Fantail	*Rhipidura rufifrons*	Migratory terrestrial bird	Mi	-	166	156, 1860-2020	Possible	No – Unlikely to occur and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Satin Flycatcher	*Myiagra cyanoleuca*	Migratory terrestrial bird	Mi	-	105	68, 1898-2020	Possible	No – Unlikely to occur and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Black-faced Monarch	*Monarcha melanopsis*	Migratory terrestrial bird	Mi	-	1	1, 1993	Unlikely	No – Unlikely to occur and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.
Yellow Wagtail	*Motacilla flava*	Migratory terrestrial bird	Mi	-	3	3, 2019	Unlikely	No – Unlikely to occur and potential habitat for this species will not be removed or modified. Species is unlikely to be directly or indirectly impacted by the proposed activity.

Appendix H

Literature review – Potential direct and indirect impacts on MNES from the use of drones

Literature review

Potential direct and indirect impacts on MNES from the use of drones

City of Greater Geelong

17 May 2024

→ **The Power of Commitment**



Project name		Drone mosquito control - DCCEEW referral advice					
Document title		Literature review | Potential direct and indirect impacts on MNES from the use of drones					
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Executive Summary

This report is subject to, and must be read in conjunction with, the scope and limitations set out in Sections 1.2 and 1.3 and the assumptions and qualifications contained throughout the Report.

The City of Greater Geelong (the City) submitted a referral to the Department of Agriculture, Water and the Environment (DAWE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for a proposed mosquito control program using helicopters, within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire (EPBC ref: 2020/8782). Since the referral and decision by DAWE, the City have changed the proposed method of deploying the mosquito control product from helicopters to unmanned aerial vehicles (UAVs), commonly called drones.

Drones are increasingly being used in areas where they may interact with wildlife, and this presents a number of challenges when considering how drone use might impact nearby wildlife. For this project, the interaction between birds and drones is a key concern since they can share the same airspace. The City has requested GHD to provide a literature review with regard to the use of drones for the deployment of mosquito control products and potential impacts on relevant Matters of National Environmental Significance (MNES).

The main objective of the review was to undertake a current and systematic review of literature pertaining to the potential direct and indirect impacts of using drones to deploy mosquito product on MNES. The review does not consider the potential impacts of the two products used by the City as this is already considered in other documentation presented by the City.

Summary of approach

In order to achieve a systematic approach, a review was undertaken of online procedures and processes that follow known and accepted literature review guidelines and protocols (e.g. PROSPERO, PRISMA, MESH and Cochrane). Following this review, an approach similar to the PRISMA model was adopted and the scientific literature search engine *Google Scholar* was selected to undertake all the searches, due to its accessibility, search potency and ability to save the searches in files compatible with MS Excel spreadsheets.

The approach included four key steps:

Step 1: Identify appropriate search criteria around research topic

Step 2: Undertake searches for relevant literature

Step 3: Screening and eligibility –evaluate and select most appropriate sources.

Step 4: Analyse, compare and discuss eligible findings.

To define and set appropriate search criteria, three key topics/questions were developed:

Question 1 - Are there any published studies that identify potential direct and indirect effects from the use of UAV/drones on MNES?

Question 2 - Are there any informal studies / grey literature that identify potential direct and indirect effects from the use of UAV/drones on MNES?

Question 3 - What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)?

Summary of findings

Question 1 *- Are there any published studies that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

The review provided five key relevant results for Question 1. Generally, the literature reviewed provided an overview of potential disturbance to animals from drones in a range of contexts and locales, but few studies were found that specifically focus on impacts on MNES. No identified studies that explore the impacts of using drones to apply mosquito treatments referred to specific MNES.

The most relevant study reviewed was by Wilson et al. (2023) which explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. The key findings from that study are that the extent of disturbance from drones varies depending on the species being disturbed. The Eastern Curlew (a large shorebird listed as threatened and migratory under the EPBC Act) was more susceptible to drone disturbance than other migratory shorebirds, such as the smaller, closely related Whimbrel (also a migratory species). When mixed flocks were present, birds often followed the behaviour of the species most sensitive to disturbance (i.e., if Eastern Curlew took flight, then so did the Bar-tailed Godwit, which is another large migratory shorebird). The study also highlighted that disturbance increased significantly with decreased distance between birds and drone, a finding consistent with other literature (Vas et. al. 2015). Wilson et al. (2023) also found that the larger and louder drone (605 mm diagonal span) was more likely to induce bird flight than three smaller drones (spans ranging between 213 – 354 mm).

Question 2 *- Are there any informal studies / grey literature that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

The review provided three key relevant results for Question 2. A number of other informal studies/grey literature articles reviewed provided small pieces of information that are not discussed specifically within the report. Overall, informal studies / grey literature provided very little information on the impacts of drones on MNES. Where articles or other information regarding drones and MNES was identified. Other sources that referred to drones and MNES (which included the Corangamite Catchment Management Authority and Wildlife Drones, which discussed the use of drones to survey individuals or habitat for Orange-bellied Parrot) did not provide any useful or new information with regards to disturbance impacts.

The key piece of information within the grey literature was from a report for the Moreton Bay Foundation by Wilson et al. (2022), who explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. This report explores and further discusses aspects of the research conducted as part of the published literature by Wilson et al. (2023) discussed for Question 1, providing specific disturbance information for specific shorebird species.

Question 3 *- What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)?*

The review provided 13 key relevant results for Question 3. Generally, the literature reviewed provides an overview of potential disturbance to animals (particularly birds) from drones in a range of contexts and locales. There were numerous studies, both locally (i.e., within Australia) and internationally, that explore the disturbance impacts of using drones for ecological monitoring and the potential to mitigate impacts on animals (particularly birds).

Most studies identified that birds and other taxa *are* disturbed by drones (McEvoy et al. 2016; Bech-Hansen et al. 2020; Bevan et al. 2018). However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors that are typically observed in most studies, including:

– The type and size of drone (i.e., quadcopter vs fixed-wing models; large vs small)
– The distance between the drone and the animal and the drone flying speed
– The species of animal and the composition of the flock (in mixed-flock situations)
– The habitat and behaviour of animal (i.e., nesting or foraging)

Another important consideration is not only the response of birds to drones but what birds do after being disturbed by drones (i.e., do they return to the same location or do they fly to different areas). One study that considered this (Mapes et al. 2020) found that following substantial drone disturbance, terns and other colonial nesting birds flew out in a semi-circle over water and then returned.

Most studies agree that if drone use around wildlife is undertaken carefully and with consideration to the species that may be impacted, then drone-related disturbance is likely to be of relatively low-risk, when considering the impact of existing techniques (Lyons et al. 2018; McKellar et al. 2021). Hodgson and Koh (2017) provide best practice principles for minimising unmanned aerial vehicle (drone) disturbance to wildlife.

Key outcomes

Overall, the authors consider that the literature discovered and assessed in this report adequately represents what is known and not known about the potential direct and indirect effects of the use of drones on MNES within Australia. The key findings identified by the literature review are summarised below.

Are birds and/or other animals disturbed by drones?

Most studies identified that birds and other taxa are disturbed by drones. However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors including:

– The type and size of drone (i.e., quadcopter vs fixed-wing models; large vs small)
– The distance between the drone and the animal and the drone flying speed
– The species of animal and the composition of the flock (in mixed-flock situations)
– The habitat and behaviour of animal (i.e., nesting or foraging)

What type/nature of response do birds and/or other animals show to drones?

Most of the reviewed studies focussed on whether animals (particularly birds) were disturbed by drones and when the disturbance occurred (i.e., at specific distances). Few studies explore the behavioural response of birds following disturbance by drones, presumably because this can be difficult to quantify (i.e., particularly in large flocks). Kaldor (2019) identified that repeated disturbance of birds (from a range of human disturbances, not just drones) can result in changed behaviour and may cause birds to 'permanently' leave an area. That study also highlighted for birds that response to disturbance is species-specific, with some flying much farther away than others.

When considering drone disturbance, it is prudent to compare this disturbance with disturbance caused by other survey methods and approaches and also the disturbance background that wildlife encounters in the absence of drones. No approach for animal observation or monitoring (or for larvicide treatment, as for this project) is likely to be entirely free of some sort of disturbance. Many authors contend that, when compared with more traditional survey methods (i.e., humans walking transects), drones often had less disturbance on birds (Valle and Scarton 2020; McKeller et al. 2021).

An important finding from a recent study was that, in mixed-flock situations, some species may serve as sentinel species for others. Wilson et al. (2023) found that flight response to drones by the Eastern Curlew is often followed by flight responses by other species. However, this effect appears to vary depending on species. For example, Black Swans rarely took flight at the same time as Eastern Curlew, whereas Bar-tailed Godwit almost always did (Wilson et al. 2023). Therefore, in mixed-flock situations, the species composition of the flock may contribute to specific species disturbance responses to drones.

Are MNES likely to be impacted by drone disturbance?

A key finding from Wilson et al. (2023) in Moreton Bay, Queensland, was that the Eastern Curlew (threatened and migratory under the EPBC Act) was highly susceptible to drone disturbance and could not be approached vertically by a drone from any tested height (up to 120 m). However, in the same study, other migratory shorebirds such as the Bar-tailed Godwit, Whimbrel and Great Knot would tolerate a drone approaching to closer distances without disturbance. Therefore, it is considered most likely that the impact of drones on avian MNES is likely to be species-specific and dependent on the nature of interaction with the drone (i.e., height of the drone, speed of the drone, angle of approach, where the drone took off, size of the drone, flock composition).

Knowledge gaps

Species-specific responses to drones for MNES

While this literature review has provided some insight into the likely responses of some MNES to drone disturbance, it has also highlighted that there is considerable species-specific variability in responses to drone disturbance, even amongst closely related species such as the Eastern Curlew and Whimbrel (Wilson et al. 2022).

For aquatic and semi-aquatic species such as the Australian Grayling and Growling Grass Frog, there was no literature found or reviewed that provided insight into how these species may be impacted by drones. However, given the size, behaviour and microhabitats occupied by these species, it is expected that the response of these species to drones would be minimal.

How does drone disturbance impact on bird behaviour and physiology in the long term?

Most studies in the reviewed literature focus on the initial behavioural response of birds to drones, with little exploration of the longer-term behavioural and physiological impact of drone disturbance on birds. Longer-term impacts are likely to be dependent on the magnitude, duration and frequency of drone disturbance, for which there is little to no information within the literature. Most studies assess drone-related disturbance as a brief snapshot in time, which fails to capture the potential longer-term implications for species where drones are a regular source of disturbance. Benjamin (2017) posits that shorebirds may be subject to physiological effects that are not visible, such as increases in heart rate, basal metabolism or release of stress hormones. Wohler (2018) concluded that the impacts of drones on shorebirds and terns are unclear and that caution is warranted, as disturbance of shorebirds or terns at any time (i.e., nesting, roosting or feeding) is likely to have adverse effects.

Drone collisions with birds

No research was uncovered in this literature review that reported on or explored the potential for bird collisions with drones (as distinct from birds, e.g., raptors, attacking drones). A number of factors, such as those discussed above (i.e., take off location, drone altitude, drone size), may influence bird collision risk and further investigation is warranted about whether drones are likely to pose a significant risk to birds due to collision.

Recommendations for future programs

The following recommendations are made with consideration of the potential future use of drones around wildlife:

– Hodgson and Koh (2017) provide guidelines for drone use and provide a suite of recommendations as the basis for a code of best practice in the use of drones in the vicinity of animals. The guidelines could be used as a starting point in formulating methods around using drones where MNES are or may be present.
– The type and size of drone are shown to influence bird disturbance. Where possible, it is recommended that small, quadcopter drones be used, to reduce the likelihood of disturbing birds and other wildlife.
– Drone take off location, flight height and flight speed have been shown to influence bird disturbance, but responses vary between species. It is recommended that a cautious approach is applied to future programs using drones
– As far as reasonably practicable to achieve program outcomes, drones should take off far away from animals, travel at high altitudes and move at slow speeds
– Consideration should be given to the number of flyovers a drone needs to make at any site. Multiple flyovers may increase disturbance, even to the point where fauna abandon a site.
– For any future program that involves drones operating near wildlife, establish an appropriate monitoring program alongside the drone use, to document observations of disturbance and gauge the level of concern that eventuates for that project at that site with those species

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Appendices

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1. Introduction

1.1 Project background

The City of Greater Geelong (the City) submitted a referral to the Department of Agriculture, Water and the Environment (DAWE) under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) for a proposed mosquito control program using helicopters, within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire (EPBC ref: 2020/8782).

On 12 November 2020, a delegate of the Minister for the Environment determined that the proposed action was a controlled action and that it required assessment by preliminary documentation. DAWE determined that further information was required to assess the relevant impacts of the proposed action.

Since the referral and decision by DAWE, the City have changed the proposed method of deploying the mosquito control product from helicopters to unmanned aerial vehicles (UAVs), commonly called drones. Following this decision, the City has requested GHD to provide a literature review in regards to the use of drones for the deployment of mosquito control products and potential impacts on relevant Matters of National Environmental Significance (MNES). This literature review will also inform the development of a revised project description for the City's Mosquito Control Program, which the City intends to re-submit to the Department of Climate Change, Energy, the Environment and Water (DCCEEW, formerly DAWE) to confirm DCCEEW's response to the EPBC Act referral process.

1.2 Scope and purpose of this report

The purpose of this report is to present the approach, methods and findings to better understand the potential direct and indirect impacts on MNES from the use of drones for the deployment of mosquito control products by the City for their proposed six-year program from 2024 through to the end of 2030.

Drones are increasingly being used in areas where they may interact with wildlife, and this presents a number of challenges when considering how drone use might impact nearby wildlife. For this project, the interaction between birds and drones is the key concern since they can share the same airspace. An impact assessment for this project should consider the potential direct and indirect impacts on MNES as a result of the proposed action (e.g. potential for drone disturbance and collision). The review does not consider the potential impacts of the two products used by the City as this is already considered in other documentation presented by the City. Furthermore, project specific impacts are discussed within the revised Preliminary Documentation associated with this project; thus, the primary aim of this literature review is to inform an assessment of potential impacts on MNES that may be relevant to the project.

Specifically, the scope of this project is to:

1. Undertake a literature review of publicly available material to identify:
    - Potential impacts of drones on wildlife with a key focus on shorebirds, waders and wetland bird species
    - Mitigation measures used by drone operators to reduce the potential impacts
2. Prepare a report (this document) that includes the following sections:
    - Introduction
    - Brief project description
    - Scope and purpose of report
    - Literature review methods, including:
        - Description of steps outlined to achieve the literature review
        - List of information sources cited in the literature review
        - Limitations – noting a focus on the limitations of the literature review
    - Analysis and evaluation of literature including:
        - Justification of discussions and conclusions based on available information

- Identification of potential impacts and relevance to MNES for this project
- Identification of key knowledge gaps
- Identification of management/mitigation measures and applicability to this project
- Recommendations and next steps

1.3 Limitations and Assumptions

This report has been prepared by GHD for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and City of Greater Geelong as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

This review is limited to the potential direct and indirect impacts of using drones for the deployment of mosquito control products upon MNES and other non-target organisms.

This literature review reports on literature gathered on the use of drones for the deployment of mosquito control products and their potential impacts on target and non-target species. The review focuses on literature produced from 2013 onwards. Recent literature articles tend to report and build on the findings from past studies, so relevant findings from pre-2013 literature are considered and incorporated into this review. Published articles are scrutinised and peer reviewed at the time of publication, so the validity of the information they report is not questioned here.

The information gathered for this literature review is considered to be of a sufficient scientific standard and encompasses enough research methods and outcomes to form a non-biased and scientific contention for the purposes of this report.

2. Project description summary

The proposed action comprises the City of Greater Geelong mosquito management program (the proposed program) within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire (see Appendix A for map of treatment sites). The City proposes to operate the six-year program from 2024 through to the end of 2030. The program will continue the activities described for the current program (refer permit EPBC 2005/2132), including:

- Monitoring of adult and larval mosquitos at breeding sites
- Review of monitoring results to determine the need for and type of treatment
- Treatment of up to 52 sites over the course of the six-year program including:
  - 9 ground-based (manual/applied by hand) treatment sites
  - 43 aerial (drone) treatment sites
- Ecological studies associated with the mosquito control program
- Annual reporting in line with current reporting requirements
- Community education

The main mosquito species found in this region is *Aedes camptorhynchus*, a salt-water breeding mosquito that is capable of surviving a broad range of climatic conditions. Its breeding habitat includes the many regional salt marshes around the City. Another predominant mosquito species is *Aedes notoscriptus*. This species breeds in temporary ponds of stagnant fresh water, including domestic containers that fill with rainwater. Its presence often indicates household breeding sources like pot plant bases and blocked drains or gutters.

The City will continue to use two mosquito control products for larval management, *Bacillus thuringiensis israelensis* (Bti) and S-methoprene. Both are approved for use in Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA). These products target specific aspects of the mosquito larvae biology. All forms of larvicide used for the proposed mosquito control program are delivered in non-liquid form (e.g. granules, sand, pellets or briquets).

The extent of the proposed action area is defined by the area of the nine ground-based sites and 43 aerial treatment sites within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire. The combined area for these sites is 3,279.72 ha, consisting of 22.41 ha of ground-based treatment sites and 3,257.31 ha of aerial treatment sites. See the Preliminary Documentation response report (GHD 2024) for greater detail regarding the number and extent of treatment sites, the volume of product applied to each site and the forecasted frequency of treatments for each site over the course of the program.

The aerial treatment program will operate between 15 August and 15 March each year and the ground-based treatment program will operate between 15 August and 31 May each year. Generally, mosquito larvae numbers are low during the winter months and, as a result, monitoring and treatment during this period is minimal.

Mosquito breeding sites within the City will be monitored on a rotating basis. If larvae are found, staff will determine the most effective treatment method for the site. Sites are either treated manually or recommended for aerial drone treatment. A 4WD vehicle may be used to access heavily vegetated breeding sites for manual treatment.

Although the conditional requirements of EPBC 2005/2132 have formally expired, the proposed program will continue to follow the conditional requirements of the EPBC 2005/2132. In particular, to minimise impacts on Orange-bellied Parrot at the Swan Bay and Lake Connewarre treatment sites:

- No aerial treatment must occur at either site between 15 March and 15 August
- Low-level aerial treatments (below 40 m) may only occur between 16 August and 14 March in Lake Connewarre (sites 3.13, 8.13, 8.14, 8.18 and 10.7) and between 16 November and 14 March in Swan Bay (sites 4.6, 7.1, 7.2, 7.3, 7.5, 14.3, and 14.4) to limit the disturbance to the Orange-bellied Parrot created by aerial treatments

– Low level (below 40 m) aerial treatment may only be undertaken at the Swan Bay site between 16 August and 15 November if surveys taken 24 hours prior to treatment confirm the Orange-bellied Parrot is not present at this site

The proposed program does not involve the removal or modification of any native vegetation or fauna habitat.

Description of drone activity

The area of the 43 drone sites totals 3,257.31 ha, of which up to 681.13 ha may be treated each season. Within the 43 sites, aerial treatments will be applied to areas suitable for mosquito breeding, including the shallow fringes of large natural wetlands (e.g. Reedy Lake), low lying shallow areas inundated from rainfall and to a lesser extent, areas that may be periodically inundated by king tides before receding. Aerial treatments are not applied to deep open waterbodies, or deep densely vegetated (e.g. tall rushes/sedges) waterbodies or areas subject to daily tidal inundation (e.g. tidal mudflats) as these areas are not suitable for mosquito breeding.

When applying larvicide, the drones are likely to fly at a height of 10-15 m above the ground, depending on weather conditions (e.g. wind) and swath width (10-15 m^2), flying back and forth across a site to apply the product effectively. Prior to application, drones can approach sites from a greater height (maximum flight height is 100 m above the ground). Prior to the application of each product, a reconnaissance site (pass over) may be undertaken, then the product will be applied. Larvicide product is primarily applied to areas with surface water, as this is the best use of the product. Larvicide is not deliberately applied to 'dry' areas (without surface water) or areas that are flowing or subject to daily tidal action (e.g., Barwon River/estuary, Swan Bay, Lake Connewarre, parts of Reedy Lake, Thompsons Creek, Lake Victoria), as those areas typically lack suitable habitat for mosquito breeding. Using drones, which can apply product more precisely than helicopters, will minimise the incidental product that may be deployed in some 'dry' and tidal areas within a site due to their close proximity to surface water containing mosquito breeding habitat (for example, a patch of dry area between surface waterbodies, or fringing dry shoreline areas surrounding a waterbody, or the fringing shoreline of Swan Bay or Lake Connewarre).

Specifications of the foldable quadcopter drone likely to be used for larvicide application are as follows (refer to: https://www.xagaustralia.com.au/p100-pro):

– Dimensions: propeller folded – 1095 mm wide x 893 mm long x 883 mm tall, propeller unfolded – 2927 mm wide x 2868 mm long x 883 mm tall
– Total Weight (Excluding battery and excluding hopper, larvicide and associated equipment): 46 kg
– Maximum Take-off Weight with full hopper and battery: 110 kg
– Maximum Operating Speed: 13.8 m/s

To understand and predict patterns of treatments of sites, the City has provided the following information:

– Drone flights will occur between morning and early afternoon (e.g. generally between the hours of 9 am – 4 pm). Flights will not occur during the early morning or late afternoon (e.g. near sunrise or near sunset)
– The time required for the treatment of each site will vary according to water inundation, level of breeding and site area. A treatment is expected to take less than 60 minutes for small sites (e.g. <33 ha; n=37), and from 40 mins up to 140 minutes for larger sites (e.g. > 33 ha; n = 6). This is based off treating the entire seasonal treatment area at once, which is not the intention of the program.
– When a site is treated, flight time for treatment within that day will vary (historical range when using a helicopter was 1 – 6 hrs, average 2 hrs per day). The maximum flight time for a treatment at any given site on any given day is expected to be approximately 60 minutes. The time taken for that treatment could be 2-3 hours, noting that the drone will stop to reload product and swap batteries at the launch site between landing and take-off. Because the drone is smaller than the helicopter and carries a smaller larvicide load, it would require more refills (i.e., return to base) than a helicopter does to treat the same area. Therefore, treatment of a specific area within a site may take longer overall using a drone than using a helicopter. As the drone is smaller and is capable of flying lower, its treatment swath is narrower. This results in more passovers within a site than would be required by a helicopter. For example, site 3.13 (341.9 ha) may require more drone passovers within a season than it would with a helicopter (e.g. 20 drone flights compared with 8 or so helicopter passes, given the broader swath of helicopter) because of the larger treatment area. Smaller sites (e.g., site 8.7; 20.9 ha) would require fewer passovers (e.g. three drone flights) due to being smaller.

– Because the drone is smaller, lower, slower and more manoeuvrable than a helicopter, it has the potential to treat a site with more precision, resulting in less product redundancy or wastage.
– Maximum flight time is also restricted by factors external to the proposed action including battery life, weather, how long the drone is permitted to fly within the airspace of the project area and other aircraft traffic
– Number of treatment days each season will vary (historical range 4 – 29 non-consecutive days per season, average = 13). A typical treatment season will most likely consist of 6-8 non-consecutive treatment days.
– A single treatment period will never aim to treat the entire area of a site. Areas proposed for treatment typically form a small portion of the entire site, and are selected specifically to target potential mosquito breeding habitat.

Section 2.4.8 of the Preliminary Documentation report (GHD 2024) provides a summary of how often (frequency) a site is expected to be treated and therefore how often it is likely to be exposed to aerial disturbance and other drone impacts each season. Of the 43 aerial sites:

– 20 sites will receive no more than one treatment per season, meaning there is a gap of at least six months, and possibly greater than 10 months, between treatments for these sites
– 23 sites may receive two or more treatments per season, with a gap between treatments varying between seven to 14 days, depending on product type. On the basis of historical observations, the need for multiple treatments of a site per season is expected to occur every two to three years, due to environmental conditions that influence mosquito breeding.

Aerial treatments are only conducted during the day and are subject to strict weather and tide conditions. Wind conditions must be below 30 km/h to ensure safety and appropriate application of product. In the days after a treatment, wind speed and direction affect how the product moves once within the site and this must also be accounted for. Rain forecast will delay application as rain could wash product out of the intended treatment area. Incoming high tides above 1.5 metres will force a reschedule of an aerial treatment, as any product applied immediately prior to a high tide has the potential to be washed outside of the intended treatment area.

A range of launch sites will be used for the drone operation, and all take-off, landing and reloading of larvicide product will be completed at launch sites. It should be noted that the drone does not land at any of the treatment sites, or hover for any extended period (e.g. more than two seconds) at any location other than the launch sites.

To understand the level of noise created by the drone, the City will use a sound meter (Bruel & Kjaer 2245) to determine the sound pressure levels measured in the logarithmic decibel (dB) scale relative to a reference value. Due to noise levels varying depending on the drone weight and flight speeds, the sound meter will be used to provide data on the weight and speed variations, to better inform any additional adaptive mitigation measures that may be required for aerial treatments.

3. Literature review

3.1 Approach

The main objective was to undertake a current and systematic review of literature pertaining to the potential direct and indirect impacts of using drones to deploy mosquito product on MNES.

In order to achieve a systematic approach, a review was undertaken of online procedures and processes that follow known and accepted literature review guidelines and protocols (e.g. PROSPERO, PRISMA, MESH and Cochrane). Following this review, an approach similar to the PRISMA model was adopted and the scientific literature search engine *Google Scholar* was selected to undertake all the searches, due to its accessibility, search potency and ability to save the searches in files compatible with MS Excel spreadsheets.

Our approach included four key steps:

Step 1: Identify appropriate search criteria around research topic

The purpose of this step was to develop key questions to meet the main project objective and then set appropriate search terms and parameters (search criteria). The following key questions/topics were developed:

1. Are there any published studies that identify potential direct and indirect effects from the use of UAV/drones on MNES? (Herein referred to as Question 1). Whilst searching for literature for this question, the following was also considered:
    - Information on impacts from similar programs elsewhere, where available, first within Australia, then citing international examples
    - Potential direct and indirect impacts over specific timeframes due to use of the drones, including cumulative effects (e.g. from repeated use of drones over time) on MNES, including listed species, migratory species and Ramsar site impacts
2. Are there any informal studies / grey literature that identify potential direct and indirect effects from the use of UAV/drones on MNES? (Herein referred to as Question 2). Whilst searching for information for this question, the following was also considered:
    a. Information on impacts from similar programs elsewhere, where available, first within Australia, then citing international examples.
    b. Potential direct and indirect impacts over specific timeframes, due to use of drones, including cumulative effects (e.g. from repeated use of drones over time) on MNES, including listed species, migratory species and Ramsar site impacts.
3. What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)? (Herein referred to as Question 3).
4. Search terms and parameters were used to filter the recent literature published since 2013 to the present (July 2023). Specific names for MNES and non-target species were searched for separately, according to slightly different strategies.

Step 2: Search for relevant literature

The search criteria developed during step 1 were entered into Google Scholar and other online databases and sources (e.g. the DCCEEW EPBC referral register, Council websites) to identify potentially relevant articles. The list of articles resulting from the search was saved as an Excel file in standard citation format including: author(s), year, title, journal title (if relevant), publisher. Original lists were saved for each search, then filtered to remove duplicates for easy screening. Relevant information provided by the City was also assessed.

Step 3: Screening and eligibility – evaluate and select most appropriate sources.

List outputs from step 2 were screened using a pre-determined classification process following a Best Professional Judgement (BPJ) approach by the authors of this report, according to the key question and search terms. The classification process aimed to:

– Identify what literature was included in the review and why,

– Identify what literature was excluded from the review and why,
– Identify how many items were finally selected for review

Each of the articles reviewed was placed into one of five classifications (Table 1), considering the key search words, information provided in the title and the abstract and, if necessary, the full document. The relevant results, which were assigned to classifications are presented in Appendix B and discussed in Section 4.

Table 1 Classification of the results according to relevance

Classification	Definition	Example of relevant article content
1	Relevant and key term/s found in the article Key terms must not be limited to title, and also within body of the article and preferably within the same sentence or multiple sentences.	E.g. search according to – Question 1, Table 6 Search A Article includes the term 'orange-bellied parrot', with at least one of the following words…impact etc
2	Relevant (article included), but not all key term/s not found in the article. Article may be missing one or more of the key terms however may contain text that is relevant to the broader understanding of the question or useful surrogate information.	Article includes 'parrot' (but not 'orange-bellied parrot), with exact phrase 'S-methoprene', with at least one of the following words…impact etc
3	Relevant (article included), but for another question. Article may contain some key terms, but does not provide information linking key terms to the question. Article may contain information about a topic for consideration.	As above – can be useful to understand broader issues but does not provide a relationship between MNES and the topic.
4	Not relevant (article excluded) – contains one or more of the above search terms however terms provided in unrelated / isolated sentences in document.	-
5	Not accessible (article excluded) (e.g. not in English)	-

Step 4: Analyse, compare and discuss eligible findings.

During this step, the accepted literature (classification 1, 2 or 3) was perused to obtain answers to the key questions, particularly to understand the potential direct and indirect impacts of the use of drones on MNES.

3.2 Search outputs for relevant literature

The search criteria developed during Step 1 were entered into Google Scholar and other online databases and sources (e.g. the DCCEEW EPBC register of projects, local council websites) to identify relevant studies, as described in Step 2, section 3.1.

After the removal of duplicates, 748 articles from published and/or peer reviewed sources were considered for Questions 1, 2 or 3 (Appendix B) and 76 other sources of information (e.g. council websites, DAWE/DCCEEW referral list) were considered for Question 2.

3.2.1 Question 1

Question 1 *- Are there any published studies that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

The Google Scholar advanced search included words and commands for each MNES listed below and as listed in Table 2 (search A and B). In order to filter the search to prioritise local studies, the word 'Australia' was also included in the key parameters. However, searches were not limited to local studies and included relevant information from international sources. In addition to specific searches for MNES, broader search terms that encompassed species groups and other relevant terms (e.g. wader, shorebird, Ramsar - Table 3, search C) were also used to capture information. Table 2 provides a summary of the search parameters and outcomes. A complete list of all these studies and their corresponding classification is provided in Appendix B.

Key MNES species included in the search terms:

– Orange-bellied Parrot (*Neophema chrysogaster*) – Critically Endangered
– Growling Grass Frog (*Litoria raniformis*) – Vulnerable
– Australian Grayling (*Prototroctes maraena*) – Vulnerable
– Eastern Curlew (*Numenius madagascariensis*) – Critically Endangered, Migratory, Marine
– Curlew Sandpiper (*Calidris ferruginea*) – Critically Endangered, Migratory, Marine
– Sharp-tailed Sandpiper (*Calidris acuminata*) – Migratory, Marine
– Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site

The list of MNES included in this review is current up to 2023, and any recent changes to MNES listings are not thought to alter the findings of this review. There is sufficient breadth in the existing search terms used to be able to extract all relevant information relevant to newly listed species and their habitat (e.g. for the Blue-winged Parrot).

Table 2 Search parameters used for Question 1, and a summary of search outcomes

Search	Google scholar advanced search commands	Key parameters	Summary of search outcomes (number of studies for each search)
A	With all the words	MNES item from list e.g. orange-bellied parrot OR Neophema chrysogaster	26 articles between 2013 – 2023, and 4 articles (no date)
	With the exact phrase	Unmanned Aerial Vehicle, Drone	
	With at least one of the words	impact, direct, indirect, collision, strike, disturbance,	
B	With all the words	MNES item from list e.g. orange-bellied parrot OR Neophema chrysogaster	20 articles between 2013 – 2023
	With the exact phrase	literature review	
	With at least one of the words	Unmanned Aerial Vehicle, Drone, impact, direct, indirect, collision, strike, disturbance,	
C	With all the words	Unmanned Aerial Vehicle, Drone	988 dated between 2013 - 2023
	With the exact phrase	-	
	With at least one of the words	fish, wader, shorebird, duck, waterbird, plover, frog, sandpiper, species, wetland, Ramsar impact, direct, indirect, collision, strike, disturbance,	

3.2.2 Question 2

***Question 2** - Are there any informal studies / grey literature that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

In order to search for grey literature (typically defined as unpublished or not peer reviewed), two processes were used:

– Internal search option of DCCEEW referral portal search tool or internal search option on a council website
– Standard Google (not Google Scholar) search using a combination of key words.

In addition to MNES-specific searches, broader search terms that encompassed species groups and other relevant terms were also used to capture information. A total of 23 sources of grey literature were found and considered (Appendix B). In addition, 53 shire council/local government websites were searched. Table 3 provides a summary of the search type, sources of information and outcomes.

Table 3 Database sources and search parameters used for Question 2, and a summary of search outcomes

Search type	Database source / search function / request type	Summary of search outcomes
Organisation database (no date limitations)	DCCEEW – Referrals list: http://epbcnotices.environment.gov.au/referralslist/ Search - filter by title Search terms – drone OR Unmanned Aerial Vehicle OR MNES No date rejected	No results were returned from the DCCEEW referrals list based on the search teams used.
Google search – then internal organisation search (no date limitations)	Google search Search term combinations for mosquito control programs in local government / shire council areas across Australia Search terms - mosquito control shire OR mosquito control council OR mosquito control city – all refined to Australian sites (results reviewed limited to pages 1- 5 for each search combination)	53 shire council/local government areas across Australia report mosquito control management. Of those, only two report information of relevance to this literature review. A list of local government websites reviewed for information with Mosquito control activities includes: Victorian – Surfcoast shire, Wellington shire, Campaspe shire, Bellarine Shire, Mornington Peninsula, Mildura Rural City Council, QLD- Noosa shire, WA - Shire of Capel, Shire of Busselton, NSW- Byron shire, Sydney Olympic Park Authority . *Summary of results* Most organisation websites provided details regarding Drone (Remotely Piloted Aircraft) Policies, public awareness. These focused primarily on privacy concerns of local residents stemming from drone use. Some organisation websites stated that drones had been used to assess local ecological values, however the information was provided in very broad terms and included no discussion regarding the impacts of drone use. No organisation mentioned/discussed indirect / direct effects of drone use to an MNES No associated documentation was found regarding drone and MNES interactions.
Information request to City of Greater Geelong	GHD requested information from the City for any background reports or additional information relating to this literature review	No information received

3.2.3 Question 3

Question 3 *- What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)?*

The Google Scholar advanced search included words and commands for relevant non-listed fauna species groups (refer to list below). In order to filter the search to prioritise local studies, the word 'Australia' was also included in the key parameters. However, searches were not limited to local studies and included relevant information from international sources. Table 3 provides a summary of the search outcomes. A complete list of all these studies and their corresponding classification is provided in Appendix B.

Relevant non-listed fauna species groups included in the search terms:

– Birds
– Amphibians
– Reptiles
– Invertebrates

Table 3 ***Database sources and search parameters used for Question 3, and a summary of search outcomes.***

Search	Commands	Key parameters	Summary of search outcomes (number of studies)
A	With all the words	Relevant non-listed fauna species or species groups from list e.g. Birds/ Amphibians / Reptiles / Invertebrates	461 dated between 2013 – 2023, and 11 articles (no date)
	With the exact phrase	Unmanned Aerial Vehicle, Drone	
	With at least one of the words	impact, direct, indirect, collision, strike, disturbance	

4. Literature findings

4.1.1 Question 1

Question 1 *- Are there any published studies that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

The systematic literature review provided five key relevant results for Question 1 (Table 4). Generally, the literature reviewed provided an overview of potential disturbance to animals from drones in a range of contexts and locales, but few studies were found that specifically focus on impacts on MNES. No identified studies that explore the impacts of using drones to apply mosquito treatments referred to specific MNES; most studies involving animals and drones were focussed on ecological monitoring.

The most relevant study reviewed was by Wilson et al. (2023) which explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. The key findings from that study are that the extent of disturbance from drones varies depending on the species being disturbed. The Eastern Curlew (a large shorebird listed as threatened and migratory under the EPBC Act) was more susceptible to drone disturbance than other migratory shorebirds, such as the smaller, closely related Whimbrel (also a migratory species). When mixed flocks were present, birds often followed the behaviour of the species most sensitive to disturbance (i.e., if Eastern Curlew took flight, then so did the Bar-tailed Godwit, which is another large migratory shorebird). The study also highlighted that disturbance increased significantly with decreased distance between birds and drone, a finding consistent with other literature (Vas et. al. 2015). Wilson et al. (2023) also found that the larger and louder drone (605 mm diagonal span) was more likely to induce bird flight than three smaller drones (spans ranging between 213 – 354 mm).

With regard to repeated disturbance from drones, there are conflicting findings within the literature. Wilson et al. (2023) found that repeated approaches by drones significantly reduced bird disturbance, possibly indicating short-term habituation. On the contrary, a report by Kaldor (2019) (discussed in section 4.1.2) suggests that repeated disturbance (not only from drones, but other disturbance) can result in changed behaviour and may cause birds to leave an area over a medium-to-longer term.

Other studies that looked at drone impacts on MNES include a study in France by Vas et. al (2015). This study looked at the response of the Common Greenshank (a shorebird species also found in Australia and listed as endangered and migratory under the EPBC Act) to drones and reported that most birds did not respond to an approaching drone that was more than 30 m above ground. Another study from Italy by Valle and Scarton (2020) had a similar finding, where Common Redshanks (another EPBC Act-listed migratory species, but rare in Australia) were disturbed only when the drone was very close (i.e., about 10 m) to the nesting bird or nest (note: Common Redshanks and most other migratory shorebird species do not nest or breed in Australia). Weimerskirch et al. (2018) found that seabirds (i.e., petrels, albatross, penguins) generally did not react to approaching drones that were at 50 m or more altitude, whereas at 10 m altitude, most species showed strong behavioural postures of stress.

No other studies that focussed on drone impacts on MNES were identified in the scientific literature. However, a number of reviewed studies provided useful information about the impacts of drones on other species (particularly birds). These are considered under Question 3 in section 4.1.3.

A table of literature relating to Question 1 and specific information relating to drone impacts on MNES is summarised in Table 4 below.

Table 4 Summary of key relevant articles for Question 1

Journal Article, Location of Study	Author/s	Relevant MNES included in article	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
Drone-induced flight initiation distances for shorebirds in mixed-species flocks. Moreton Bay, Queensland, Australia.	Wilson et al. (2023)	– Eastern Curlew – Bar-tailed Godwit – Gull-billed Tern – Whimbrel – Caspian Tern – Curlew Sandpiper – Great Knot – Grey-tailed Tattler – Marsh Sandpiper – Terek Sandpiper	– Drones can be an effective, low-disturbance tool for shorebird surveys; however, they can also be a significant source of disturbance for bird flocks containing highly sensitive species (i.e., Eastern Curlew) – Extent of disturbance varies between species, even between closely related species occupying the same habitat – Most species are unlikely to take flight when approached by a small drone at altitudes above 60 m (< 20% probability), except the Eastern Curlew, which is extremely sensitive to drone-induced disturbance – In general, disturbance increased significantly with decreasing distance between drone and bird	– The investigators varied the drone launch distance (from the birds) between 20 and 830 m at roughly 100 m intervals, and the drone approach vertical distance (altitude) between 3 and 120 m at roughly 10 m intervals – Type and position of the drone significantly impacted the likelihood of the birds taking flight. The larger and louder drone (605 mm diagonal span) was more likely to induce flight than three smaller drones (spans ranging between 213 – 354 mm). – Faster approach velocities and slower perpendicular velocities (e.g. moving sideways near bird) increased disturbance – Repeat approaches significantly reduced disturbance, possibly indicating short-term habituation	– Eastern Curlew was found to be extremely susceptible to drone-induced disturbance and would not allow an approaching drone to be directly above at any altitude tested (up to 120 m) – Flight response to drones by Eastern Curlew is often followed by flight by other species. This suggests that the Eastern Curlew is a sentinel species, but this varies depending on species. For example, Black Swans rarely took flight at the same time as Eastern Curlew, whereas Bar-tailed Godwit almost always did.	– Recommend drone approach altitude of 30 m or more – The study authors recommend using the results of their study to inform measures to mitigate drone-induced disturbance near sensitive species. For example, to limit the flight initiation probability to <20%, 0.35 m or larger diagonal quadcopter drones should not be operated within 300 m horizontal distance of shorebird roosting sites containing Eastern Curlew.

Journal Article, Location of Study	Author/s	Relevant MNES included in article	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
Approaching birds with drones: First experiments and ethical guidelines. Montpellier and Candillargues, France.	Vas et al. (2015).	Common Greenshank But study also investigated mallards and flamingos.	– In 80% of all cases, one specific drone type could fly to within 4 m of the birds without visibly modifying their behaviour – Approach speed, drone colour and repeated flights had no measurable impact on bird behaviour, yet birds reacted more to drones approaching vertically (from above the bird)	– 204 approach flights with a quadcopter drone (350 mm diagonal span), noise level 60 dB at 2 m – Drone launched at minimum 50 m and 100 m from birds – Speed and angle of approach varied in four categories (speed: 2, 4, 6 and 8 m/s; angle: 20, 30, 60 and 90 degrees) – Bird reactions were classified in three categories: (type 1) no reaction; (type 2) brief head and tail movements followed by animal movements away from the drone, either walking or swimming at the water surface; (type 3) flying off	For greenshanks, no reaction was recorded in 53 cases (87%), type 2 reactions in five cases, and type 3 reactions in two cases; those reactions occurred when the drone was 4–10 m from the birds.	Recommend launching drones farther than 100 m from the birds, not approaching them vertically and adjusting approach distance according to species.

Journal Article, Location of Study	Author/s	Relevant MNES included in article	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
Drones Improve Effectiveness and Reduce Disturbance of Censusing Common Redshanks Tringa totanus Breeding on Salt Marshes Venice, Italy.	Valle and Scarton (2020)	Common Redshank	– Compared with traditional ground counts, drones found to improve census effectiveness and reduce disturbance of Redshanks breeding on saltmarshes. Note, however, that disturbance was measured as time spent per transect and impacts on vegetation during survey.	– Thirty-one drone flights on 29 marsh islands – Small drone with maximum speed 60 km/h, noise 70.0 dB(A) – Drone flew at 15 km/h and at an altitude of 10 m above surface level	Redshanks reacted only when drones were very close to the nesting individual or nest (i.e., within about 10 m). However, drone use undoubtedly caused disturbance to incubating birds by forcing them off nests. Physiological stress found in drone-disturbed animals was also shown in on-foot disturbances. Consequently, the authors concluded that drone flights constituted the less invasive option for studies on the breeding biology of Redshanks.	– Launching the drone from at least 100 m from the presumed nesting sites – restricting drone flights over the nesting site to <1 min – if predators are nesting close by, carefully observing potential predation events on temporarily unattended nests of the targeted species and, if this is the case, immediately suspending flights

Journal Article, Location of Study	Author/s	Relevant MNES included in article	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
Flights of drones over sub-Antarctic seabirds show species- and status-specific behavioural and physiological responses Crozet Islands, Southern Indian Ocean	Weimerskirch et al. (2018).	Seabirds (i.e., Petrels, Albatross, Penguins).	– Behavioural responses differed between species depending on the altitude of the drone approach – The study confirmed the expected link between physiological and behavioural response in King Penguin chicks – Breeding adult King Penguins showed no behavioural sign of stress, but had a significant increase in heart rate, the relative increase being higher in adults than in chicks	– Quadcopter drone (350 mm in length) – 60 dB noise at 2 m – Drone launched at minimum 100 m from birds and ascended vertically up to 50 m high – Horizontal flights above target birds carried out at 2 m/s – Birds passed over at three heights: 50 m, 25 m and 10 m	With the drone at 50 m altitude, only one of the studied species showed a detectable reaction, whereas at 10 m altitude, most species showed strong behavioural postures of stress. Adult penguins breeding in large colonies and some albatross species showed little behavioural response to the drone, even when the drone was as close as 3 m. Contrastingly, other species, such as giant petrels or cormorants, appeared highly sensitive to drone approaches.	– When used at an altitude of 50 m or more, the drone impact is likely to be negligible for all species

4.1.2 Question 2

Question 2 *- Are there any informal studies / grey literature that identify potential direct and indirect effects from the use of UAV/drones on MNES?*

The systematic literature review provided four key relevant results for Question 2 (see Table 5). A number of other informal studies/grey literature articles reviewed provided small pieces of information that are not discussed specifically within the report.

Overall, informal studies / grey literature provided very little information on the impacts of drones on MNES. Where articles or other information regarding drones and MNES was identified, it was typically a summary of journal articles or research that was considered under Question 1 (see 4.1.1). Other sources that referred to drones and MNES (which included the Corangamite Catchment Management Authority and Wildlife Drones, which discussed the use of drones to survey individuals or habitat for Orange-bellied Parrot) did not provide any useful or new information with regards to disturbance impacts.

The key piece of information within the grey literature was from a report for the Moreton Bay Foundation by Wilson et al. (2022), who explored the impact of drones on shorebirds and waterbirds at Moreton Bay, Queensland, Australia. This report explores and further discusses aspects of the research conducted as part of the published literature by Wilson et al. (2023) discussed for Question 1, providing specific disturbance information for specific shorebird species.

Another study on shorebirds in the UAE by Benjamin (2017) found that drone height and speed were important factors in determining the likelihood of shorebirds being flushed. Interestingly, body size was also found to be important in determining likelihood of flushing, with smaller shorebirds (i.e., sandpipers, plovers) 33 times more likely to flush than larger birds (i.e., gulls and herons).

The DCCEEW website provides an article by Eric J. Wohler, from Birdlife Australia (Tasmania), that discusses the potential impact of drones (among other disturbance sources) on shorebirds and terns. However, the article considers a range of human disturbance threats on birds and acknowledges that there are substantial knowledge gaps with regards to the impacts of drones on these birds and that caution is warranted, as disturbance of shorebirds and terns at any time (i.e., nesting, roosting or feeding) is likely to have adverse effects. Note that most shorebirds that occur within the project area for this City of Greater Geelong project are migratory and do not breed or nest in Australia.

Table 5 Summary of key relevant articles for Question 2

Report/Article, Location of Study	Authors	Relevant MNES	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
Using Drones to Survey Shorebirds Moreton Bay, Queensland, Australia.	Wilson et al. (2022)	– Eastern Curlew – Bar-tailed Godwit – Gull-billed Tern – Whimbrel – Caspian Tern – Curlew Sandpiper – Great Knot – Grey-tailed Tattler – Marsh Sandpiper – Terek Sandpiper	– General guidelines for minimising drone-induced bird disturbance – Fixed-wing drones and larger drones generally cause more disturbance – Disturbance impacts may be more severe for birds closer to migration – High drone speeds and sudden changes in drone direction cause more disturbance – Mixed-species flocks react according to the most sensitive species – Some species are more sensitive to disturbance than others – Extensive drone-based shorebird surveys within Moreton Bay are neither practical nor ethical	– Four quadcopter drones used, with diagonal sizes of 605, 354, 350 and 213 mm respectively. Drone noise level ranges were 78, 74, 75 and 70 dBA respectively	– Eastern Curlew is extremely susceptible to drone-induced disturbance and would not allow the approaching drone to be directly above at any vertical distance tested (up to 120 m) – A flight response to drones by Eastern Curlew was often followed by a flight response by other species. This suggests that the Eastern Curlew is a sentinel species, but this varies depending on species. For example, Black Swans rarely took flight at the same time as Eastern Curlew, whereas Bar-tailed Godwit almost always did.	– Estimated drone altitude that induced flight response for relevant MNES. The height at which these MNES had < 10 % probability of flight: – Eastern Curlew (>120 m) – Bar-tailed Godwit (75 m) – Whimbrel (80 m) – Great Knot (50 m)
Bird Disturbance From Human Activity: Potential Effects From Recreational Activities On Sea And Shore Birds Christchurch, New Zealand.	Bonnie Kaldor (2019)	– Caspian Tern – Australasian Bittern – Bar-tailed Godwit	– Repeated disturbance (not only from drones) can result in changed behaviour and may cause birds to permanently leave an area. – Response of birds to disturbances is species-specific, with some flying much farther away than others. The behaviour is often modified when they land again, with increased time for vigilance there is less time for feeding activity and this could result in reduced condition.	– The majority of the flushing behaviour occurred when the drone was flown at low altitudes (below 30 m), where there was an emitted noise of approximately 80-90 decibels	No mention of drone impacts on specific MNES (but references to other studies where MNES have been considered).	– No mention of specific mitigation for drone impacts on MNES

Report/Article, Location of Study	Authors	Relevant MNES	Key relevant findings	Drone type/distance/frequency	Species response to drone/Potential impacts on MNES	Mitigation measures
An overview of the major threats to resident and migratory shorebirds and small terns in Tasmania Tasmania, Australia.	Woehler (2021).	– Species that use study area included: – Bar-tailed Godwit – Common Greenshank – Curlew Sandpiper – Double-banded Plover – Red-necked Stint. – Little Tern – Fairy Tern. – Hooded Plover	– Identifies birds using the area and focus for future studies and monitoring	– A drone flown over disturbed an entire colony of terns during surveys. But drone disturbance was not the specific focus of the study	– Increased human usage of the Prosser River following dredging/channelisation resulted in an abandoned Tern breeding colony. Almost certainly as a result of disturbance to the nesting birds (drones perhaps part of the problem).	– No mention of specific mitigation for drone impacts on MNES
Use of Drones in Avian Conservation: Exploring the use of commercially available drones in wetlands shorebird population monitoring Sharjah, UAE	Benjamin (2017).	Shorebirds	– Altitude and speed of drone approach as well as bird body size and grouping arrangement were significant in influencing flushing rates	– Distance of 150 m flown at: 4 m, 9 m and 13 m high at speeds of 6 km/h, 10 km/h and 15 km/h – Three replications of each transect (two) completed on same day	– Smaller-sized shorebirds (i.e., sandpipers, plovers) had a far greater tendency (33 times more likely) to be flushed than larger birds (i.e., gulls, herons)	– Flushing predicted to be eliminated at drone heights > 15 m based on model prediction – Slower drone speeds resulted in less flushing

4.1.3 Question 3

Question 3 *- What are the potential direct and indirect impacts of drone use on other relevant non-listed fauna species, including, for example, birds, amphibians (frogs), reptiles (e.g. freshwater turtles, water dragons)?*

The systematic literature review provided 13 key relevant results for Question 3 (see Table 6). Generally, the literature reviewed provides an overview of potential disturbance to animals (particularly birds) from drones in a range of contexts and locales. There were numerous studies, both locally (i.e., within Australia) and internationally, that explore the disturbance impacts of using drones for ecological monitoring and the potential to mitigate impacts on animals (particularly birds).

As would be expected, most studies identified that birds and other taxa *are* disturbed by drones (McEvoy et al. 2016; Bech-Hansen et al. 2020; Bevan et al. 2018). However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors that are typically observed in most studies, including:

– The type and size of drone (i.e., quadcopter vs fixed-wing models; large vs small)
– The distance between the drone and the animal and the drone flying speed
– The species of animal and the composition of the flock (in mixed-flock situations)
– The habitat and behaviour of animal (i.e., nesting or foraging)

Another important consideration is not only the response of birds to drones but what birds do after being disturbed by drones (i.e., do they return to the same location or do they fly to different areas). One study that considered this (Mapes et al. 2020) found that following substantial drone disturbance, terns and other colonial nesting birds flew out in a semi-circle over water and then returned.

Although the primary focus of the literature is on drone impacts on birds, Bevan et al. (2018) also showed that other taxa (sea turtles and saltwater crocodiles) were disturbed by drones. In particular, saltwater crocodiles showed a range of behaviours when approached by a drone that was flying below 50 m altitude, whereas sea turtles generally showed no disturbance behaviours from drones at 20-30 m altitude. In the same study, terns were consistently disturbed by approaching drones flown below 60 m altitude, thus strengthening the notion that there is variability in species-specific responses to drones.

Most studies agree that if drone use around wildlife is undertaken carefully and with consideration to the species that may be impacted, then drone-related disturbance is likely to be of relatively low-risk, when considering the impact of existing techniques (Lyons et al. 2018; McKellar et al. 2021). Hodgson and Koh (2017) provide best practice principles for minimising unmanned aerial vehicle (drone) disturbance to wildlife and these principles are described in Table 6.

Table 6 Summary of key relevant articles for Question 3

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
Evaluation of unmanned aerial vehicle shape, flight path and camera type for waterfowl surveys: disturbance effects and species recognition New South Wales, Australia	McEvoy et al. (2016).	Waterbirds	– Across both study sites and all UAV models, the level of disturbance observed was generally minimal – Resident raptors elicited similar responses to drones, with most birds on the lake taking flight as the raptors flew overhead but birds often responded more markedly to raptors than drones – The flight response to the drones, when it did occur, included birds flying away from shore at low altitude for short periods to settle on open water. In contrast, the response to the arrival of a raptor was far more marked with large flocks of birds taking flight and flying for longer periods high above the water before resettling. – Mixed-species flocks of wild birds were observed to take flight in response to a drone that was launched from the take-off site (either 10 m of the shore or 300-500 m from shore) and flown toward the flock at low altitude (<40 m)	– Five models of drone used (three fixed wing and two multi-rotor) and of varying sizes – Delta-wing design drone caused the greatest level of disturbance and flee behaviour, possibly due to the drone resembling a raptor – Disturbance from multi-rotor drones was more subtle; drones flown at 15 m altitude resulted in birds swimming away from the approaching drone, without taking flight	No mention of drone impacts on specific MNES (but references to disturbance of other waterbirds). For all fixed-wing drones, a flight response occurred when drones took off near birds at low altitude (10 – 15 m). However, for the multi-rotor drones at low altitude (15 m and 50 m), only a vigilance response (i.e., ceased foraging, looking at drone or slowly swimming away) was observed.	No mention of specific mitigation for drone impacts on MNES. However, findings demonstrate that if take-off and landing occur out of sight of the target species and the drone has reached its survey altitude before crossing into view of the birds, disturbance should be minimal with in-flight noise quieter than manned fixed-wing aircraft.
Bird interactions with drones, from individuals to large colonies	Lyons et al. (2018).	Birds	– Drone flight around non-territorial birds in Australia poses relatively low risk to birds – Encountered several birds that appeared to be territorial and aggressive/defensive, particularly during the breeding season (including Australian Magpie, Currawongs and Masked Lapwing)	– Combination of quadcopter and fixed-wing drones used – Flying speeds between 5 – 10 m/s – Flight lines were 20 - 100 m apart at heights of 20 -100 m	No mention of drone impacts on specific MNES. However, waterbirds (ducks, piscivores and waders) showed no obvious reaction to drones and tended not to take flight while drone present.	No mention of specific mitigation for drone impacts on MNES.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
Dual visible-thermal camera approach facilitates drone surveys of colonial marshbirds Saskatchewan, Canada	McKellar et al. (2021).	Marshbirds	– Number of birds observed off their nests varied among colonies and flight periods – Given the small sample of sites and the fact that flight altitude was confounded with species composition at each colony, the disturbance results should be considered preliminary – The article authors believe disturbance from drone flights is likely still much less than disturbance from ground surveyors physically traversing colonies, not only in terms of birds being scared off nests, but also in total length of disturbance, disruption to emergent vegetation, and potential attraction of nest predators	– Octocopter drone – Drones flown at altitude of 45, 60, or 120 m above ground	There was no statistically significant difference in number of birds disturbed before, during, and after drone flights.	No mention of specific mitigation for drone impacts on MNES.
Evaluation of disturbance effect on geese caused by an approaching unmanned aerial vehicle	Bech-Hansen et al. (2020)	Geese	– Increasing UAV flight altitude as well as increasing take-off distance from the flocks both decreased the risk of bird flocks being flushed	– Twenty-four flocks of foraging geese were approached with a quadcopter UAV at altitudes of 50–100 m and disturbance effects were analysed	No mention of drone impacts on specific MNES. However, Geese were increasingly disturbed when approached by a UAV, with birds showing increased vigilance behaviour within approximately 300 m.	Flight altitudes of 100 m or more and take-off distances of ideally ~500 m are recommended, to minimise initial disturbance and reducing the risk of birds flushing.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
Using unmanned aerial vehicle (UAV) imagery to characterise pursuit-diving seabird association with tidal stream hydrodynamic habitat features Pentland Firth, UK	Slingsby et al. (2022).	Seabirds	– Demonstrated the ability of UAVs as a survey platform within tidal streams and highlighted new insights into seabird behaviour	All 38 drone surveys were manually flown at a consistent speed, and altitude (70 m), while also maintaining a consistent position ahead of the vessel (100 m). – Survey durations ranged between 10-30 minutes	Deemed that no disturbance resulting from either the UAV or vessel was present at the operational range of the UAV.	None specifically referenced.
Escape responses of terrestrial and aquatic birds to drones: Towards a code of practice to minimize disturbance Victoria, Australia	Weston et al. (2020)	Birds	– Drone altitude does not necessarily correspond to response distances - flight-initiation distances (FIDs) generally exceeded altitude. Most birds responded before the drone was overhead – Species varied substantively in FID, i.e., varied from 8 m (Crested Pigeon) to 65 m (Little Raven) – the highest non-response rates (60%) to drone approaches at 4 m altitude involved waterbirds (Pacific Black Duck, Eurasian Coot, Purple Swamphen)	– Drone 29 cm wide – Two approach altitudes (4 m and 10 m) – Two phases of approach (take off - ascent and approach – level directional flight) – Approach speed of 2.22 m/s toward focal birds	No mention of drone impacts on specific MNES. For half of 10 species examined, FIDs evoked by drones at either altitude (4 m and 10 m) appeared longer than those evoked by walkers. For three species, FIDs for walkers and drones were roughly similar. Some birds escaped the drone disturbance by flying, while others did not. Drones caused more escape by flying in only two species (Magpie-lark and Australian Wood Duck), and less escape by flying in four ground-foraging species (Crested Pigeon, Galah, Masked Lapwing and Purple Swamphen).	– Managing separation distances between ascending drones and birds might assist in minimizing avian disturbance According to this study, a prescription of not flying a drone closer than 100 m to any bird would mean few bird escape responses would occur.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
Testing a key assumption of using drones as frightening devices: Do birds perceive drones as risky? North Dakota, USA	Egan et al. (2020)	Birds	– Birds perceived drones with predatory characteristics (i.e. aerial raptor model) as riskier than common drone models (i.e. fixed-wing and multirotor platforms)	– Three drones used (aerial raptor model, fixed-wing and multirotor) – Two approach types (head-on and overhead) – Drone height for horizontal head-on approach was 6 m, for overhead approach 5 m	Red-winged Blackbirds showed alert responses earlier, alarm-called more frequently, returned to forage later, and allocated more time to vigilance in response to the predator model compared with the other 2 drone types. No blackbirds took flight in response to the multirotor at either head-on or overhead approaches.	– Drones should be modified with additional stimuli to increase perceived risk when used as frightening devices, but avoided if used for wildlife monitoring or other studies where disturbance is not desired
Best practice for minimising unmanned aerial vehicle disturbance to wildlife in biological field research	Hodgson and Koh (2017)	None specifically referenced.	– This article provides a suite of recommendations as the basis for a code of best practice in the use of UAVs in the vicinity of animals or for the purpose of animal research	– NA	No mention of drone impacts on specific MNES.	The following principles are recommended: ***Adopt the precautionary principle in lieu of evidence:*** When researchers cannot make informed decisions about minimum wildlife disturbance flight practices for their environment or study species, they should exercise caution, particularly if endangered species or ecologically sensitive habitats are involved. ***Utilise the institutional animal ethics process to provide oversight to UAV-derived animal observations and experiments:*** Ensuring

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
						all UAV methods are in accordance with approved institutional ethics permits. ***Adhere to relevant civil aviation rules and adopt equipment maintenance and operator training schedules.*** May include restrictions on flying beyond visual line of sight, above a defined altitude, at night and near people or in the vicinity of important infrastructure and prohibited areas. ***Select appropriate UAV and sensor equipment.*** Consider type of drone and way it moves. ***Exercise minimum wildlife disturbance flight practices.*** Particular attention should be given to siting launch and recovery sites away from animals (out of sight if possible) and maintaining a reasonable distance from animals at all times during flight. ***Cease UAV operations if they are excessively disruptive.*** Animal responses should be measured during UAV

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
						operations (and before and after if possible). ***Provide detailed, accurate reporting of methods and results in publications.*** UAV specifications and flight practices should be reported accurately and in full.
A colonial-nesting seabird shows no heart-rate response to drone-based population surveys East Bay Island, Canada	Geldart et al. (2022)	Ducks	– Drones can be a suitable tool for surveying wildlife populations while minimizing disturbance – Drone surveys offer a less invasive alternative to ground- and occupied aircraft-based surveys, which have been associated with increases in heart rate by colonial-nesting seabirds	– Small, quadrotor drone – Transects at 30 m altitude	found that incubating eider ducks did not leave their nest, nor alter their heart rate, in response to a rotary propeller drone flying over them as part of grid-pattern survey fights.	Research that monitors both behavioural and physiological responses of wildlife during comprehensive drone-based survey methods will help improve population survey results, as well as evaluate the impacts of drone use for wildlife studies, and ultimately help to minimize disturbance to wildlife.
Thermal Imaging of Beach-Nesting Bird Habitat with Unmanned Aerial Vehicles: Considerations for Reducing Disturbance and Enhanced Image Accuracy North Carolina, USA	Mapes et al. (2020)	Least tern and other species of colonial beach-nesting birds.	– Evidence that a combination of sky-blue camouflage and flying on cloudless days eliminated disturbance in nesting birds at our study site – Biggest reduction in bird disturbance occurred when flying on cloudless days and when the UAV was camouflaged with solid sky blue – Findings may not be transferrable to surveys using rotocopter-style UAVs	– Fixed-wing drone used – Launch/landing location at least 350 m outside of the nesting area – UAV would circle for at least 30 to 60 s so that the UAV was observable to the birds before entering the airspace over the colony – Whole-colony flushing occurred, so modifications to the UAV were made. Bird responses to the	In two trials, birds were disturbed substantially, flying out in a semi-circle over water then returning. Less disturbance and flushing occurred when the UAV was programmed to make additional passes further from the colony. Birds demonstrated very different behavioural responses between flights flown at similar altitude; thus, authors conclude that behavioural reactions	Recommend that UAV flight paths should allow the target bird species additional time to observe the UAV in flight outside of the colony boundaries or habitat area, therefore allowing the UAV to be assessed as a non-threat or allowing birds to habituate to its presence.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
				modified UAV were then assessed. Multiple physical modifications were made to its color, including the use of dazzle camouflage and painting the underside of the UAV. – Flight altitudes of 85 m to 120 m – Monitored disturbance to beach-nesting birds using continuous behavioural observations	were likely influenced more by other factors such as cloud cover or specific UAV flight path.	
Nest defense behaviour of four raptor species (osprey, bald eagle, ferruginous hawk, and red-tailed hawk) to a novel aerial intruder – a small rotary-winged drone Saskatchewan, Canada and Montana USA.	Junda et al. (2016)	Raptors – four species	– All four species showed similar aggressive responses to both ground and UAV surveys – Although aggression varied, no species showed aggression at levels that would discourage the use of UAVs to survey raptor nests	– Quad-copter used (60 dB at 3m) – Each survey was split into three stages: approach, at nest, and withdraw – Majority of surveys started at approximately 100 m distant, and pilot would then launch the UAV from an open site, gain elevation until above nest height, and then fly towards the nest, attempting to hover over the nest – Nest height varied between species but was between 4 – 20 m	Overall, each species showed significantly different responses to drones but consistent with nest defence behaviour for their species, to the UAV in the air near their nests. Ospreys were most aggressive to the UAV.	None specifically mentioned, but authors stated that when a proper flight technique is adopted, UAVs can offer a useful tool for surveying raptor nests.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
Species-Specific Responses of Bird Song Output in the Presence of Drones **Pennsylvania, USA**	Wilson et al. (2021).	Songbirds	– Study concludes that a drone hovering at 48 m above ground level for 3 min causes little overall change in songbird output in the area below the drone, within a 50 m radius	– Hovered a small quadcopter over a pre-determined count location for 3 min at 48 m high.	There were significant impacts of the drone on the detection of the songs of two species: the Yellow Warbler, which saw a substantial drop in song detection while the drone was overhead, and the Northern Cardinal, which saw a significant increase in song detection, especially after the drone's departure. Pronounced increase in Northern Cardinal contact/alarm calls during and following the drone flights	Researchers who propose to use drones to record bird vocalizations should do so cautiously by using the quietest vehicle that would suit their needs, and by flying the drone at a height that will minimize the possibility of noise disturbance.
Measuring behavioural responses of sea turtles, saltwater crocodiles, and crested terns to drone disturbance to define ethical operating thresholds Northern Territory and Western Australia, Australia	Bevan et al. (2018).	Sea turtles, crocodiles and crested terns.	– Study demonstrates that the drone altitude that elicits disturbance varies by taxa – Factors that contribute to the specific disturbance threshold for a given species include the ability of a species to detect the visual disturbance of drones and the unique sound signature of a particular drone, the degree to which drone disturbance is associated with a threatening stimulus (a predator), and the ambient noise level of a given habitat	– 350 mm quadcopter drone – Flight altitudes between 10 and 60 m (varied between species and habitat)	Sea turtles in nearshore waters off nesting beaches or in foraging habitats exhibited no evasive behaviours (e.g. rapid diving) in response to the drone at or above 20–30 m altitude. Flyovers elicited a range of behaviours from crocodiles, including minor, lateral head movements, fleeing, or complete submergence when a drone was present below 50 m altitude. A colony of crested terns resting on a sand-bank displayed disturbance behaviours	Using drones to study colonies of crested terns requires a higher altitude approach (> 60 m) than for the other species investigated to avoid disturbance.

Article, Location of Study and Classification	Authors	Relevant species/taxa	Key relevant findings	Drone type/distance/frequency	Species response to drone/potential impacts	Mitigation measures
					(e.g. flight response) when a drone was flown below 60 m altitude.	

5. Conclusion

5.1 Key outcomes

The key findings identified by the literature review are summarised below.

5.1.1 Are birds and/or other animals disturbed by drones?

Most studies identified that birds and other taxa are disturbed by drones (McEvoy et al. 2016; Bech-Hansen et al. 2020; Bevan et al. 2018). However, the degree of disturbance and associated bird or animal response (i.e., flying away, vigilance behaviour, not visibly disturbed) appears to be influenced by a range of factors, which are discussed below.

The type and size of drone

Evidence from the literature indicates the type of drone influences the level of disturbance (for birds, at least), and that quadcopter model drones are less likely to disturb birds than fixed-wing drones (McEvoy et al. 2016; Lyons et al. 2018). A common suggestion made by some authors is that fixed-winged drones more resemble the shape of an aerial predator (i.e., raptor) (McEvoy et al., 2016; Egan et al., 2020). This hypothesis was consistent with findings from Mapes et al. (2020), who found that terns and other colonial nesting birds could not be approached by a fixed-wing drone without significant disturbance until drone modifications were made (i.e., camouflaging the drone). Drone size also appears to be an important factor in disturbing birds, with larger drones (i.e., 605 mm diagonal span) more likely than smaller drones (ranging between 213 – 354 mm diagonal span) to induce flight (Wilson et al. 2023).

The distance between the drone and the animal

Most studies investigating the effects of drone disturbance on animals assess the point at which the focal animal (i.e., a flock of birds) detects an approaching drone. Wilson et al. (2023) concluded that disturbance generally increases within decreased distance between the drone and the animal. This finding is consistent with other studies that found greater disturbance responses when a drone was flown closer to Common Redshank, seabirds and shorebirds (Valle and Scarton 2020; Weimerskirch et al. 2018; Benjamin 2017). Some studies show that the drone launching location is important, with increased distance between the launch location and animal location resulting in less disturbance (McEvoy et al. 2016). The angle of approach may also be a contributing factor in disturbance. In France, Vas et al. (2015) found that birds (flamingos, mallards and Common Greenshank) reacted most when the drone was directly overhead while approaching the birds. However, when the drone was not directly overhead, there was little significant reaction from the birds.

The species of animal and the composition/size of the flock (in mixed-flock situations)

Throughout the literature, many studies identify that different species and taxa respond differently to drone disturbance. Wilson et al. (2023) found the Eastern Curlew (a large shorebird) to be extremely sensitive to drone-induced disturbance and could not be approached from above by a drone from any tested height (up to 120 m). However, the closely related Whimbrel (a large shorebird, but smaller than the curlew) was less sensitive to drone-induced disturbance and could mostly be approached to 80 m without disturbance (Wilson et al. 2022). Other smaller migratory shorebirds tested in that same study (e.g., Great Knot) could be approached to within 50 m before being disturbed (Wilson et al. 2022).

Conversely to Wilson et al. (2022), a study from the UAE by Benjamin (2017) found that smaller shorebirds were 33 times more likely to be flushed by a drone than larger shorebirds, but did acknowledge that flushing from one or more members of birds in a group can elicit flushing behaviour of other birds that may not have flushed individually. Benjamin (2017) also considered that group size may influence bird flushing behaviour, with birds occurring in groups more likely to flush than birds that were alone (but that observation was potentially confounded by bird body size – birds on their own tended to be larger).

Variability in species response is prevalent throughout the literature. Weston et al. (2020) reported the highest non-response rates (60%) to drone approaches at 4 m altitude involved waterbirds (Pacific Black Duck, Eurasian Coot, Purple Swamphen) but Little Raven would regularly exhibit a flight response when the drone was up to 65 m high. For non-avian fauna, saltwater crocodiles were shown to elicit a range of disturbance responses from drones below 50 m, while sea-turtles would often not respond to a drone at or above 20–30 m altitude (Bevan et al. 2018).

The habitat and behaviour of animal (i.e., nesting or foraging)

Many of the reviewed studies focussed on the response of animals during a specific period of their life cycle (e.g., the breeding season). Geldart et al. (2022) found that ducks did not leave their nests in response to drone disturbance, a finding consistent with that found by Weimerskirch et al. (2018) in penguin breeding colonies, even when drones approached as close as 3 metres. It is possible that species-specific responses vary depending on the timing of drone disturbance within an animal's life cycle stage (i.e., adults more inclined to take flight when not nesting). Wilson et al., (2022) proposed that the impacts from drone disturbance on migratory shorebirds may be more severe closer to the period of migration.

5.1.2 What type/nature of response do birds and/or other animals show to drones?

Do animals return to normal behaviour/back to same habitat after drone disturbance?

Most of the reviewed studies focussed on whether animals (particularly birds) were disturbed by drones and when the disturbance occurred (i.e., at specific distances). Few studies explore the behavioural response of birds following disturbance by drones, presumably because this can be difficult to quantify (i.e., particularly in large flocks). Kaldor (2019) identified that repeated disturbance of birds (from a range of human disturbances, not just drones) can result in changed behaviour and may cause birds to 'permanently' leave an area. That study also highlighted for birds that response to disturbance is species-specific, with some flying much farther away than others. Problematically, a bird's behaviour when they land again is often modified, with birds showing increased vigilance. Increased time for vigilance means less time for feeding activity and this can result in reduced condition (Kaldor 2019).

When considering drone disturbance, it is prudent to compare this disturbance with disturbance caused by other survey methods and approaches and also the disturbance background that wildlife encounters in the absence of drones. Background disturbances may include birds of prey, introduced predators and pets (i.e., cats, foxes, dogs), humans, wind and other birds. When considering this background disturbance, it is important to understand if additional disturbance caused by drones will have substantial costs for a particular species.

No approach for animal observation or monitoring (or for larvicide treatment, as for this project) is likely to be entirely free of some sort of disturbance. Many authors contend that, when compared with more traditional survey methods (i.e., humans walking transects), drones often had less disturbance on birds (Valle and Scarton 2020; McKeller et al. 2021).

Species-specific responses (flocks influenced by most susceptible species)

An important finding from a recent study was that, in mixed-flock situations, some species may serve as sentinel species for others. Wilson et al. (2023) found that flight response to drones by the Eastern Curlew is often followed by flight responses by other species. However, this effect appears to vary depending on species. For example, Black Swans rarely took flight at the same time as Eastern Curlew, whereas Bar-tailed Godwit almost always did (Wilson et al. 2023). This finding was also consistent with findings from a study in the UAE with regards to shorebird flushing behaviour in response to drones (Benjamin 2017). Therefore, in mixed-flock situations, the species composition of the flock may contribute to specific species disturbance responses to drones.

5.1.3 Are MNES likely to be impacted by drone disturbance?

A key finding from Wilson et al. (2023) in Moreton Bay, Queensland, was that the Eastern Curlew (threatened and migratory under the EPBC Act) was highly susceptible to drone disturbance and could not be approached vertically by a drone from any tested height (up to 120 m). However, in the same study, other migratory shorebirds such as the Bar-tailed Godwit, Whimbrel and Great Knot would tolerate a drone approaching to closer distances without disturbance (up to 50 m for Great Knot, but 75 m and 80 m for the Bar-tailed Godwit and Whimbrel respectively). Other MNES, such as the Common Greenshank, tolerated an approaching drone at 30 m high with no reaction recorded 87% of the time (Vas et al., 2015). Another study by Benjamin (2017) found that shorebirds were less likely to be flushed by a drone approaching at heights greater than 15 m and travelling a slower speeds. Therefore, it is considered most likely that the impact of drones on avian MNES is likely to be species-specific and dependent on the nature of interaction with the drone (i.e., height of the drone, speed of the drone, angle of approach, where the drone took off, size of the drone, flock composition).

5.2 Knowledge gaps

5.2.1 Species-specific responses to drones for MNES

While this literature review has provided some insight into the likely responses of some MNES to drone disturbance, it has also highlighted that there is considerable species-specific variability in responses to drone disturbance, even amongst closely related species such as the Eastern Curlew and Whimbrel (Wilson et al. 2022). This presents a significant challenge when assessing impacts of drone disturbance on species for which there is currently no information available, such as MNES species: Orange-bellied Parrot (*Neophema chrysogaster*), Growling Grass Frog (*Litoria raniformis*), Australian Grayling (*Prototroctes maraena*) and Sharp-tailed Sandpiper (*Calidris acuminata*).

For aquatic and semi-aquatic species such as the Australian Grayling and Growling Grass Frog, there was no literature found or reviewed that provided insight into how these species may be impacted by drones. However, given the size, behaviour and microhabitats occupied by these species, it is expected that the response of these species to drones would be minimal. For example, unlike birds, frogs do not occupy the same space as drones (i.e., not using the airspace, so no risk of collision) and are generally less mobile and occupy smaller home ranges than most birds. Drone disturbance would not result in frogs leaving their home range and is unlikely to have a substantial energetic cost on frogs. In response to drones, frogs would be expected to, at most, temporarily change microhabitat use (i.e., hop into water, burrow into vegetation) or behaviour (i.e., cessation of calling during a drone pass over) which frogs are expected to regularly undertake in response to other disturbance (i.e., predators, humans).

5.2.2 How does drone disturbance impact on bird behaviour and physiology in the long term?

Most studies in the reviewed literature focus on the initial behavioural response of birds to drones, with little exploration of the longer-term behavioural and physiological impact of drone disturbance on birds. Longer-term impacts are likely to be dependent on the magnitude, duration and frequency of drone disturbance, for which there is little to no information within the literature. Most studies assess drone-related disturbance as a brief snapshot in time, which fails to capture the potential longer-term implications for species where drones are a regular source of disturbance. Benjamin (2017) posits that shorebirds may be subject to physiological effects that are not visible, such as increases in heart rate, basal metabolism or release of stress hormones. These effects could have important deleterious impacts on some species, such as migratory shorebirds. Weimerskirch et al. (2018) explored the link between the behavioural and physiological response of King Penguins to drone disturbance and found that even when breeding adults showed no behavioural sign of stress, they had a significant increase in heart rate. Wohler (2018) concluded that the impacts of drones on shorebirds and terns are unclear and that caution is warranted, as disturbance of shorebirds or terns at any time (i.e., nesting, roosting or feeding) is likely to have adverse effects.

5.2.3 Drone collisions with birds

No research was uncovered in this literature review that reported on or explored the potential for bird collisions with drones (as distinct from birds, e.g., raptors, attacking drones). A number of factors, such as those discussed above (i.e., take off location, drone altitude, drone size), may influence bird collision risk and further investigation is warranted about whether drones are likely to pose a significant risk to birds due to collision.

5.3 Recommendations for future programs

The following recommendations are made with consideration of the potential future use of drones around wildlife:

- Hodgson and Koh (2017) provide guidelines for drone use and provide a suite of recommendations as the basis for a code of best practice in the use of drones in the vicinity of animals or for the purpose of animal research (see Table 6). The guidelines could be used as a starting point in formulating methods around using drones where MNES are or may be present.
- The type and size of drone are shown to influence bird disturbance. Where possible, it is recommended that small, quadcopter drones be used, to reduce the likelihood of disturbing birds and other wildlife
- Drone take off location, flight height and flight speed have been shown to influence bird disturbance, but responses vary between species. It is recommended that a cautious approach is applied to future programs using drones, by incorporating the guidelines provided by Hodgson and Koh (2017) and considering other information contained within this literature review.
- As far as reasonably practicable to achieve program outcomes, drones should take off far away from animals, travel at high altitudes and move at slow speeds
- Consideration should be given to the number of flyovers a drone needs to make at any site. Multiple flyovers may increase disturbance, even to the point where fauna abandon a site
- For any future program that involves drones operating near wildlife, establish an appropriate monitoring program alongside the drone use, to document observations of disturbance and gauge the level of concern that eventuates for that project at that site with those species

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Appendix A

Treatment sites

PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1a

Proposed Treatment Site Changes

- Existing Aerial Site
- Proposed Aerial Site Removal
- Proposed Ground Site Removal



0 400 800 1,600 m

N

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PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1b

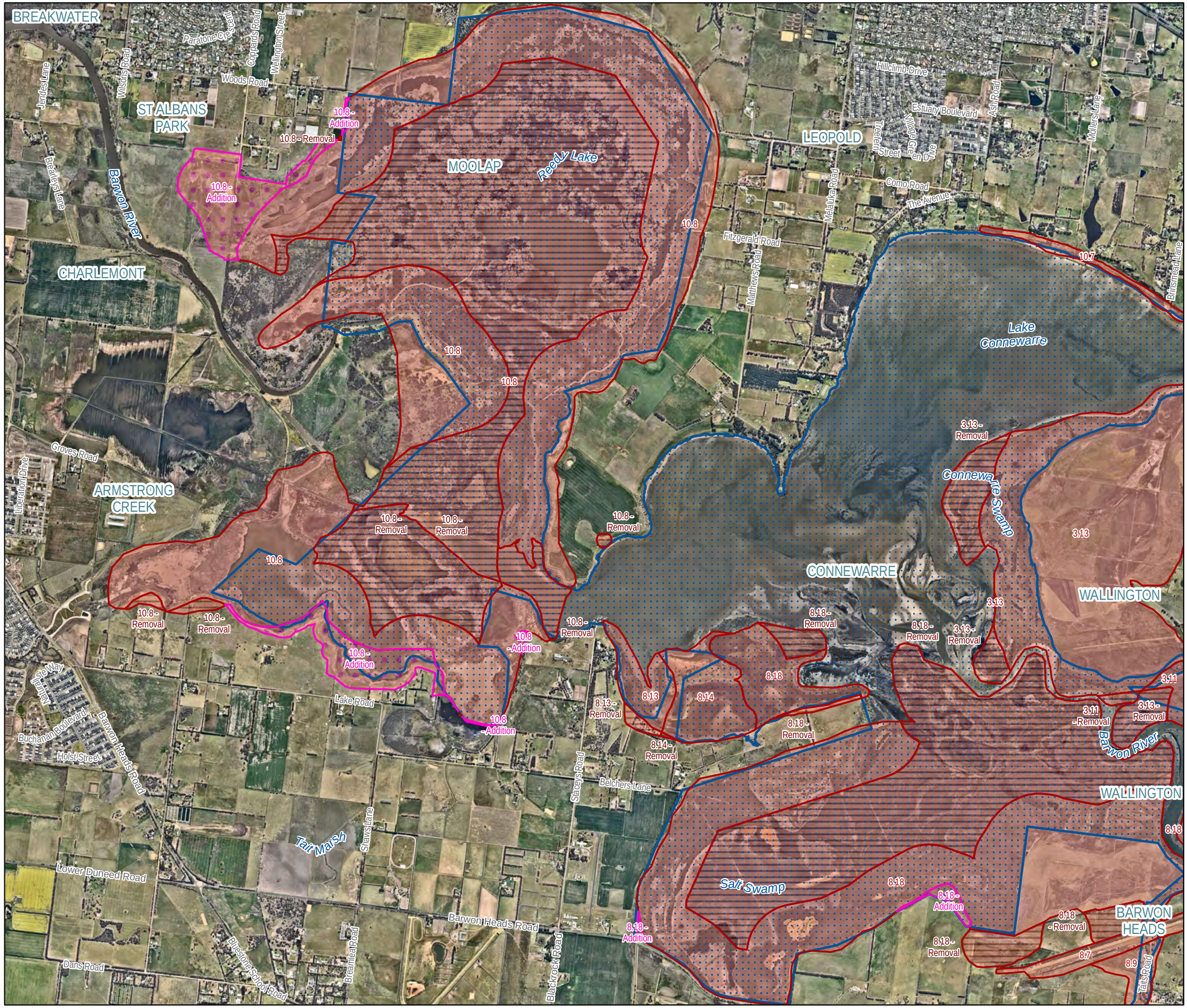
Ramsar Wetland

Proposed Treatment Site

Existing Aerial

Proposed Aerial Site

Proposed Aerial Site

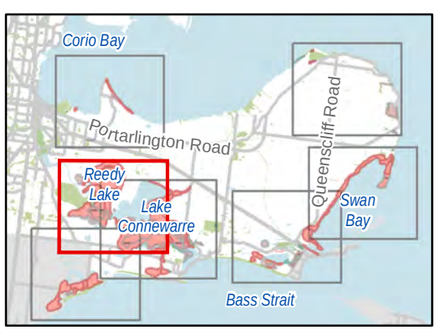


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PREVIOUS REFERAL &
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FIGURE - 1c

Ramsar Wetland

Proposed Treatment Site Changes

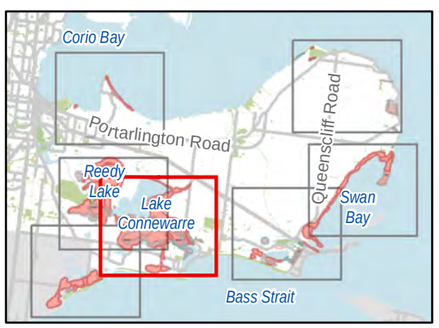
- Existing Aerial Site
- Proposed Aerial Site
- Proposed Aerial Site Removal
- Existing Ground Site
- Proposed Ground Site Addition
- Proposed Ground Site Removal

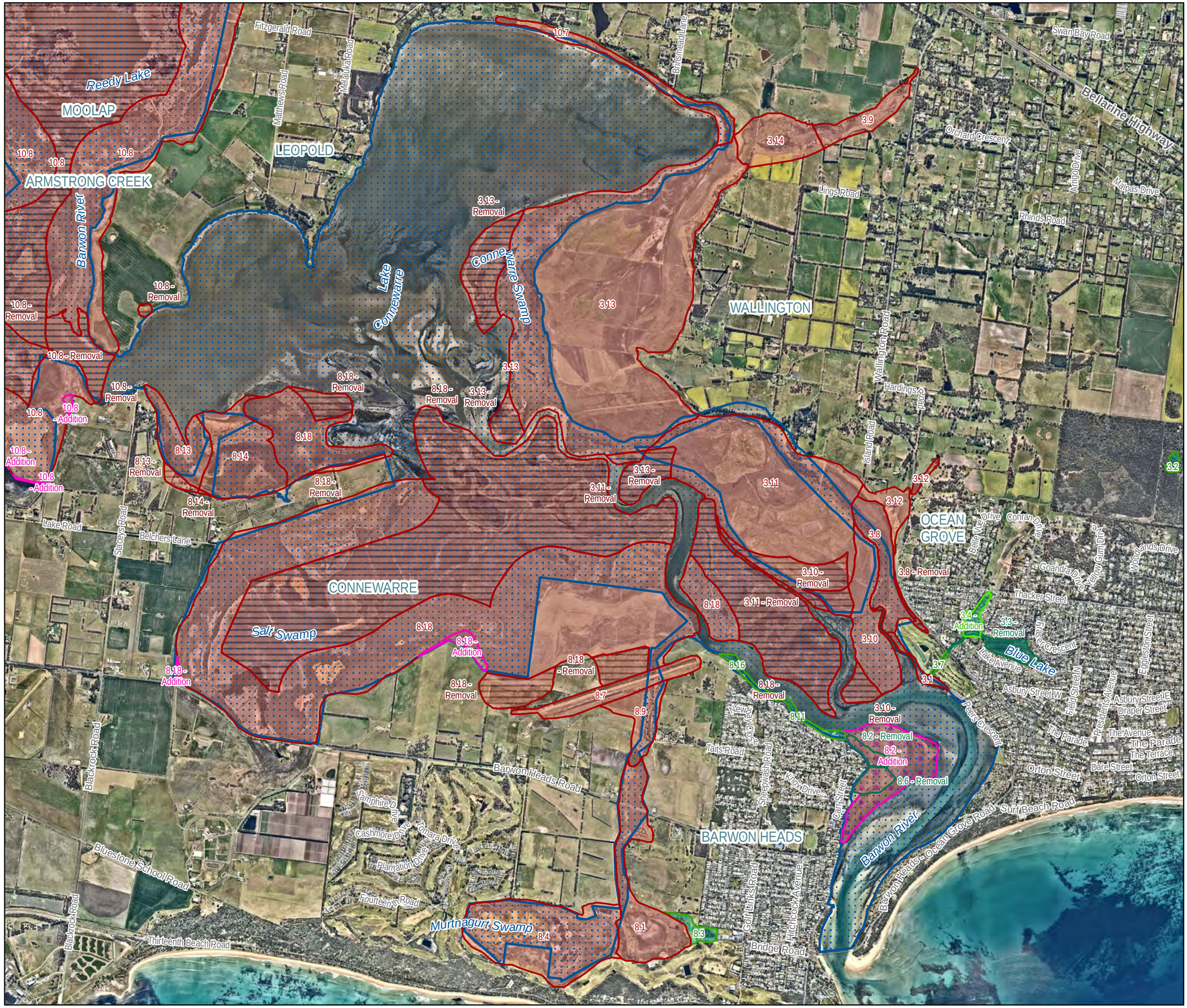
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PREVIOUS REFERAL &
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FIGURE - 1d

Ramsar Wetland

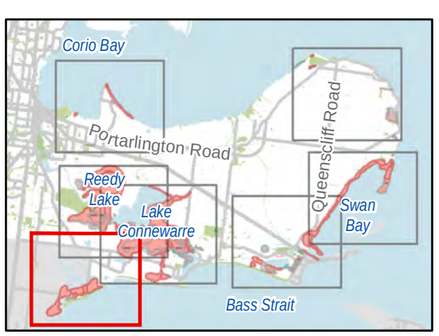
Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site

Proposed Aerial Site Removal





0 400 800 1,600 m

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PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1e

Site 1.7- Ground Treatment

Ramsar Wetland

Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site

Proposed Aerial Site Removal

Existing Ground Site

Proposed Ground Site Addition

Proposed Ground Site Removal

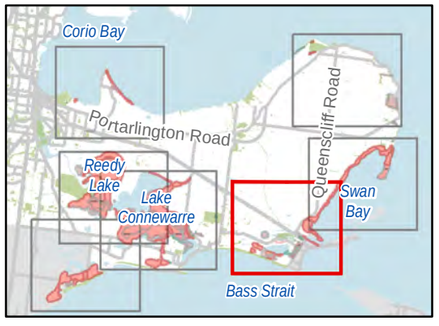
Marine National Park

0 400 800 1,600 m

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FIGURE - 1f

Ramsar Wetland

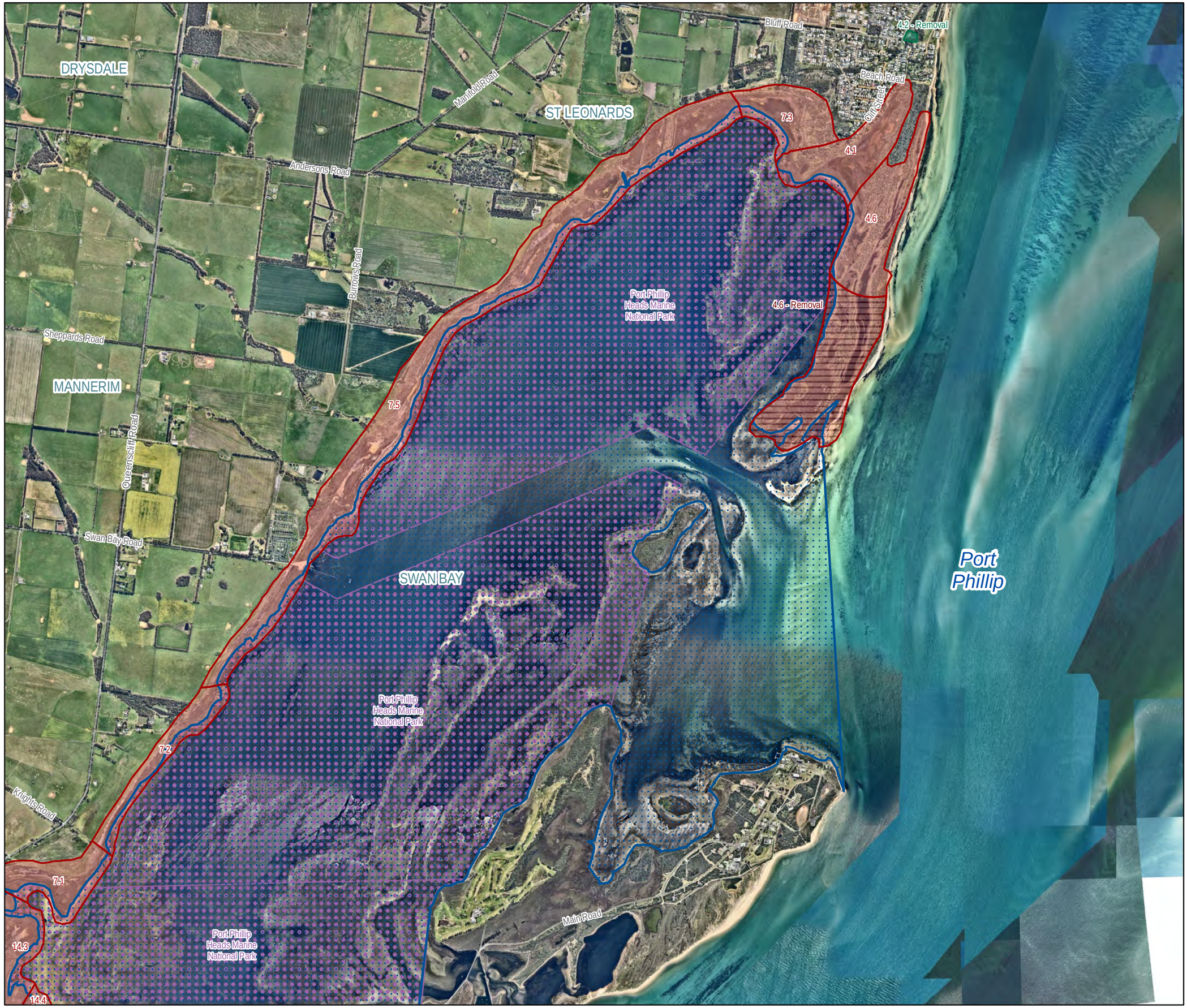
Proposed Treatment Site Changes

Existing Aerial Site

Proposed Aerial Site Removal

Proposed Ground Site Removal

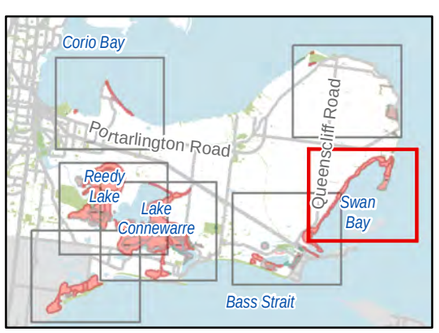
Marine National Park



0 400 800 1,600 m

N

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PREVIOUS REFERAL &
PROPOSED SITE ADDITIONS

FIGURE - 1g

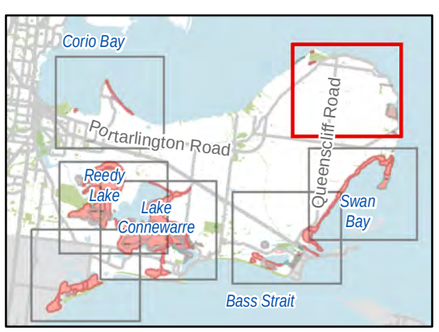
Proposed Treatment Site Changes

- Existing Aerial
- Proposed Aerial Site
- Existing Ground Site
- Proposed Ground Site Removal

0 400 800 1,600 m

N

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Appendix B

List of all literature

Authors	Title	Publication	Publisher	ArticleURL	Classification	Question
A Aabid, B Parveez, N Parveen, SA Khan…	Reviews on design and development of unmanned aerial vehicle (drone) for different applications	Journal of Mechanical Engineering Research	jmerd.net	https://jmerd.net/Paper/Vol.45,No.2(2022)/	4	1
A Abdulkarim, AB Alhassan	A Review on Unmanned Aerial Vehicle Energy Sources and Management	nternational Conference on Emerging Applications and Technologies for Industry 4.0	books.google.co	https://books.google.com/books?hl=en&lr=	4	1
A Alaimo, V Artale, G Barbaraci…	LQR-PID control applied to hexacopter flight	Journal of Numerical Analysis, Industrial and Applied Mathematics	jnaiamcont.org	http://jnaiamcont.org/uploads/Volume9-10_	4	1
A Al-Hourani, K Gomez	Modeling cellular-to-UAV path-loss for suburban environments	IEEE Wireless Communications	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Al-Mousa, BH Sababha, N Al-Madi…	UTSim: A framework and simulator for UAV air traffic integration, control, and communication	nternational Journal of Advanced Robotic Systems	journals.sageput	https://journals.sagepub.com/doi/abs/10.11	4	1
A Al-Naji, AG Perera, J Chahl	Remote measurement of cardiopulmonary signal using an unmanned aerial vehicle	IOP Conference Series: Materials Science and Engineering	iopscience.iop.or	https://iopscience.iop.org/article/10.1088/1	4	1
A Al-Naji, AG Perera, J Chahl	Remote monitoring of cardiorespiratory signals from a hovering unmanned aerial vehicle	Biomedical engineering online	Springer	https://link.springer.com/article/10.1186/s1	4	1
A Alonso-Arroyo, A Camps, A Monerris…	The light airborne reflectometer for GNSS-R observations (LARGO) instrument: Initial results from airborne and Rover field campaigns	IEEE Geoscience and Remote Sensing Symposium	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Al-Rawabdeh, F He, A Moussa, N El-Sheimy…	Using an unmanned aerial vehicle-based digital imaging system to derive a 3D point cloud for landslide scarp recognition	Remote sensing	mdpi.com	https://www.mdpi.com/2072-4292/8/2/95	4	1
A Alsahlani, T Rahulan…	Composite structural analysis of a high altitude, solar powered unmanned aerial vehicle	International Journal of Mechanical Engineering and Robotics Research	salford-repositon	https://salford-repository.worktribe.com/out	4	1
A Alshearya, A Almagbile, M Alqrashi, J Wang, H Khalil…	Assessment of the applicability of unmanned aerial vehicle (UAV) for mapping levels of crowd density	Proceedings of the 9th International Symposium on Mobile Mapping Technology			4	1
A Baldini, R Felicetti, A Freddi, S Longhi…	Actuator fault tolerant position control of a quadrotor unmanned aerial vehicle	4th Conference on Control and Fault Tolerant Systems	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Boretti	Modeling unmanned aerial vehicle jet ignition wankel engines with CAE/CFD	Advances in aircraft and spacecraft science	techno-press.org	http://www.techno-press.org/content/?page	4	1
A Boretti	High power-density, high efficiency, mechanically assisted, turbocharged direct-injection jet-ignition engines for unmanned aerial vehicles	SAE International Journal of Aerospace	sae.orgsae.org	https://www.sae.org/publications/technical-	4	1
A Bouguettaya, H Zarzour, AM Taberkit, A Kechida	A review on early wildfire detection from unmanned aerial vehicles using deep learning-based computer vision algorithms	Signal Processing	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
A Briggs	Using Unmanned Aerial Vehicle Technology to Enhance Conservation Biology Research	N/A - not released within publication	digitalcommons.u	https://digitalcommons.unl.edu/honorsthes	3	1
A Bulgakov, D Sayfeddine, T Bock…	Generation of orthomosaic model for construction site using unmanned aerial vehicle	Proceedings of the International Symposium on Automation and Robotics in Construction	search.proquest.	https://search.proquest.com/openview/5fd3	4	1
A Burkart, VL Hecht, T Kraska, U Rascher	Phenological analysis of unmanned aerial vehicle based time series of barley imagery with high temporal resolution	Precision agriculture	Springer	https://link.springer.com/article/10.1007/s1	4	1
A Cruden, S Vollgger, G Dering…	High spatial resolution mapping of dykes using unmanned aerial vehicle (UAV) photogrammetry: new insights on emplacement processes	Acta Geologica Sinica	researchgate.net	https://www.researchgate.net/profile/Tahse	4	1
A Desai, DJ Lee, M Zhang	Using accurate feature matching for unmanned aerial vehicle ground object tracking	Advances in Visual Computing: 10th International Symposium	Springer	https://link.springer.com/chapter/10.1007/9	4	1
A Di Tommaso, A Betti, G Fontanelli, B Michelozzi	A multi-stage model based on YOLOv3 for defect detection in PV panels based on IR and visible imaging by unmanned aerial vehicle	Renewable Energy	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
A Dunstan, K Robertson, R Fitzpatrick, J Pickford…	Use of unmanned aerial vehicles (UAVs) for mark-resight nesting population estimation of adult female green sea turtles at Raine Island	N/A - not released within publication	journals.plos.org	https://journals.plos.org/plosone/article?id=	3	1
A Ellenberg, A Kontsos, F Moon…	Bridge related damage quantification using unmanned aerial vehicle imagery	Structural Control and Health Monitoring	Wiley Online Libr	https://onlinelibrary.wiley.com/doi/abs/10.1	4	1
A Finn, K Rogers	An analysis of unmanned aerial vehicle-based acoustic atmospheric tomography	Proc. Acoustics 2016: The Second Australiasian Acoustical	acoustics.asn.au	https://acoustics.asn.au/conference_proce	4	1
A Finn, K Rogers, F Rice, J Meade…	A comparison of vertical atmospheric wind profiles obtained from monostatic sodar and unmanned aerial vehicle–based acoustic tomography	Journal of Atmospheric and Oceanic Technology	journals.ametsoc	https://journals.ametsoc.org/view/journals/a	4	1
A Hamilton, AHS Magdalene	Study of solar powered unmanned aerial vehicle to detect greenhouse gases by using wireless sensor network technology	J Sci Eng Educ (ISSN 2455-5061)	ccetbhilai.ac.in	https://www.ccetbhilai.ac.in/wp-content/upl	4	1
A Hamza, U Akram, A Samad, SN Khosa…	Unmaned aerial vehicles threats and defence solutions	2020 IEEE 23rd International Multitopic Conference	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Harmat, M Trentini, I Sharf	Multi-camera tracking and mapping for unmanned aerial vehicles in unstructured environments	Journal of Intelligent &Robotic Systems	Springer	https://link.springer.com/article/10.1007/s1	4	1
A Hodgson, N Kelly, D Peel	Unmanned aerial vehicles (UAVs) for surveying marine fauna: a dugong case study	PloS one	journals.plos.org	https://journals.plos.org/plosone/article?id=	3	1
A Jeon, J Kang, B Choi, N Kim, J Eun, T Cheong	Unmanned aerial vehicle last-mile delivery considering backhauls	IEEE Access	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Kavvadias, E Psomiadis, M Chanioti…	Unmanned Aerial Vehicle (UAV) data analysis for fertilization dose assessment	Remote Sensing for Agriculture, Ecosystems, and Hydrology XIX	spiedigitallibrary.	https://www.spiedigitallibrary.org/conferenc	4	1
A Kreij, J Scriffignano, D Rosendahl, S Ulm	Aboriginal stone-walled intertidal fishtrap morphology, function and chronology investigated with high-resolution close-range Unmanned Aerial Vehicle …	Journal of Archaeological Science	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
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A Malaver, N Motta, P Corke, F Gonzalez	Development and integration of a solar powered unmanned aerial vehicle and a wireless sensor network to monitor greenhouse gases	Sensors	mdpi.com	https://www.mdpi.com/1424-8220/15/2/407	4	1
A Matese, A Berton, V Chiarello, R Dainelli, C Nati…	Determination of riparian vegetation biomass from an unmanned aerial vehicle (UAV)	Forests	mdpi.com	https://www.mdpi.com/1999-4907/12/11/15	4	1
A Matus-Vargas, G Rodriguez-Gomez…	Ground effect on rotorcraft unmanned aerial vehicles: A review	Intelligent Service Robotics	Springer	https://link.springer.com/article/10.1007/s1	4	1
A McLachlan, O Defeo, E Jaramillo, AD Short	Sandy beach conservation and recreation: Guidelines for optimising management strategies for multi-purpose use	Ocean & coastal management	ElsevierElsevier	ElsevierElsevierElsevierElsevierElsevier	4	1
A Michez, H Piégay, L Jonathan, H Claessens…	Mapping of riparian invasive species with supervised classification of Unmanned Aerial System (UAS) imagery	International Journal of Applied Earth Observation and Geoinformation	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
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A Navarro, M Young, B Allan, P Carnell…	The application of Unmanned Aerial Vehicles (UAVs) to estimate above-ground biomass of mangrove ecosystems	Remote sensing of environment	ElsevierElsevier	https://www.sciencedirect.com/science/arti	3	1
A Nishar, S Richards, D Breen, J Robertson, B Breen	Thermal infrared imaging of geothermal environments and by an unmanned aerial vehicle (UAV): A case study of the Wairakei–Tauhara geothermal field, Taupo, New …	Renewable Energy	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
A Poissant, L Castano, H Xu	Mitigation of Ground Impact Hazard for Safe Unmanned Aerial Vehicle Operations	Journal of Aerospace Information	arc.aiaa.org	https://arc.aiaa.org/doi/abs/10.2514/1.I010	4	1
A Rahman, S Sakif, N Sikder, M Masud…	Unmanned Aerial Vehicle Assisted Forest Fire Detection Using Deep Convolutional Neural Network	Intell. Autom. Soft Comput.	cdn.techscience.	https://cdn.techscience.cn/ueditor/files/iasc	4	1
A Rawluk, R Beilin, H Bender, R Ford, A Rawluk, R Beilin, H Bender	Adaptive Doing in Tarerer/Kelly Swamp	Practices in Social Ecological Research: Interdisciplinary collaboration in'adaptive doing'	Springer	https://link.springer.com/chapter/10.1007/9	4	1
A Roder, KKR Choo, NA Le-Khac	Unmanned aerial vehicle forensic investigation process: Dji phantom 3 drone as a case study	arXiv preprint arXiv:1804.08649	arxiv.org	https://arxiv.org/abs/1804.08649	4	1
A Samad, D Alvarez Florez, I Chourdakis, U Vogt	Concept of using an unmanned aerial vehicle (UAV) for 3D investigation of air quality in the atmosphere—example of measurements near a roadside	Atmosphere	mdpi.com	https://www.mdpi.com/2073-4433/13/5/663	4	1
A Samsu, AR Cruden, S Micklethwaite, L Grose…	Scale matters: The influence of structural inheritance on fracture patterns	Journal of Structural Geology	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
A Santos-Rufo, FJ Mesas-Carrascosa, A García-Ferrer…	Wavelength selection method based on partial least square from hyperspectral unmanned aerial vehicle orthomosaic of irrigated olive orchards	Remote Sensing	mdpi.com	https://www.mdpi.com/2072-4292/12/20/34	4	1
A Sattar, L Wang, A Mohamed…	System identification of fixed-wing uav with multi-segment control surfaces	2019 Australian & New Zealand Control Conference	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
A Shafique, A Mehmood, M Elhadef, KH Khan	A lightweight noise-tolerant encryption scheme for secure communication: An unmanned aerial vehicle application	Plos one	journals.plos.org	https://journals.plos.org/plosone/article?id=	4	1
A Simic Milas, AP Cracknell…	Drones–the third generation source of remote sensing data	International Journal of Remote Sensing	Taylor &Francis	https://www.tandfonline.com/doi/full/10.108	4	1
A Simic Milas, JJ Sousa, TA Warner…	Unmanned Aerial Systems (UAS) for environmental applications special issue preface	International Journal of Remote Sensing	Taylor &Francis	https://www.tandfonline.com/doi/full/10.108	4	1
A Singhal	Impact of drone technology on human life	Bodhi Int. J. Res. Human. Arts Sci	researchgate.net	https://www.researchgate.net/profile/Roy-V	4	1
A Smirnov, E Smolokurov, E Timofeeva…	Problems and prospects for the development of unmanned aerial vehicles in Russia	E3S Web of Conferences	search.proquest.	https://search.proquest.com/openview/4d0	4	1
A Su, X Sun, H Liu, X Zhang…	Online cascaded boosting with histogram of orient gradient features for car detection from unmanned aerial vehicle images	Journal of Applied Remote Sensing	spiedigitallibrary.	https://www.spiedigitallibrary.org/journals/J	4	1
A Sunantyo, S Siswosukarto…	Digital Elevation Model Generated by Unmanned Aerial Vehicle to Determine Available Head Assessment for Micro Hydro Power Plant in Merawu River …	International Energy Conference	researchgate.net	https://www.researchgate.net/profile/Supra	4	1
A SYETIAWAN, Y SUSILO, S SUSILO…	DIRECT GEOREFERENCING IN UNMANNED AERIAL VEHICLE USING QUASI-ZENITH SATELLITE SYSTEM.	Geographia Technica	technicalgeograp	http://technicalgeography.org/pdf/1_2023/C	4	1
A Van Asares, PS Ko, JS Minlay…	Design of an unmanned aerial vehicle blimp for indoor applications	International Journal of Mechanics, Engineering and Robotics	ijmerr.com	http://www.ijmerr.com/uploadfile/2018/1228	4	1
A Vinci, R Brigante, C Traini, D Farinelli	Geometrical characterization of hazelnut trees in an intensive orchard by an unmanned aerial vehicle (UAV) for precision agriculture applications	Remote Sensing	mdpi.com	https://www.mdpi.com/2072-4292/15/2/541	4	1
A Wang, T Chan	Estimation of drag for a quadplane hybrid unmanned aerial vehicle	Student Conference Region VII-AUAt: Melbourne, Australi	researchgate.net	https://www.researchgate.net/profile/Alwin-	4	1

A Wirasatriya, R Pribadi, SB Iryanthony, L Maslukah…	Mangrove Above-Ground Biomass and Carbon Stock in the Karimunjawa-Kemujan Islands Estimated from Unmanned Aerial Vehicle-Imagery	Sustainability	mdpi.com	https://www.mdpi.com/2071-1050/14/2/706	4	1
AA Ateya, A Muthanna, I Gudkova…	Latency and energy-efficient multi-hop routing protocol for unmanned aerial vehicle networks	International Journal of Distributed Sensor Networks	journals.sageput	https://journals.sagepub.com/doi/abs/10.11	4	1
AA Hoshu, L Wang, S Ansari, A Sattar, MHA Bilal	System Identification of Heterogeneous Multirotor Unmanned Aerial Vehicle	Drones	mdpi.com	https://www.mdpi.com/2504-446X/6/10/309	4	1
AA Molina, Y Huang, Y Jiang	A Review of Unmanned Aerial Vehicle Applications in Construction Management: 2016–2021	Standards	mdpi.com	https://www.mdpi.com/2305-6703/3/2/9	4	1
AB Potgieter, B George-Jaeggli, SC Chapman…	Multi-spectral imaging from an unmanned aerial vehicle enables the assessment of seasonal leaf area dynamics of sorghum breeding lines	Frontiers in Plant Science	frontiersin.org	https://www.frontiersin.org/articles/10.3389	4	1
AC Van Andel, SA Wich, C Boesch…	Locating chimpanzee nests and identifying fruiting trees with an unmanned aerial vehicle	American journal of primatology	Wiley Online Libr	https://onlinelibrary.wiley.com/doi/abs/10.1	3	1
AD Tang, T Han, H Zhou, L Xie	An improved equilibrium optimizer with application in unmanned aerial vehicle path planning	Sensors	mdpi.com	https://www.mdpi.com/1424-8220/21/5/181	4	1
AE Mather, RM Fyfe, CC Clason…	Automated mapping of relict patterned ground: An approach to evaluate morphologically subdued landforms using unmanned-aerial-vehicle and structure-from …	Progress in Physical Geography: Earth and Environmen	journals.sageput	https://journals.sagepub.com/doi/abs/10.11	4	1
AE Onuora, CC Mbaocha, PC Eze…	Unmanned aerial vehicle pitch optimization for fast response of elevator control system	International Journal of Scientific Engineering and Science	ijses.com	http://ijses.com/wp-content/uploads/2018/0	4	1
AEC Tan, J McCulloch, W Rack, I Platt…	Radar measurements of snow depth over sea ice on an unmanned aerial vehicle	IEEE Transactions on Geoscience and Remote Sensing	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
AF Rees, L Avens, K Ballorain, E Bevan…	The potential of unmanned aerial systems for sea turtle research and conservation: a review and future directions	Endangered Species Research	int-res.com	https://www.int-res.com/abstracts/esr/v35/p	3	1
AFH Rusli, MSM Aras, MK Aripin…	Modelling of unmanned aerial vehicle (UAV) for altitude control using system identification technique	Journal of Fundamental and Applied Sciences	pjfas.jfas.info	https://www.pjfas.jfas.info/index.php/jfas/ar	4	1
AH Fahim, A Ismail	Intelligent Control of Unmanned Aerial Vehicle	N/A - not released within publication	academia.edu	https://www.academia.edu/download/6438	4	1
AIN Alshbatat, PJ Vial, L Dong	Effect of polytetrafluoroethylene material on dynamic behaviour of an underactuated unmanned aerial vehicle	N/A - not released within publication	ro.uow.edu.au	https://ro.uow.edu.au/eispapers/3323/	4	1
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AJ Mathews, JLR Jensen	Visualizing and quantifying vineyard canopy LAI using an unmanned aerial vehicle (UAV) collected high density structure from motion point cloud	Remote sensing	mdpi.com	https://www.mdpi.com/2072-4292/5/5/2164	4	1
AJ Torija, P Chaitanya, Z Li	Psychoacoustic analysis of contra-rotating propeller noise for unmanned aerial vehicles	The Journal of the Acoustical Society of America	pubs.aip.org	https://pubs.aip.org/asa/jasa/article/149/2/8	4	1
AK Patel, RD Joshi	Coverage Estimation Using Probabilistic Line-of-Sight Model for Unmanned Aerial Vehicle Communication	International Conference on Unmanned Aerial System in Geomatics	Springer	https://link.springer.com/chapter/10.1007/9	4	1
AK Sibley, TN Jain, M Butler, B Nicholson…	Remote scene size-up using an unmanned aerial vehicle in a simulated mass casualty incident	Prehospital Emergency Care	Taylor &Francis	https://www.tandfonline.com/doi/abs/10.10	4	1
AKN Amaral, CA Souza, RS Momoli…	Use of unmanned aerial vehicle to calculate soil loss	Pesquisa Agropecuária Tropical	SciELO Brasil	https://www.scielo.br/j/pat/a/4gtyNwdyr7qY	4	1
AL Fernandes Jr, WE Medeiros, FHR Bezerra…	GPR investigation of karst guided by comparison with outcrop and unmanned aerial vehicle imagery	Journal of Applied Geophysics	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
AL Imoize, SMN Islam, T Poongodi, LK Ramasamy…	Unmanned Aerial Vehicle Cellular Communications	N/A - not released within publication	Springer	https://link.springer.com/book/9783031083	4	1
AL Wiseman, F Bezombes, AJ Moore…	Non-invasive methods: the applicability of unmanned aerial vehicle (UAV) technology for recording fossilised footprints	Digital Applications in Archaeology and Cultural Heritage	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
AN Alves	Control of an unmanned aerial vehicle (UAV) using deep reinforcement learning (DRL) approach	N/A - not released within publication	repositorio.unesp	https://repositorio.unesp.br/handle/11449/2	4	1
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AP Erasmus	Stabilization of a rotary wing unmanned aerial vehicle with an unknown suspended payload	N/A - not released within publication	scholar.sun.ac.z	https://scholar.sun.ac.za/handle/10019.1/1	4	1
AR Jones, R Raja Segaran, KD Clarke…	Estimating mangrove tree biomass and carbon content: a comparison of forest inventory techniques and drone imagery	Frontiers in Marine Science	frontiersin.org	https://www.frontiersin.org/articles/10.3389	4	1
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AR Yusoff	Camera Calibration for Unmanned Aerial Vehicle Mapping	N/A - not released within publication	eprints.utm.my	http://eprints.utm.my/id/eprint/53992/1/Ahm	4	1
AT Tefera, BP Banerjee, BR Pandey, L James…	Estimating early season growth and biomass of field pea for selection of divergent ideotypes using proximal sensing	Field Crops Research	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
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AT Uribe, MP Bunds, J Andreini…	Using Point Clouds Generated from Unmanned Aerial Vehicles Imagery Processed with Structure from Motion to Address Tsunami vs Storm Wave Boulder Deposition …	AGU Fall Meeting Abstracts	ui.adsabs.harvar	https://ui.adsabs.harvard.edu/abs/2017AG	4	1
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AZJ Chen, JPT Mo	Modelling of unmanned aerial vehicle deliveries in populated urban areas for risk management	2016 10th International Conference on Software, Knowledge, Information Management & Applications	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
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B Lee, P Park, K Kim	Operational control logic of series hybrid power system for the unmanned aerial vehicle	Journal of the Korean Society of Propulsion Engineers	The Korean Society of Propulsion …		4	1
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B Liu, W Ni, RP Liu, YJ Guo…	Optimal routing of unmanned aerial vehicle for joint goods delivery and in-situ sensing	IEEE Transactions on Intelligent Transportation Systems	ieeexplore.ieee.c	https://ieeexplore.ieee.org/abstract/docume	4	1
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B Miziński, T Niedzielski	Fully-automated estimation of snow depth in near real time with the use of unmanned aerial vehicles without utilizing ground control points	Cold Regions Science and Technology	ElsevierElsevier	https://www.sciencedirect.com/science/arti	4	1
B Munakamwe	Suitability of Unmanned Aerial Vehicle to Support Communal Land Registration in Zimbabwe	N/A - not released within publication	essay.utwente.nl	http://essay.utwente.nl/91515/	4	1
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Appendix I

Method Statement

City of Greater Geelong Mosquito Control Program – Monitoring Method Statement

17 May 2024

1. Introduction

The City of Greater Geelong municipality (the City) monitors mosquitoes around the Bellarine Peninsula and Greater Geelong region on a weekly basis, upon agreement with the Victorian Department of Health. This typically occurs between August and March each year but may be required outside these periods depending on current research focus. Mosquito monitoring provides a better understanding of mosquito population dynamics in the Greater Geelong region, the potential public health risk from mosquitoes and aims to manage potential outbreaks before they occur through virological testing of mosquito samples. The City monitors both mosquito larvae and adults. In response to the results of the monitoring, the City controls the abundance of adult mosquitoes in the Greater Geelong region with the use of ground and agricultural drone aerial treatments targeting mosquito larvae. The treatment areas include sections of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. The City is currently seeking approval from the Department of Climate Change, Energy, the Environment and Water (DCCEEW) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to conduct aerial treatments at sites that are in the boundaries of Ramsar wetlands, within the municipality, as a part of the City's mosquito management program.

Two larvicides are to be deployed using a calibrated hopper from an aircraft (drone), which treats large areas known to be mosquito breeding habitats. To allow the City to monitor and manage potentially adverse effects of deploying the larvicides (either from the use of a drone or the chemicals themselves), the City is seeking submissions from appropriately qualified consultants to conduct ecological surveys in accordance with requirements proposed to DCCEEW.

2. Purpose of this document

This document provides the detail of methods proposed to be used by GHD for non-target aquatic invertebrate monitoring and bird monitoring for the City. The City proposes to undertake a mosquito management program within the City of Greater Geelong municipality and in the bordering Borough of Queenscliffe and Surf Coast Shire.

3. Limitations

This document: has been prepared by GHD for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and City of Greater Geelong as set out in section 2 of this document.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this document. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this document were limited to those specifically detailed in the report and are subject to the scope limitations set out in the document.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described throughout this document. GHD disclaims liability arising from any of the assumptions being incorrect.

4. Methods

4.1 Non-target aquatic invertebrate monitoring

The following sections detail our proposed methods to allow for site selection and monitoring of non-target aquatic invertebrates. Our methods align with the objectives proposed in the Preliminary Documentation prepared by the City to address the information required by the Minister under section 95A of the EPBC Act for the assessment of the relevant impacts to the proposed action – City of Greater Geelong, Mosquito Control Program (EPBC 2020/8782):

– *3A – Develop and implement non-target aquatic invertebrate monitoring program for the proposed action*
– *3B – Commence monitoring program before the 2022 – 2023 mosquito treatment program of aerial treatment sites.* It is noted that since the issue of the preliminary documentation, the City has changed its method of delivery and subsequently the program timelines have changed. The City now proposes to commence the monitoring program before the 2024-2025 treatment program
– *3C – Undertake seasonal monitoring for three seasons*
– *3D – Apply adaptive mitigation measures pending results of three consecutive seasons of monitoring*

The monitoring program will essentially follow a BACI (Before-After; Control-Impact) study design using multiple lines of evidence to assess the level of risk to non-target invertebrate communities. This 'weight of evidence' approach is consistent with the Environment Reference Standard (Victorian Govt 2021) to make an overall assessment of impacts and associated management.

4.1.1 Site selection

The monitoring program will include 'impact' sites (i.e. locations which will be directly treated) and 'control' sites. For all sites, safe and cost-efficient (i.e. easily accessible) sites will be prioritised.

Desktop assessment

We will initially complete a desktop assessment of sites, using:

– The City-supplied maps of treatment areas (including accompanying spatial and meta-data)
– The City-supplied information regarding proposed mosquito treatment, including timing, frequency, mode of application and product type
– Aerial imagery
– Background information regarding habitat conditions (the City-supplied/publicly available data)

The desktop assessment will allow for documentation of:

– Existing understanding of each waterbody, including waterbody type, connectivity, water quality, typical depths, habitat type(s), size, connectivity
– Knowledge gaps – and any actions for the City to fill (if required)

In terms of impact sites, the following considerations will be taken into account:

– Sites that will be directly treated, as these locations are where any impacts are most likely to be detected
– Frequency of treatment (i.e. sites with frequent treatment will be prioritised)
– Likely presence of MNES at these locations

Control sites would ideally be selected in areas which:

– Have never been treated by Bti or S-methoprene and will not in the future
– Have no hydrological connection to the impact sites
– Are in close vicinity to the impact sites (to minimise other influences/impacts)
– Have similar hydrological, topographical and water quality characteristics to impact sites

It is acknowledged that the ability to meet these criteria is likely to be limited and as such a pragmatic approach will be required during site selection.

The key criterion for both impact and control sites will be to allow for collection of samples that meet the various habitat types, as the mosquito treatment areas encompass a range of aquatic habitats (e.g. salt marsh, intermittent freshwater lakes, estuarine lagoons). This may, for example, require the collection of control samples from one area that would be used as a control for more than one impact site or the use of control sites in an untreated area of a larger waterbody where some treatment does occur.

Site assessment

Following the desktop assessment an initial site visit will be completed to verify findings of the desktop assessment. The site assessment will be completed by two GHD ecologists.

We will provide the City with site coordinates prior to the site visit. The City will then investigate the landowner details and contact Parks Victoria and gain permission before the site assessment commences.

The site assessment will include an initial habitat and water quality assessment following similar criteria to the desktop assessment. Geo-referenced photos of each site will be recorded. All site data will be recorded using ArcGIS Survey 123, allowing for site information to be stored consistently in a digital format throughout the monitoring program.

Access to sites will also be assessed and documented noting as sampling is shoreline, all sites will use land-based access only.

Site selection documentation

The site selection process will therefore allow for a multi-criteria assessment to:

1. Characterise and tabulate impact sites in each of the locations based on criteria above.
2. Select and tabulate corresponding control site areas based on the above criteria.
3. Preparation of a site selection technical memorandum detailing selected sites.

All assumptions and limitations of the study design (e.g. where compromises are required to select a site) will be documented. It is noted that this is a long-term monitoring program and that control or impact sites may change during the program's lifespan – e.g. due to changes in access or where more suitable sites are located in future years. In the event this occurs, we would discuss the changes with the City and, if agreed, provide justification for any changes to the program in the monitoring report for that year.

The technical memorandum would be a stand-alone document that would be drafted and provided to the City for review. Following receipt of one set of consolidated comments we would finalise the document. It is expected that this memorandum would be included in the non-target invertebrate survey reports as an appendix, to summarise site selection for the program.

4.1.2 Survey method

Definitions

For the purposes of this method the following definitions apply:

Site: An aerial treatment area within a location.

Location: A wetland reserve area. May have multiple aerial treatment sites.

Control site: A sample location representative of conditions with no aerial treatment.

Impact site: A sample location representative of conditions with aerial treatment.

BACI: Before-After, Control-Impact study design. Monitoring occurs at impact and control sites both before and after aerial treatment has occurred. This allows for existing differences to be considered regardless of impact.

Method selection

It is recognised that the mosquito treatment areas encompass a range of aquatic habitats (e.g. salt marsh, intermittent freshwater lakes, estuarine lagoons). This in turn influences the invertebrate community composition and will therefore drive the methods selected to sample these habitats.

The monitoring program framework would be based on the macroinvertebrate component of the *Environmental Quality Guidelines for Victorian Lakes* (EPA Victoria, 2010), which is included within the Environment Reference Standard (Victorian Govt 2021) as a standard assessment to determine environmental quality of Victorian lakes and wetlands.

The guidelines include the ability to assess the macroinvertebrate community of a wetland against objectives within the Environment Reference Standard and to assign a level of risk to the wetland based on the biological index results. This includes measures of diversity and 'VLAKES', an index developed by EPA Victoria based on the composition of macroinvertebrates found at a site weighted by their sensitivities to pollution.

It is recognised that the EPA Victoria (2010) method requires modification to allow for a more robust study design and to allow for the additional lines of evidence to be included. Modifications are described below, which focus on:

– Sampling methods used to collect invertebrates
– Sample processing methods
– Data analysis

Invertebrate sampling methods

EPA Victoria (2010) recommends the use of 'sweep/edge sampling' to collect samples. While this is likely to be the primary method used, we recognise that this may not be the most effective method to sample benthic habitat. As such, we would aim to use sweep/edge sampling at each site but would also consider the use of 'airlift' sampling as an alternative method. The sample technique would be confirmed during the baseline sampling event and for each site either a sweep/edge sample would be collected, or an airlift sample noting that differing techniques may limit the ability to compare between sites.

Sweep/edge sampling: Macroinvertebrates would be collected from edge habitats using standard methods (see EPA 2021). Edge habitats would be sampled by vigorously sweeping the net through the water column and above the substrate, ensuring that the substrate is sufficiently disturbed so bottom dwelling macroinvertebrates are suspended in the water column and collected in the net. Any aquatic vegetation present in edge habitats would be sampled in a similar manner. A 10 m transect would be sampled per site, with the aim of sampling all microhabitats present. One sweep sample will be collected per site using a 250 µm mesh sweep net with a 30 cm x 30 cm opening.

Airlift sampling: Airlift sampling is an effective method to sample benthic habitat, especially in deeper water (see Figure 1). Samples are collected by passing compressed air through the apparatus to dislodge macroinvertebrates from benthic habitat, into a collection jar. Where this method is selected, we would collect three replicate samples (each being between 5-10 seconds of air flow, depending on substrate composition) from each site and process them as a single composite sample.

In addition to these methods, we will assess site conditions and, where applicable, use additional alternative techniques (e.g. potentially use of sediment cores) if conditions are not suitable for sweep/edge or airlift sampling. Any change in method would be discussed with the City prior to implementation.

Sampling methods assume that samples can be collected without the use of a boat/watercraft. Where the Site Selection task (section 4.1.1) concludes that boat use is required, we would review proposed field time and may require a variation to our corresponding fee to allow for boat use/coxswain.

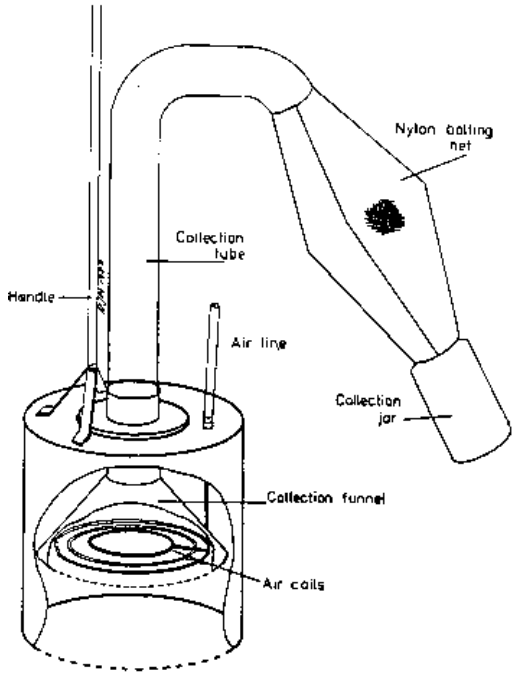


Figure 1 Airlift sampler schematic

Sample processing

Processing will broadly follow methods developed by the University of Melbourne (Walsh, 1997). This method has been used during our long-term monitoring program for Melbourne Water. The method expands on the EPA Victoria (2010) wetland monitoring method by allowing for macroinvertebrate abundances to be calculated for each site.

The key reason for including this method is to provide another line of evidence when assessing the macroinvertebrate community – i.e. the assessment can focus on diversity and macroinvertebrate sensitivity (as per the EPA Victoria 2010 method) *and* an estimate of abundance – providing a more thorough assessment of impacts to community composition. This method is consistent with the City of Busselton EPBC Ref: 2016/7780 non-target invertebrate assessment completed by Paice (2016).

In summary, 10% of the total sample would be sub-sampled and sorted for invertebrates. Only the first 50 individuals of any one family will be picked per sample. Once all sub-sampling is completed, a scan of the remaining unprocessed sample will be undertaken to check for taxa not collected in the sub-sample. These taxa are added to the data set as 'coarse picks'.

In terms of taxonomy the following is proposed:

– Macroinvertebrates processed as per EPA (2021) – i.e. majority to 'family' level, other than Oligochaeta (worms) and Acarina (mites) to order level and Chironomidae (non-biting midges) to sub-family level
– Microcrustacea to order level

This level of taxonomy is consistent with EPA Victoria (2010), with the addition of microcrustacea, which are a component of the invertebrate community that may also be impacted by mosquito treatment and hence, an additional line of evidence for the assessment.

Baseline Sampling

Timing

EPA Victoria (2010) recommends that samples are collected in autumn, spring or summer. As aerial treatment is proposed to occur in August through to March, baseline sampling is proposed to occur in August prior to treatments commencing. Control/Impact sampling will be timed to occur within 2 weeks either side of a treatment event, weather pending.

Number of samples

EPA Victoria (2010) recommends a minimum of two samples and at least four samples are collected for 'large' wetlands. However, the classification of wetlands is multifaceted and habitat complexity, hydrology, geomorphological features, vegetation, and the specific ecosystem services provided are important considerations in sample design[1].

This assessment will build upon the EPA Victoria (2010) method, by incorporating a BACI design. However, we recommend that the first sampling event focuses on baseline data collection at each location, without differentiating between control and impact sites. This would establish a baseline (of between site variability) across the locations prior to any treatment and assist with selecting control sites, based on habitat conditions and in terms of invertebrate community composition across the sites. To that end, four samples would be collected from each of the following locations:

- Site 2.17, 2.4, 2.5 and 2.7 – Lonsdale lakes wetlands
- Site 4.12 – Salt Lagoon Ibbotson Street West side
- Sites 3.9, 3.13, 3.14, 8.13, 8.14, 8.18, 10.7 and 10.8 - Lake Connewarre Wildlife Reserve including Reedy Lake (within Ramsar site)
- Sites 4.1, 4.6, 7.1, 7.2, 7.3, 7.5, 14.3 and 14.4 - Swan Bay including Swan Bay – Edwards Point Wildlife Reserve (within Ramsar site)
- Sites 8.1 and 8.4 - Lake Murtnaghurt (eastern portion within Ramsar site)
- Sites 14.1 and 14.8 - Point Lonsdale and Queenscliff Foreshore Reserves (partially within Ramsar site)

In total, this would mean that 24 samples (6 locations x 4 samples) are collected during the initial sampling event and available to provide baseline data for each location.

It is noted that there may be benefits of collecting additional samples from each wetland and/or collecting samples during multiple seasons as invertebrate community composition can vary widely across wetlands or seasonally. However, we consider our proposed method to offer the minimum requirement to assess wetland macroinvertebrate health, based on the EPA Victoria (2010) monitoring framework, with the level of effort providing the most cost-effective program that can be completed across multiple sites.

Sites at Breamlea Salt Marshes and Karaaf (9.1, 9.2, 9.3, 9.5 and 15.8) have been excluded due site impacts from the Surf Coast Shire stormwater diversions and Barwon Waters Treatment Plant.

Additional field tasks

To aid in the interpretation of the data collected we would also collect the following data at each location. All data would be recorded using ArcGIS Survey 123, to allow for consistent data storage:

- **Water quality:** pH, Dissolved Oxygen, Electrical Conductivity/Salinity, Turbidity, Temperature
- **Habitat description:** photographs, substrate composition, macroinvertebrate habitat description, weather conditions, depth, tide status

Estimate of effort – post baseline sampling event

It should be noted that the first year of sampling would include additional effort to define the method for future years and to select sites.

However, as the overall monitoring program builds on the EPA Victoria (2010) method, by incorporating a BACI design, monitoring during treatment years would include additional sampling effort to allow for:

- Four 'control' samples
- Four 'impact' samples

The use of control and impact sites for ongoing monitoring is based on EPA Victoria (2010) the number of samples collected from 'smaller' or less complex wetland locations may be reduced to two samples, if habitat is not sufficient.

[1] Meisam, Amani., Sahel, Mahdavi., Olivier, Berard. (2020). Supervised wetland classification using high spatial resolution optical, SAR, and LiDAR imagery. *Journal of Applied Remote Sensing*, 14(2)

In future years, we understand that all locations may not be treated to manage mosquitoes. It is understood that there would only ever have been a maximum of six locations per year, with eight samples (four control and four impact) collected for each location.

We note that the monitoring program may be influenced by weather – i.e. there may be times when mosquito treatment cannot proceed. As we are based locally – in Melbourne and Geelong – we have the ability to postpone and reschedule surveys if given reasonable notice.

4.2 Bird monitoring

Definitions

For the purposes of this method the following definitions apply:

Site: An aerial treatment area within a location.

Location: A wetland reserve area. May have multiple aerial treatment sites.

Control site: A sample location representative of conditions with no aerial treatment.

Impact site: A sample location representative of conditions with aerial treatment.

The following sections detail our proposed methods to allow for site selection and monitoring for birds. The purpose of the bird monitoring is to assist the City in avoiding significant threat to the recovery efforts for the Orange Bellied Parrot, or any other species (all birds listed as Migratory under the *EPBC Act* (i.e., including terns, etc), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc).

Although the City proposes to use drones to deploy mosquito control products instead of helicopter, our methods align with the original objectives proposed in the Preliminary Documentation (EPBC 2020/8782):

– *1B – Conduct pre-treatment monitoring of migratory and wetland birds*
– *1C – Restrict aerial treatment program – treatment area, duration, timing and period*
– *1D – Conduct pre-, during and post treatment surveys to monitor the impact of helicopter operations* (now drone operations) *on migratory shorebird populations and their behaviour at the sites*
– *2C – Consult with DELWP* (now DEECA) */ recovery team to understand Orange-bellied Parrot movements within the treatment areas prior to commencement of program each season*

Although the Orange-bellied Parrot is a key species for consideration we do not believe targeted on-ground surveys are warranted, particularly if using drones for the deployment of mosquito control product. Instead, consultation with DEECA / recovery team and assessment of relevant databases (e.g. VBA) is warranted to understand the species locations and movements with regard to the seasonal treatment schedule. Our fee would allow a small provision to liaise with DEECA / recovery team and report this information in January each year. We will then use this information to inform the City's forthcoming control program. This information would be initially provided as a short letter to the City in late February pending receival of information from external parties then included in the draft report and final reports.

In the absence of DEECA or other information to understand the Orange-bellied Parrot locations and movements with regard to the seasonal treatment schedule, the City will engage a suitably qualified ecologist for consultation with DEECA / recovery team and assessment of relevant databases (e.g. VBA) to understand the species locations and movements with regard to the seasonal treatment schedule. This information will be reported in January each year.

The following desktop and field survey assessments undertaken for the project have been reviewed and used to inform the survey design and approach:

– GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020
– GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019

– GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018
– GHD 2021 - Desktop assessment of Orange-bellied Parrot, history of habitat use in proposed action area. Unpublished report to the City of Greater Geelong, December 2021

4.2.1 Site selection

Bird survey sites will be chosen to be representative of favoured shorebird / other MNES bird locations at the key locations (e.g. Swan Bay, Lake Victoria, Lake Murtnaghurt, Lake Connewarre, Reedy Lake and Breamlea) and to be relatively accessible to allow timely and repeatable observations of all sites all within one day. Survey sites at key locations and other locations (if warranted) will be chosen based on studies undertaken to date by GHD including the most recent survey in May 2023 and past-10-year observations (using source: e-Bird.org) of species such as the Red-necked Stint and Sharp-tailed Sandpiper, which tend to be the most common Migratory shorebirds in Victoria.

Given the size of the key locations, and area of relevant habitat (e.g. a mix of tidal/estuarine, freshwater habitats) for most bird species listed as MNES relevant to this project it is unlikely that many new sites will be needed to inform future aerial treatment flights. Furthermore, an adaptive approach is recommended when choosing survey sites each year given that sites surveyed previous years may not be suitable for survey subsequent years.

4.2.2 Pre-, during and post treatment surveys to monitor the impact of drone operations on migratory shorebird populations

4.2.2.1 Pre- treatment surveys

The purpose of this phase of the assessment is to determine the presence and relative abundance of bird species at sites before drone operation occurs. This will provide information for the City to alter their program based on the location of these birds if required. Surveys will ideally be timed to take place during the migratory bird period, November through to February.

Occurring withing 1-2 days prior to aerial treatment GHD will conduct pre-treatment surveys consisting of two (2) surveys at each site (morning and afternoon) for two (2) consecutive days. From the best available and easily accessible vantage point at each site, a point count of all bird species will be conducted on foot by at least one experienced observer using binoculars and, if deemed necessary, a high-powered spotting scope and tripod. We will conduct three (3) surveys at each site. We will document the:

– Observer qualifications
– Survey methods and effort
– Species list including observations of all threatened and migratory species recorded including approximate numbers for each species at each site
– Spatial data that indicates the location of large aggregations of birds and colonial breeding sites at each survey site
– Photographs of survey location at time of survey
– The tide phase and weather observations

Timely reporting of key information

A brief summary of the pre-treatment survey outcomes including spatial data identifying large aggregations of birds and colonial breeding sites will be provided as an email within 24 hrs of completing the survey.

A daily site update will also be conveyed on a daily basis to the City project manager via telephone.

4.2.2.2 During application surveys

The purpose of this phase is to determine whether the birds are disturbed by the drone flyover, and to gather information about the nature and magnitude of the disturbance.

Using pre-arranged flight locations and times, two experienced observers will watch the responses of birds at the sites while the drone flies over the sites. At each site, this is done, another full count of birds is made – this effectively adding another (third) pre-disturbance sample. We will conduct three (3) surveys at each site. We will document the:

- Approximate number of each species disturbed and first bird species disturbed
- The number of passes until disturbance (e.g. 2 of 4) and the period of time between the initial disturbance and when the birds resettle at the original or nearby location
- Approximate time between response to other disturbances (e.g. people, other wildlife) and birds returning to the treatment site
- Observer qualifications
- Survey methods and effort
- Species list including observations of all threatened and migratory species recorded including approximate numbers for each species at each site
- Spatial data that indicates the location of large aggregations of birds and colonial breeding sites at each survey site
- Provide a standardised approach to response type (record how the birds react – e.g. as per descriptions provided in GHD 2023 in draft, and GHD 2018-2020)
- Photographs of survey location at time of survey
- The tide phase and weather observations

4.2.2.3 Post application surveys

The purpose of this part of the assessment will be to determine if species remain at or return to the site and in similar numbers. It will effectively be a repeat of the pre-disturbance assessment, to allow for a before and after comparison.

We will conduct three (3) surveys at each site (pre-, during and post treatment) and plan for the post treatment surveys to be conducted (completed) not more than 24 hours after treatment has finished.

4.2.3 Drone surveys of birds

There are recent published examples of UAVs being used to survey bird populations including shorebirds, waders and wetland birds within Australia (e.g. Wilson et al 2022)[2] and internationally. GHD proposes to introduce drone surveys of birds during the second year of monitoring. The drone surveys would not replace the need for the observation studies outlined in section 4.2.2, however would be used as a complimentary tool to undertaking a bird census. Following a review of the first season results (e.g. post April 2025), GHD would then design a survey using both methods to survey birds. This would allow sufficient time and additional data to evaluate the potential impact of drones over the course of a season and allow for any modifications to the program regarding the use of drones to avoid, then minimise impacts.

4.3 Reporting

4.3.1 Non-target invertebrates

The first year of the monitoring program would essentially act as a 'pilot study' to define methods and site locations.

The report format can be discussed at project inception to suit the City's needs, but would likely follow the following format:

- Outline project purpose, scope and monitoring methods
- Identify site locations (map), describe each location in terms of habitat/physico-chemical characteristics

[2] https://moretonbayfoundation.org/wp-content/uploads/2022/10/Surveying-Shorebirds_Final_Report_26-08-2022-1.pdf

– Tables/figures and text presenting results for each location (including macroinvertebrate indices – VLAKES, species richness)
– Depending on results, graphing of indicator species/groups for each location (e.g. Chironomidae abundances)
– Multivariate analysis (see detail below)
– Discussion of findings in relation to monitoring program objectives
– Recommendations and conclusions

We would welcome incorporation of the City's mosquito monitoring data for inclusion within the report, as another line of evidence to assess impacts to non-target invertebrates, assuming that data is provided in a reasonable format for inclusion. It is assumed that the City would provide this data for review during the project's inception.

Multivariate analyses – non-target invertebrates

Multivariate analyses will be used to compliment the univariate indices of the macroinvertebrate data (i.e. VLAKES, species richness, etc) using PRIMER V7 (Clarke and Warwick 2001). The multivariate analyses expand on the univariate indices as it considers the full suite of taxa present in a sample, as well as the abundance of each taxa (i.e. multivariate community data). The multivariate analyses will initially investigate if significant differences in macroinvertebrate community composition exist spatially. That is, once the background data (i.e. pre-treatment) is collected, the null hypothesis to be tested will be:

– H_0: There are no differences in the macroinvertebrate community composition in the different locations.

Initially, the data will be transformed (e.g. square root) to increase the influence of rare species and decrease potential sample variability based on the inherent variation associated with sample collection or surveys. A similarity matrix will be subsequently calculated between all samples based on the Bray-Curtis similarity measure. Non-metric multidimensional scaling (nMDS) will then be used to produce an ordination plot as a graphical representation of key spatial trends in the data. The stress value associated with the nMDS ordination will be examined to identify the accuracy of the ordination. A stress value <0.2 indicates a potential useful two-dimensional ordination (Clarke and Warwick 2001). Analysis of Similarity (ANOSIM) or Permutational Analysis of Variance (PERMANOVA) will be performed to test the significance of differences between the locations. All hypothesis tests will use a probability of $P < 0.05$ as criteria for statistical significance, which is an accepted industry standard when undertaking statistical tests (Clarke and Warwick 2001).

Following collection of the post-treatment data, the nMDS ordinations and test of significance will be updated to include the additional data and null hypotheses to be tested will include:

– H_0: There are no differences in the macroinvertebrate community composition over time in the different locations
– H_0: There are no differences in the macroinvertebrate community composition between control and impact sites in the different locations

An example of a nDMS ordination based on macroinvertebrates from a previous project undertaken by GHD that incorporates both multivariate community data and univariate biological indices is included below in Figure 2.

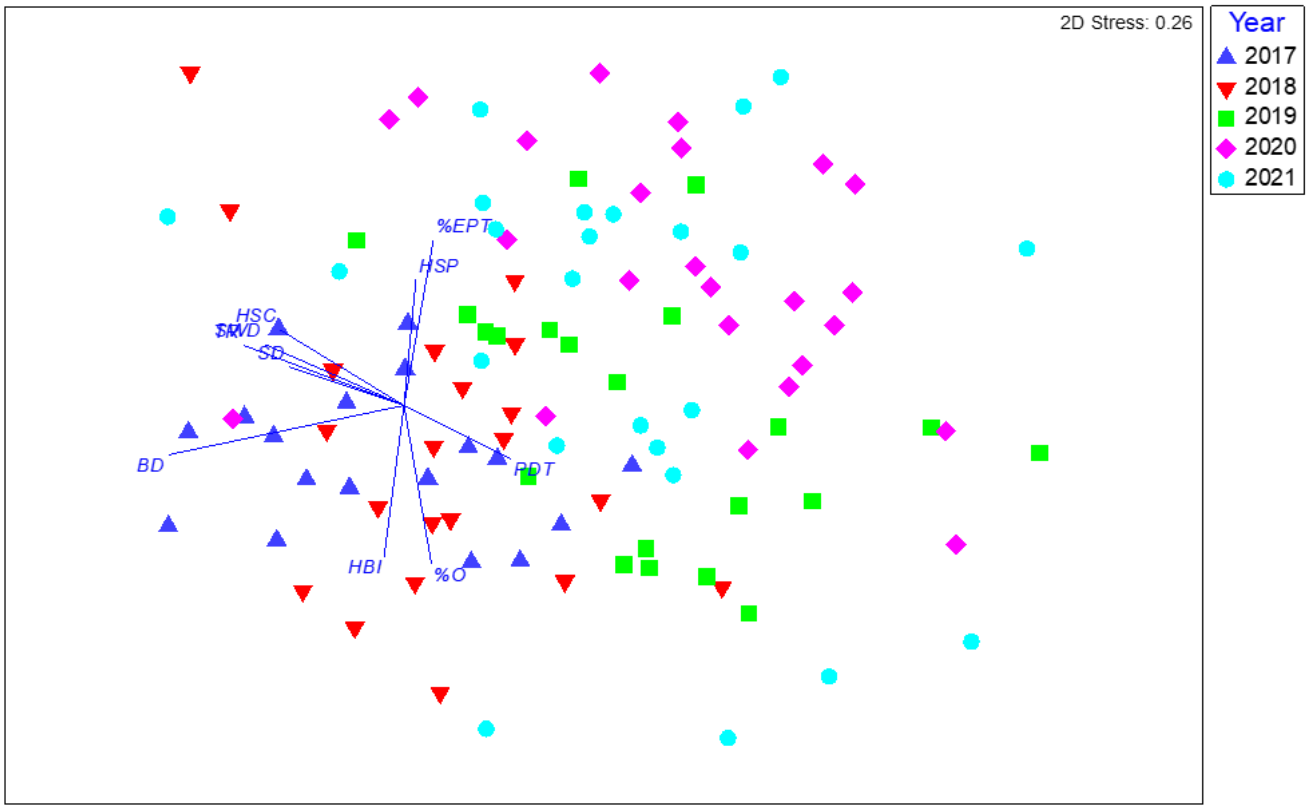


Figure 2 *nMDS ordination plot of multivariate macroinvertebrate data in a river system from 2017 – 2021 with vectors overlayed to indicate relationship to univariate indices*

PDT = Percent Dominant Taxon; BD = Benthic Density; TR = Taxa Richness; %EPT = Percent Ephemeroptera, Plecoptera and Trichoptera taxa; SWD = Shannon-Weiner Diversity; HIB = Hilsenhoff Biotic Index; SD = Simpson Diversity; %O = Percentage Oligochaetes; HSC = Hyalella Species Count; HSP = Hyalella Species Percent

The separation of 2017 and 2018 from other years in the above nMDS indicates the macroinvertebrate community was different in these years compared to other years. The main reason for this separation, as indicated by the relative direction and length of the vectors, was due to higher benthic densities (BD) of macroinvertebrates. To a lesser extent, univariate indices including taxa richness (TR), Shannon-Weiner diversity (SWD), Simpson diversity (SD) were higher at the sites during 2017 and 2018. Overall, the nMDS indicates that there was a different macroinvertebrate community in 2017 and 2018 compared to other years and the overall, this community was also healthier. Alternatively, the community in 2019, 2020 and 2021 was less healthy with the most abundant taxa present (i.e. the pollution tolerant Chironomids) being found in higher percentages (as indicated by the Percentage dominant taxa (PDT) index). That is, the community in 2019, 2020 and 2021 was mainly composed of Chironomids while in earlier years there was a more diverse community.

While the above example of a nMDS used different indices to what would be adopted in this project, it does demonstrate the general approach that is proposed. The vectors that will be used in this project may include species richness, density/abundance and other indices relevant for both macroinvertebrates and birds. Furthermore, the groupings/symbols on the nMDS would be relevant to different components of the project such as locations, control/impact sites and times. Ultimately, this information would inform research questions such as:

– Was there a change in the macroinvertebrate community following treatment?
– Did any change in the macroinvertebrate community result in a less healthy community?

Multi-year analysis

It is expected that a similar level of reporting effort would be completed following each year of monitoring, with format as per above.

Each year of monitoring data would be analysed alongside previous years, to allow for an assessment of:

– Before/After treatment
– Control/Impact differences

Where impacts due to the mosquito treatments are observed, the use of multi-year, multivariate analysis would allow for an assessment of whether the effect has diminished over time, which again allows for another line of evidence to assess longer-term impacts. This data could then be used to develop trigger values that could be used to delay or halt treatment. The ability to develop these triggers would be assessed as the project develops – likely requiring multiple seasons of data to establish a strong understanding of existing conditions. We would discuss this process with the City during project inception.

4.3.2 Bird survey reporting

The Pre-, During and Post diurnal bird survey report would detail the following:

– Introduction including project background, project area and purpose
– Methods including for site selection, desktop assessment, field survey techniques and effort and observer qualifications
– Results including, weather and tide observations, species list for each site, including observations of all threatened and migratory species recorded including approximate numbers for each species at each site
– Spatial data that indicates the location of large aggregations of birds and colonial breeding sites at each survey site
– Discussion and recommendations for future survey events

The reports will follow a similar structure and results presentation as presented in GHD's previous reports submitted to the City (GHD 2023 in draft, and GHD 2018-2020).

Project name	The City EPBC referral variation & update prelim doc						
Document title	Detail of methods to be used for non-target aquatic invertebrate monitoring and bird monitoring						
Project number	12628831						
File name	12628831-Drafting of Method Statement.docx						
Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
S4	0	[redacted]	[redacted]		[redacted]		26 April 2024
S4	1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	17 May 2024
[Status code]							
[Status code]							
[Status code]							

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Appendix J

GHD Technical Reports

GHD 2023 - Migratory shorebird monitoring and drone disturbance trials in April 2023. Unpublished report to the City of Greater Geelong, October 2023.

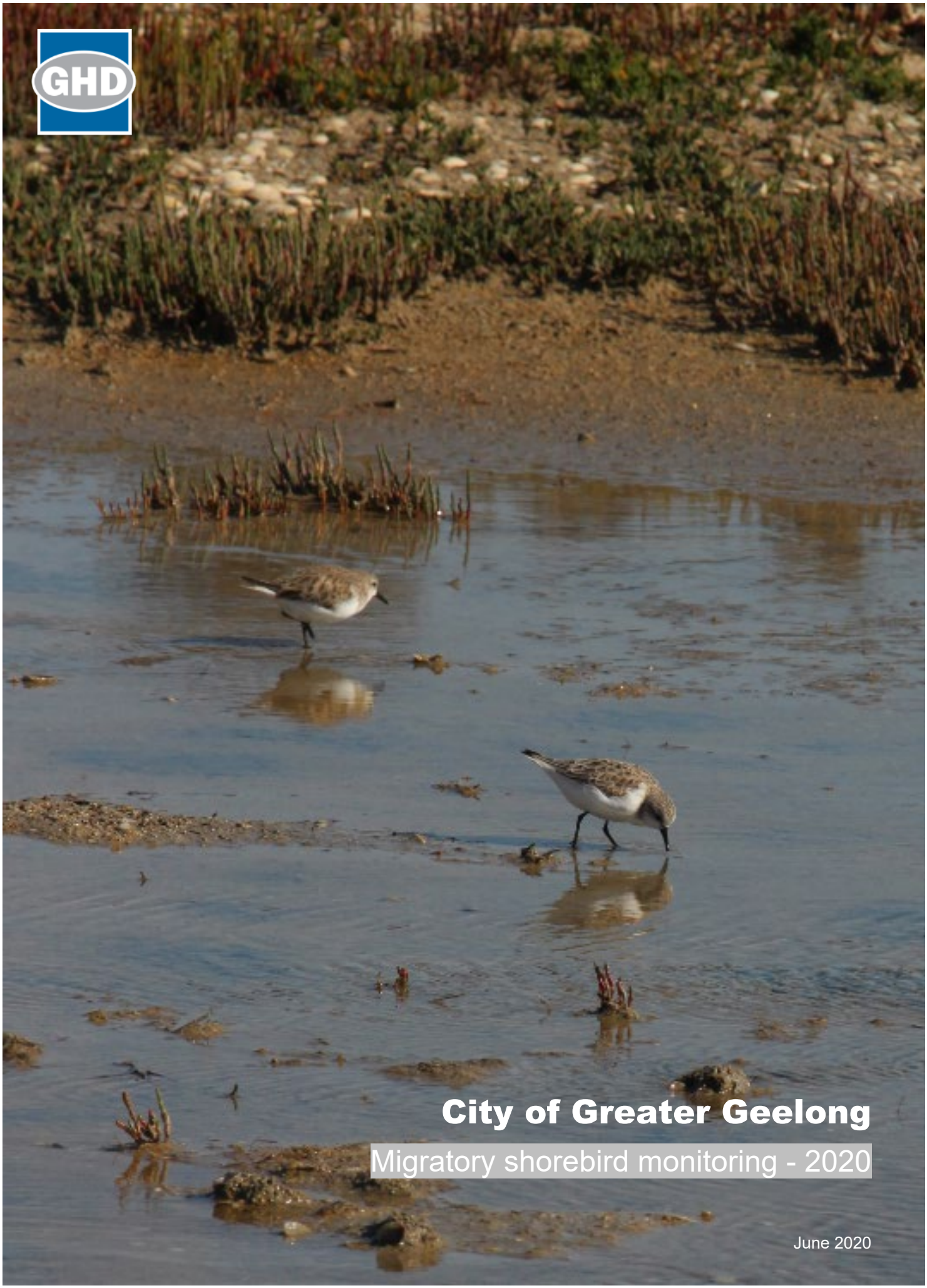
GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020

GHD 2021 - Desktop assessment of Orange-bellied Parrot, history of habitat use in proposed action area. Unpublished report to the City of Greater Geelong (updated December 2021)

GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019

GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018.

GHD 2020 - Migratory bird monitoring March 2020. Unpublished report to the City of Greater Geelong, April 2020



City of Greater Geelong

Migratory shorebird monitoring - 2020

June 2020

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1. Introduction

1.1 Project Background

The City of Greater Geelong (CoGG) monitors mosquitoes around the Bellarine Peninsula and Greater Geelong region on a weekly basis between August and March each year (CoGG 2016). Mosquito monitoring provides a better understanding of mosquito population dynamics in the Greater Geelong region, the potential public health risk from mosquitoes and aims to manage potential outbreaks before they occur. CoGG monitors both mosquito larvae and adults.

In response to the results of the monitoring, CoGG controls the abundance of adult mosquitoes in the Greater Geelong region with the use of ground and helicopter aerial treatments targeting mosquito larvae (CoGG 2016). The treatment areas include sections of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. The aerial treatments are conducted in accordance with an *Environment Protection and Biodiversity Conservation Act* (EPBC) approval 2005/2132.

The EPBC approval 2005/2132 lists a number of conditions to minimise the impact of the mosquito control project on the ecological character of the Ramsar site and listed migratory species. Condition 4D requires that *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour*.

A literature review of migratory shorebirds and a background review of migratory shorebirds in the study area were undertaken as part of the project last year, with the findings reported in GHD (2018).

On-ground assessments were undertaken by GHD in February/March 2018 and March 2019 to directly document disturbance of birds (particularly migratory shorebirds) during aerial applications (GHD 2018, GHD 2019). Due to the occupational health and safety risks for observers being beneath larvicide pellets as they are dropped, the assessments were made during a simulated aerial application (i.e., a dummy flyover by the helicopter, without the larvicide). This report presents the findings of similar monitoring undertaken in March 2020.

1.2 Project area

The project area for mosquito treatment consists of 37 sites from two areas, namely Swan Bay and Lake Connewarre, that are subject to aerial application. These locations are identified by the EPBC approval conditions (EPBC 2005/2132) and shown in GHD (2018).

On the basis of historical shorebird observations, six of the 37 sites were monitored for bird disturbance in 2018 and 2019. Those same sites were considered for the 2020 monitoring (Figure 1), although wetland conditions at the time meant that four sites, not six, were used for the 2020 aerial simulation.

1.3 Purpose of this report

The federal Department of Agriculture, Water and the Environment (DAWE; was Department of the Environment and Energy, DoEE) has advised that for a variation to the EPBC approval to be considered, information about migratory bird presence and behaviour in the treatment areas is required. The report stemming from bird monitoring in 2018 (GHD 2018) included a review of existing knowledge of the migratory shorebird species known or likely to occur in the aerial application treatment areas, and reports stemming from 2018 and 2019 bird monitoring (GHD 2018, GHD 2019) included the findings of field assessments of bird disturbance.

This report builds on that information and presents the methods and results of a bird monitoring assessment during March 2020, including species and abundance at a range of sites before, during and after the simulated helicopter operations.

1.4 Legal Limitations

This report has been prepared by GHD Pty Ltd (GHD) for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and the City of Greater Geelong, as set out in section 1.3 of this report. The assessment focuses on environmental risks to birds and does not consider risks to human health.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD, as described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by City of Greater Geelong and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

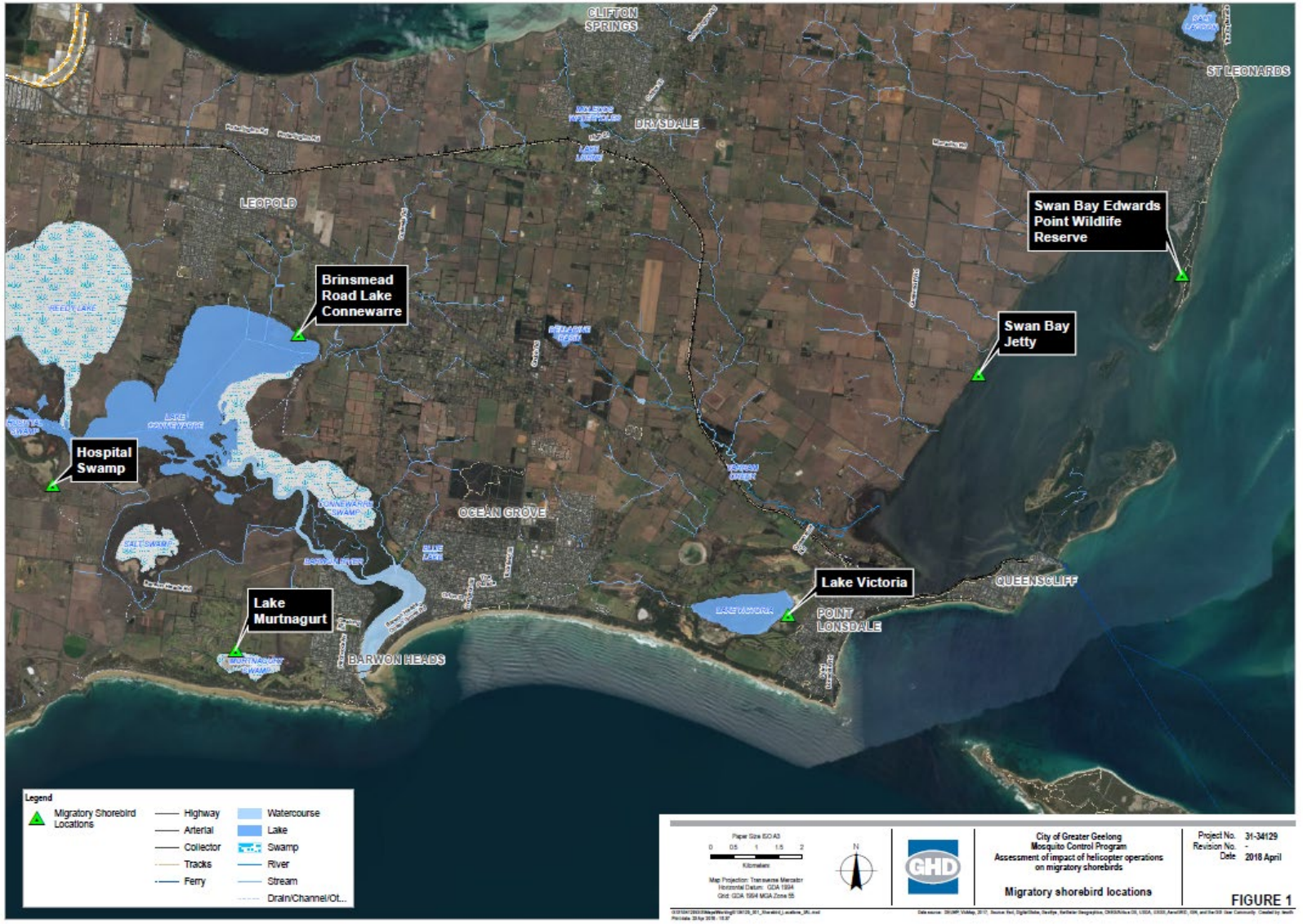


Figure 1 Sites assessed for shorebird disturbance during the simulated aerial application.

2. Methods

To support the findings of previous monitoring, a five-day field assessment was undertaken in early 2020 to document observations of migratory bird disturbance caused by the helicopter flying over the treatment areas. The assessment was conducted between 6 and 17 March 2020, with the intention being that it would detect migratory shorebirds before they had departed on their northerly migration.

Fieldwork was undertaken over 5 days: two days prior to a flyover event (a simulated larvicide application), one day during the event, and two days after the event. The five days were close together, but were not necessarily consecutive. For each phase of the assessment, observations recorded included bird species and abundance, and behaviour (e.g., foraging, roosting, preening).

The aim was to focus observations on migratory shorebirds. However, given the general scarcity of those species at most sites, observations were made of all birds listed as Migratory under the EPBC Act (i.e., including terns, etc.), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc.).

Six locations (tidal and non-tidal) were identified for the assessment, as was done for GHD (2018). Those sites were chosen to be representative of favoured shorebird locations in this region and to be relatively accessible to allow timely and repeatable observations of all sites all within one day. Sites chosen were based on past-10-year observations (using source: e-Bird.org) of species such as the Red-necked Stint and Sharp-tailed Sandpiper, which tend to be the most common Migratory shorebirds in Victoria.

The sites are shown in Figure 1 and include:

- Hospital Swamps (non-tidal)
- Lake Connewarre – Brinsmead Lane (tidal)
- Lake Murtnaghurt (south of Lake Connewarre, north of 13th beach life saving club) (non-tidal)
- Lake Victoria – east end (non-tidal)
- Swan Bay Edwards Point Wildlife Reserve (tidal)
- Swan Bay Jetty (tidal)

Visits to all sites on days 1 and 2 determined that only four sites were suitable for the assessment under current conditions. Lake Murtnaghurt and Lake Connewarre were currently supporting very few birds (and no shorebirds) within observable range. Those sites were subsequently omitted from the aerial simulation, and the full before, during and after assessment was undertaken for the four remaining sites.

2.1 Pre-application assessment

The purpose of this phase of the assessment was to determine the presence and relative abundance of wetland, waterbird and shorebird species at sites before helicopter operation occurred.

From the best available and easily accessible vantage point at each site, a point count of all wetland, waterbird and shorebird species was conducted on foot by one or two experienced observers using binoculars and, if deemed necessary, a high-powered spotting scope and tripod. The objectives were to:

- Determine species present and relative abundance, noting those that are listed as Migratory under the EPBC Act and those that are not.
- Determine habitat use of Migratory species at locations (roosting, foraging).
- Assess tide phase (tidal sites only), which may influence bird behaviour (e.g., high-tide roosting).

Each of the four sites was assessed twice (Day 1, then Day 2), with order of sites visited mixed up for the second visit so that, as far as possible, every site was assessed once in the morning and once in the afternoon. Visiting sites twice reduced bias due to poor weather conditions, chance and time of day. Visits occurred on 6th and 10th March 2020 (days 1 and 2; before helicopter flyover).

A count of birds at each site on Day 3 (11th March 2020), prior to the helicopter flying over, effectively added another (third) pre-disturbance sample.

2.2 During-application assessment

The purpose of this phase was to determine whether the birds were disturbed by the helicopter flyover, and to gather information about the nature and magnitude of the disturbance.

On Day 3 (11th March 2020), using pre-arranged flight locations and times, two experienced observers watched the responses of birds at the four sites while the helicopter flew over the sites, as though it was applying larvicide (note – this was a simulated application, so that no larvicide was dropped). At each site, this was done after another full count of birds had been made – this effectively added another (third) pre-disturbance sample.

In keeping with what would be done for a normal larvicide application, the helicopter made repeated aerial passes over each site. Passes were made parallel to the shoreline, with each pass approximately 25 m towards or away from the water relative to the previous pass.

The helicopter flew over at approximately 30-50 ft (10-17 m) above the ground, which is the normal height from which larvicide pellets are dropped. Helicopter speed was general slow, but prevailing winds (head or tail wind) made it difficult for the pilot to fly at the same speeds on all passes.

After flying over each site, the pilot landed the helicopter (at the Swan Bay Holiday Park) and waited for the ground-based ecologists to be in position at the next site, before flying over the next site. The flyover schedule was as follows:

- Swan Bay Jetty (9:30 am)
- Swan Bay Edwards Point (10:30 am)
- Lake Victoria (12:05 pm)
- Hospital Swamps (1:30 pm)

2.3 Post-application assessment

The purpose of this part of the assessment was to determine if species remain at or return to the site and in similar numbers. It was effectively a repeat of the pre-disturbance assessment, to allow for a before and after comparison.

This part of the assessment was undertaken on 12th and 17th March 2020 (assessment days 4 and 5; after helicopter flyover).

3. Results – Disturbance of migratory birds

3.1 Weather during the assessment

The weather on day 1 was cool, windy, overcast and occasionally drizzly, later clearing to sunny breaks. The weather on days 2, 3, 4 and 5 was relatively mild to warm, and generally calm - ideal for observing shorebirds. Day 4 was breezy, but conditions were still acceptable for observing birds. Daily weather observations for the Geelong Bureau of Meteorology site (station 087184) and made on site during the assessment are shown in Table 1.

Temperatures during the assessment were mostly mild to warm (20 – 30 ºC), except for day 1, where the maximum temperature for Geelong did not rise above 19.4 ºC.

Winds were variable. Conditions were breezy on days 1 and 4, but generally light on other days, including the day of the helicopter simulation. Winds began as southerly on days 1 and 2, then became calm for day 3, then shifted northerly for the final two days. Maximum recorded gust wind speed during the assessment period was 41 km/h at 13:41 at Geelong (BoM station).

During the assessment, days 2, 3, 4 and 5 were dry, while day 1 had light passing showers, and 3.0 mm was recorded in Geelong. The assessment was done following a relatively wet period for southern Victoria in late summer. A total of 181.6 mm of rain was recorded in Geelong between 1 January and 17 March 2019 (77 days)(Jan: 74.0 mm; Feb: 83.4 mm; March 1-17: 24.2). This was more than twenty times the rainfall recorded for a similar period in 2019 (8.4 mm between 1 January and 4 March 2019).

Table 1 Weather observations during the assessment

Date (2020) / Attribute	6 March	10 March	11 March	12 March	17 March
Day	1	2	3	4	5
Max Temp (ºC)*	19.4	21.4	29.3	30.6	29.7
Min Temp (ºC)*	14.9	10.0	11.4	15.7	13.0
Cloud cover (representative of the day, as observed by GHD) (x/8)	8 (4 later)	1	1	0	0
Wind (max gust; km/h and dir)*	41 SSW	33 SSE	24 SE	26 N	39 NW
Wind (9 am; km/h and dir)*	13 SSW	7 SE	calm	13 NE	9 NE
Rainfall to 9 am (mm)*	3.0	0	0	0	0
Conditions	Intermittent drizzle, sunny breaks later, cool, windy	Mild, calm, sunny, clear	Warm, calm, sunny clear	Warm, breezy, sunny, clear	Warm, calm, sunny, clear

***BoM station 087184, Geelong.**

Tides at St Leonards (east side of Bellarine Peninsula, within Port Phillip Bay) began as generally high during the middle of the day for day 1, then shifted to being low during the middle of the day for days 2, 3, 4, then shifted again to . The daily inter-tide range varied from 0.53 m (0.67 m – 0.14 m) on day 2 to 0.67 m (0.8 m – 0.13 m) on day 5. These ranges are approximately 69% and 87 % of the maximum range observed for this time of year at St Leonards (a low of 0.07 m to a high of 0.84 m in the January – March period).

3.2 Representative images of sampled habitat at sites



Red-necked Stint at Edwards Point (Swan Bay)



Saltmarsh habitat at Edwards Point



Swan Bay Jetty (looking north)



Lake Murtnaghurt (looking south).



Lake Victoria (looking southeast)



Lake Victoria (looking west)



Lake Connewarre (looking west)



Hospital Swamps (looking north)

3.3 Waterbird species richness at sites

Over the five-day assessment, small to moderate numbers of waterbird species were observed at most sites, ranging from 23 species at Lake Victoria to three species at Lake Murtnaghurt. A total of 39 species were observed overall (Table 2). Not all of those species were Migratory species – most (35 of 39) were non-Migratory. Migratory species were seen at four sites: Edwards Point, Swan Bay Jetty, Lake Victoria and Lake Murtnaghurt.

The most species seen at any one site on any one day was 18 species at Lake Victoria on day 2 and again on day 5.

Overall, wetland, waterbird and shorebird species counts in 2020 were higher than in 2019 (30 species) and equal to those in 2018 (39 species).

Table 2 Counts of waterbird species (split into migratory and non-migratory) observed at each site during the assessment

Site	Migratory species	Non-Migratory species	Total species
Swan Bay (Edwards Point)	2	13	15
Swan Bay (Jetty)	2	15	17
Lake Victoria	4	19	23
Hospital Swamps	0	13	13
Lake Murtnaghurt*	1	2	3
Lake Connewarre (Brinsmead Lane)*	0	18	18
All sites	**4**	**35**	**39**

***not visited on day 3 (helicopter day).**

The waterbird species richness at most sites remained relatively consistent across the survey days (Figure 2). Generally, Lake Victoria and Swan Bay Jetty had more species present each day than the other sites, and this pattern was observed in 2018 and 2019 also. Daily fluctuations in species richness occurred at most sites, with notable fluctuations at Swan Bay Jetty (14 species on day 2; ten or fewer on other days) and at Lake Connewarre (12 species on on day 2; seven or fewer on others days).

The day 3 counts shown in Figure 3 are pre-helicopter. Lake Murtnaghurt and Lake Connewarre were not visited on that day. There was no consistent evidence at any site that species richness reduced on or after day 3 (helicopter flyover).

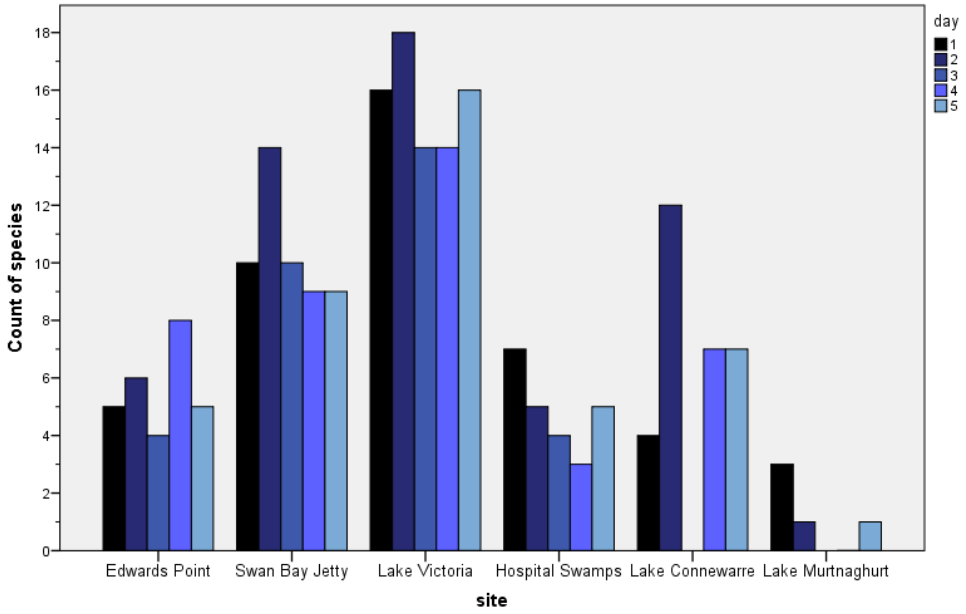


Figure 2 Total wetland, waterbird, and shorebird species counts at the sites across the five-day assessment

3.4 Relative abundance of species at sites – all species

Waterbird and shorebird abundance at sites varied, but most sites had relatively large numbers of wetland birds and waterbirds observable in the broader area, and a few had shorebirds. This was to be expected, as the sites had been chosen on the basis of their bird history. At all sites, birds were engaged in a range of behaviours – foraging, roosting, rafting, preening, flying.

At Edwards Point (Figure 3, top), all birds counted were observed within Swan Bay itself, and most were well off-shore. No birds were observed within the flooded saltmarsh habitat targeted by the aerial treatment of mosquitos. Counts and species present were variable. The highest count was on day 1, comprising relatively large numbers of Red-necked Stint (a Migratory shorebird species) and smaller numbers of Black Swans. The Stint were not seen at this site on any of the other days. On day 4, bird observations were dominated by a large flock of Silver Gulls. On other days, the numbers of birds observed were much smaller, particularly on day 3, just prior to the helicopter flying over. In general, and as noted in previous years, waterbirds at this site appear to visit irregularly and temporarily (presumably to forage), rather than remain at the site for longer lengths of time – they may be present one day, then absent the next. Overall, post-disturbance counts (days 4 and 5) equalled or exceeded two of the three pre-disturbance counts.

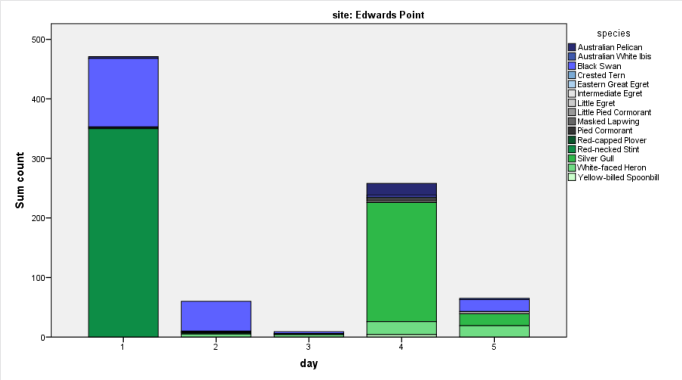
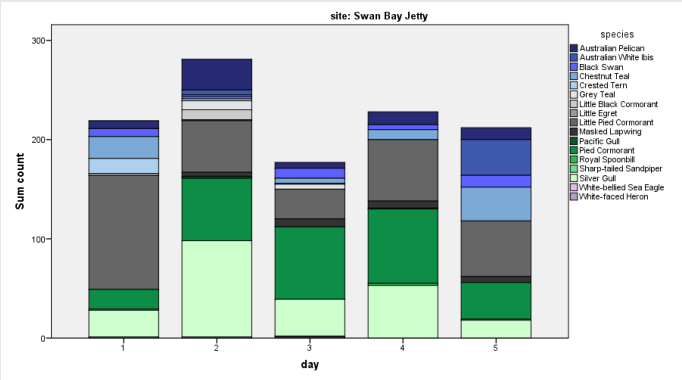
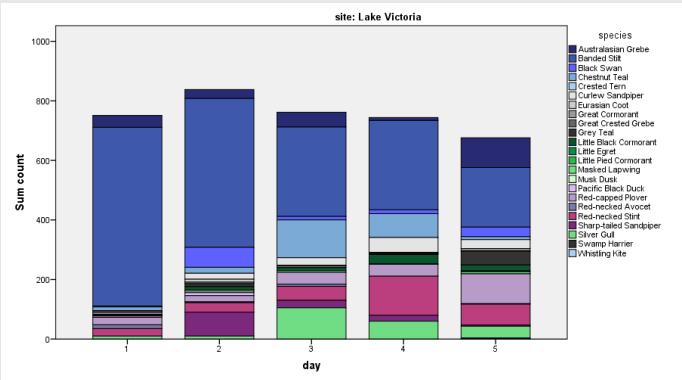
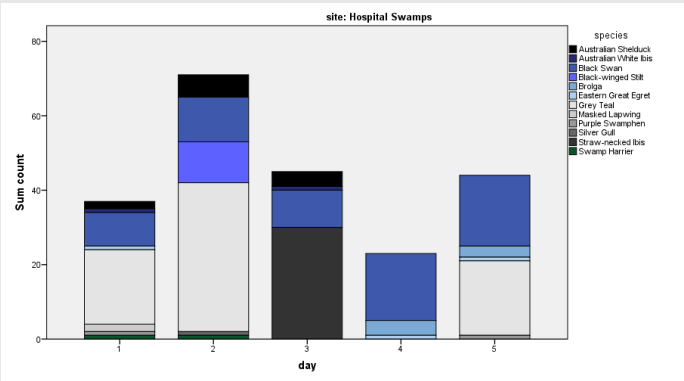
At Swan Bay Jetty (Figure 3, second from top), counts on all five days were consistently high, with 180 or more waterbirds observed each day. This matches the observations at this site from 2018 and 2019. Three species were consistently present in relatively large numbers: Silver Gull, Pied Cormorant and Little Pied Cormorant. Overall, post-disturbance counts (days 4 and 5) equalled or exceeded at least one of the pre-disturbance counts.

At Lake Victoria (Figure 3, second from bottom), bird counts remained high across the five days, ranging from about 700 birds on day 5 to approximately 850 on day 2. The most consistently numerous species were Banded Stilt, Silver Gull, and Red-necked Stint.

Other notable counts were of Sharp-tailed Sandpiper on day 2 and Curlew Sandpiper on Day 5, but these observations were inconsistent across the days, and representative of fluctuating detection of species' presence and abundance. Banded Stilt numbers were highest on day 1 (estimate of 600 birds within the single flock), and gradually reduced upon each visit (200 counted on day 5). Where the birds went is unknown. Interestingly, a flock of 400 Banded Stilts was reported (eBird.org) on 20/3/2020 at Lake Rosine, near Cressy, approximately 95 km northwest of Lake Victoria, and a flock of 200 Banded Stilts was reported (eBird.org) on 10/3/2020 and 16/3/2020 at the Western Treatment Plant, near Werribee, approximately 30 km north of Lake Victoria.

At Hospital Swamps (Figure 3, bottom), bird counts were relatively small, from approximately 70 on day 2 to approximately 20 on day 4. The most consistent and abundant species were the Grey Teal, with Black Swan, Straw-necked Ibis and Australian Shelduck also present in notable numbers on some days. Overall, the post-disturbance counts were small on day 4, but equal to two of the pre-disturbance counts on day 5. Four Brolgas were seen at Hospital Swamps in 2020, but were not seen in 2018 or 2019.

Figure 3 Relative abundance of species (including Migratory and non-migratory) at the four sites during the five-day assessment

Site	Observations per day at each site – all wetland-associated species (Observations on day 3 are pre-disturbance)
Edwards Point	
Swan Bay Jetty	
Lake Victoria	
Hospital Swamps	

3.5 Relative abundance of species at sites – Migratory species only

At most sites, richness and relative abundance of Migratory species was low. Migratory species (as listed under the EPBC Act) were observed at four sites: Edwards Point, Swan Bay Jetty, Lake Victoria and Lake Murtnaghurt. At three of those sites, the counts of Migratory birds were too low to justify graphical presentation and too low to enable comments on pre and post-disturbance effects. At Edwards Point, 350 Red-necked Stints were observed on one day, then not again, while two Crested Terns were observed there on day 4, but not on other days. At Swan Bay Jetty, one Sharp-tailed Sandpiper was seen on day 1, then not again, while small numbers of Crested Terns were seen there on days 1, 2 and 3, but not after that. At Lake Murtnaghurt (not visited by the helicopter), 120 Red-necked Stints were observed on day 1, then not again.

This reflects a fairly typical pattern for migratory species, which opportunistically exploit productive sites. Favoured locations can occasionally or regularly attract large numbers of migratory birds when conditions are suitable, but those species may be absent when conditions at those sites are less favourable or are more favourable at sites elsewhere.

At Lake Victoria, larger numbers of Migratory species were observed each day (Figure 4). Maximum counts of these species at Lake Victoria were markedly higher than at any other site, totalling approximately 200 on day 4, and 100 or more on three other days. However, these numbers are notably smaller than those for this site in 2019 (up to 1500 Migratory birds counted on one day). Counts of migratory species at Lake Victoria are likely to be very much influenced by the prevailing conditions there and elsewhere. In 2019, conditions in the months up to the survey period were dry and the water level at Lake Victoria (rain fed and non-tidal) was low, meaning the shoreline was greatly receded and extensive sand flats were exposed, which provide good foraging habitat for migratory shorebirds. In 2020, conditions in the months up to the survey period were relatively wet, and the water level at Lake Victoria was high, with smaller areas of exposed sand flats.

The most abundant and consistent Migratory species at Lake Victoria was Red-necked Stint, which was observed there on all five days (Figure 4). Similar patterns were observed in 2018 and 2019 also, although there was more variability in the numbers of stint and other species (Figure 5). The two notable large peaks in shorebird numbers in 2019 were influenced almost entirely by the presence of large flocks of Red-necked Stint (days 2 and 4). The other two most numerous Migratory species at Lake Victoria in 2020 (Figure 4) were Curlew Sandpiper (particularly on days 3 to 5) and Sharp-tailed Sandpiper (particularly on days 2 to 4). All migratory shorebird species (i.e., excluding Crested Tern) were observed at Lake Victoria on days prior to and after the helicopter disturbance.

Figure 4 Relative abundance of Migratory species at Lake Victoria during the five-day assessment

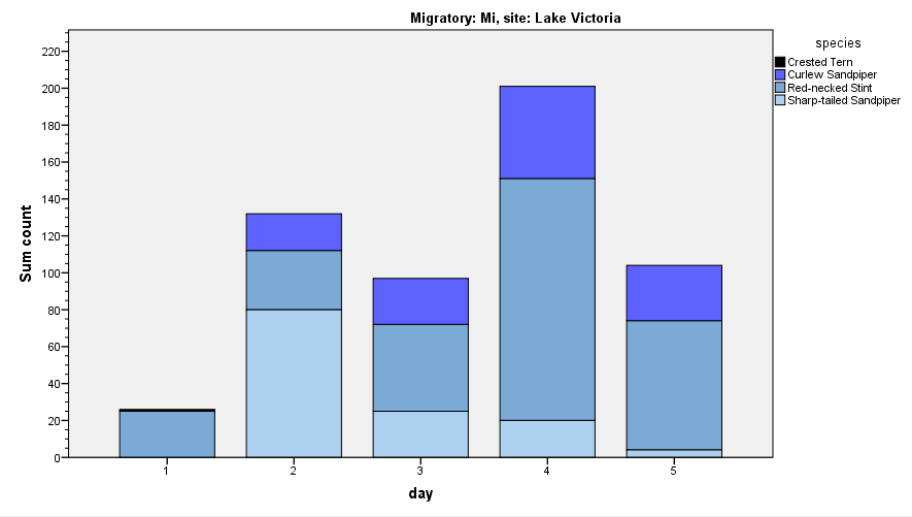
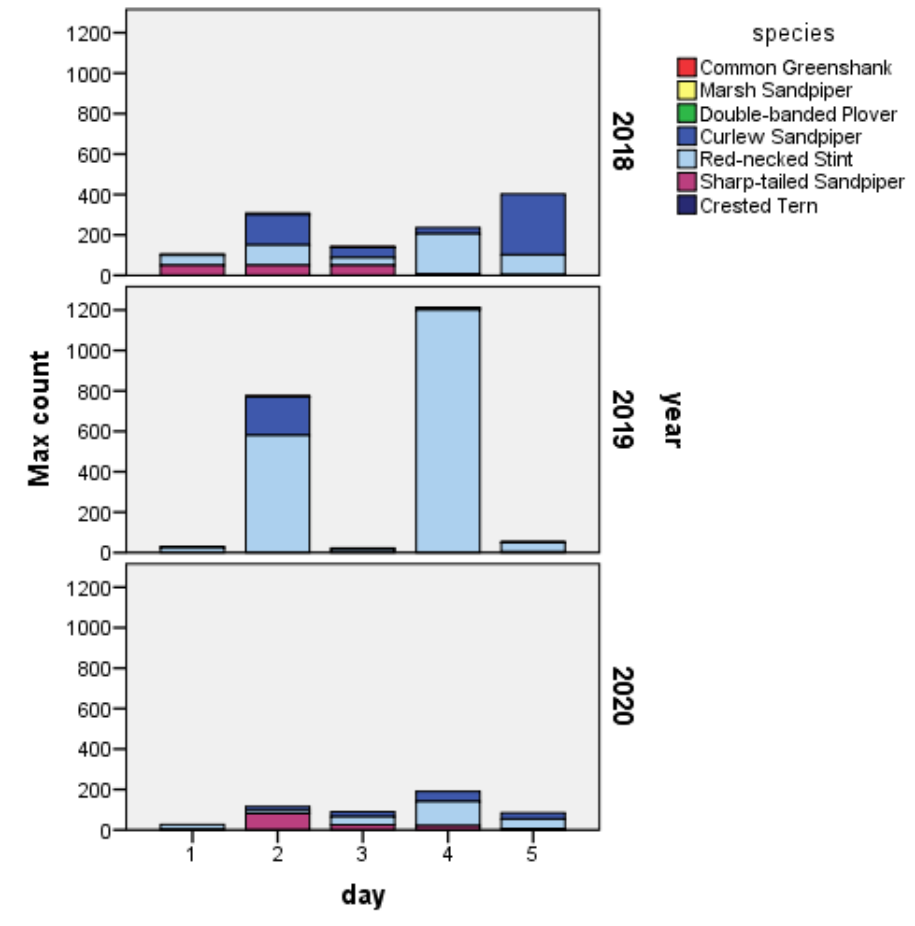
Site	Observations per day – Migratory species only (Observations on day 3 are pre-disturbance)
Lake Victoria	

Figure 5 Comparison of relative abundance of Migratory species at Lake Victoria during 2018, 2019 and 2020

Site	Observations per day – Migratory species only (Observations on day 3 are pre-disturbance)
Lake Victoria	

3.6 During-disturbance observations (Day 3)

As observed in previous years, the helicopter flying repeatedly over the site resulted in high disturbance for all birds present at the site and near the site. Again, to the human observers, the noise was the most obvious sign of approaching disturbance, but whether it is noise or appearance (i.e., resembling an aerial predator) of the helicopter that disturbs the birds is unknown. The pilot for 2020 was the same pilot as for 2019.

The helicopter treatment simulation in 2020 was done at a time when the numbers of birds at sites was relatively low. Therefore, the data and observations from 2020 were not as strong or conclusive as those from previous years, but similar patterns in bird responses were evident, nonetheless.

Descriptions of bird responses are shown in Table 3. As for previous years, species varied in how quickly they made the move to flee from the helicopter, and in how they fled. Some went early, and took to the skies; others went later and swam away. Species also varied in response behaviour – some flew off and landed in deeper water, others took to the skies and remained airborne. When disturbed, birds tended to group up with their own kind, then re-settle as a tight group, then commence spreading out again, once re-settled.

Species varied in how rapidly they returned to the site. Generally, soon after the helicopter disturbance, the species and numbers of birds present at the sites resembled the pre-disturbance observations, although the post-helicopter numbers of birds were smaller at three of the four sites (Figure 6). At Edwards Point, before and after observations of bird species and numbers were identical, mainly because the birds were too distant to be disturbed by the helicopter (Figure 6, top). At Swan Bay Jetty, before-disturbance numbers were higher, mainly due to small flocks of Chestnut Teal, Grey Teal and Little Pied Cormorants taking off and not returning immediately. However, after the helicopter there were more Australian Pelicans and Silver Gulls present, so the before-after numbers reflect some re-distribution of birds (Figure 6, second from top). At Lake Victoria, before-disturbance numbers were higher, mainly due to higher first counts of Chestnut Teal, Australasian Grebe and Silver Gulls (Figure 6, second from bottom). These species are not dependent on the habitats targeted by the larval treatment, and are likely to have moved on to habitats elsewhere in the Lake Victoria system. Hospital Swamps, like Swan Bay Jetty, showed before-after changes in numbers that reflected some re-distribution of birds (Figure 6, bottom). A flock of 30 Straw-necked Ibis was disturbed by the helicopter and didn't return immediately, but were replaced by a group of 20 Grey Teal after the helicopter.

As was noted in 2018 and 2019, birds at these sites are generally easily and commonly disturbed by things other than helicopters. The coming and going of large numbers of birds appears to be normal and typical of these sites. Disturbance sources include people, dogs, noises, gunshots, golf balls, foxes, swamp harriers, whistling kites, low-flying aeroplanes and helicopters.

Observations on days 4 and 5 demonstrate that helicopter disturbance of birds is short-lived – bird species and counts on days prior to the helicopter are generally similar to those on days after the helicopter (Figure 3).

Figure 6 Day 3 bird counts before and after the helicopter disturbance.

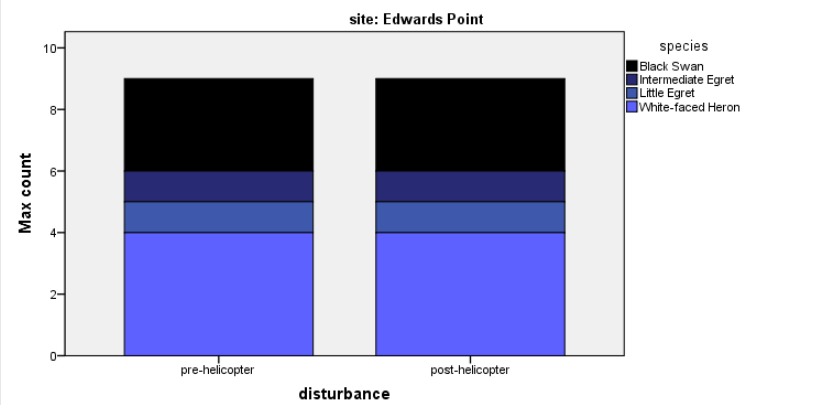
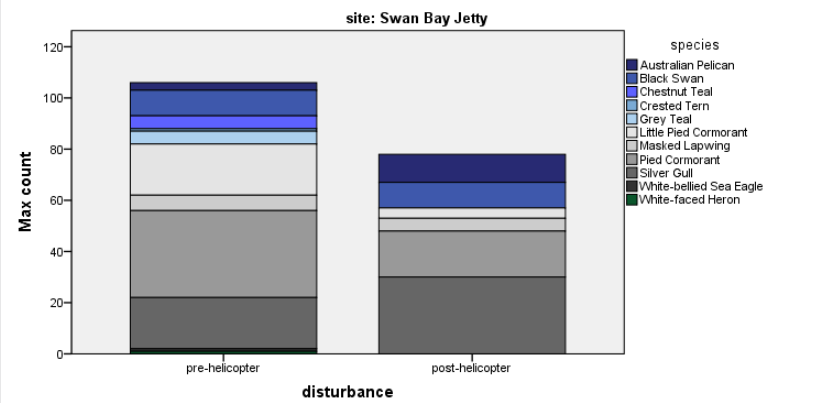
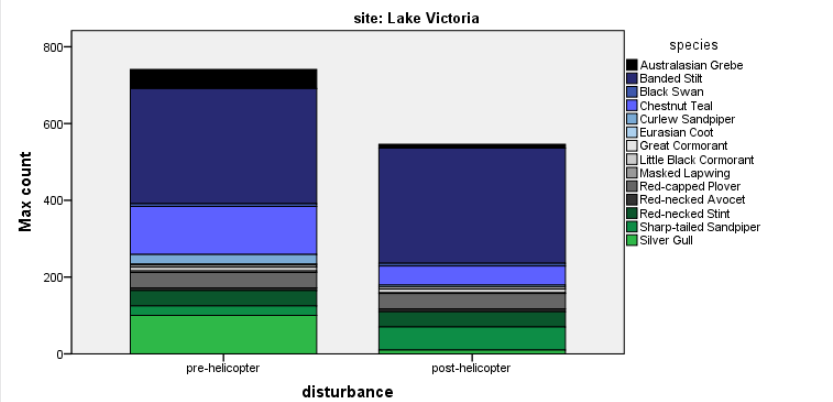
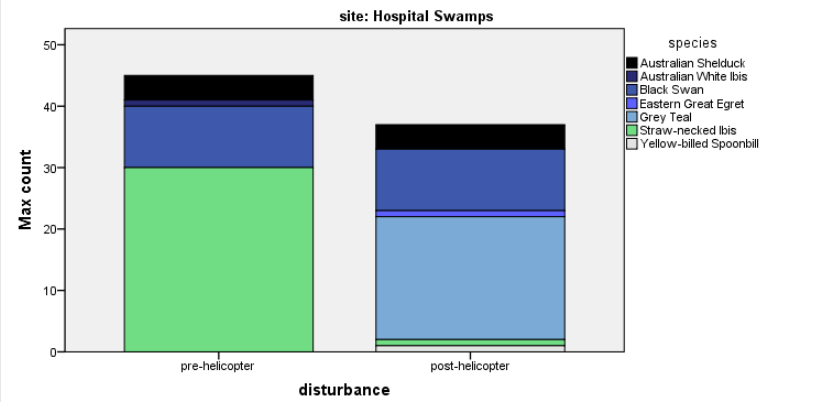
Site	
Edwards Point	
Swan Bay Jetty	
Lake Victoria	
Hospital Swamps	

Table 3 Disturbance responses by birds at each site during and after the helicopter flyover (day 3)

Site	Helicopter movement	Time	Flight direction (helicopter)	What did birds do?
Swan Bay Jetty	helicopter warming up for take off	9:21		Not many birds around. No shorebirds. Fishermen present on jetty, so earlier disturbance of birds on and near the jetty is likely. Most birds observable are distant.
	helicopter take off, to nw	9:25		Cormorants on NE fence fly off. One remains. Most no longer visible, perhaps flown off into Swan Bay. Jetty and south - no change.
	1st pass	9:26	north to south	Cormorants on SE fence fly up or into the water; most remain local. SE teal go up or into the water; most remain local. White-faced heron up - not seen again. Silver Gulls up, and circle around to re-settle. Crested tern not seen now, so must have flown off. Missed it. Swans and pelicans didn't fly or move away. Yacht cormorants didn't fly.
	2nd pass	9:28	south to north	1st pass alignment was out to sea (east), with each subsequent pass being progressively further west. Again, Cormorants on SE fence go up or into the water, again remaining local. Overall numbers perhaps getting smaller with each pass. Same for teal. Silver Gulls up, and circle around to re-settle. Swans and pelicans didn't fly or move away. Yacht cormorants didn't fly.
	3rd pass	9:29	north to south	Cormorants on NE and SE fences go up or into the water, again remaining local, but overall numbers getting smaller and smaller with each pass. Same for teal. Yacht cormorants didn't fly. Silver Gulls up, and circled around to re-settle. Swans and pelicans didn't fly or move away.
	4th pass (final)	9:30	south to north	Cormorants up from SE fence; remain local. Pelicans and swans unmoved. 2 Masked lapwings to the north remain, along with 25 silver gulls.
	After	9:35		Pelicans remain, swans remain. 2 Masked lapwings to the north remain, along with 25 silver gulls. Grey Teal all gone, one Little Pied Cormorant and one Silver Gull still on NE fence; 4 Masked lapwings on N mudflats (distant). Jetty no change, because people walking along it. SE fence - cormorants: 20, including 2 Little Pied Cormorant. Also 5 pelicans and 9 swans. In distance, 5 more swans, 4 Masked lapwings, 5 cormorants in water, swimming, taking off to the south - away from the site. 9:38 - helicopter now quiet. Birds stable. Count made.
Edwards Point	1st pass	10:28	north to south	1 x white-faced heron flies up from Swan Bay, another one not put up. Swamp Harrier up, 2 x egrets up (1 x Little and 1 x Intermediate), nothing put up over salt pans - No birds seen there. One White-fronted Chat seen. Striated Fieldwren heard earlier. To south, swans lift heads, but don't fly.
	2nd pass	10:29	south to north	further east - away from Swan Bay. Nothing flew up - no birds. Egrets have returned to where they were. 1 x White-faced heron still there.
	3rd pass	10:31	north to south	further east - away from Swan Bay. Nothing flew up - no birds.
	4th pass	10:32	south to north	further east - away from Swan Bay. Nothing flew up - no birds. All birds on Swan Bay now unaffected - foraging as normal.
	5th pass (final)	10:33	north to south	further east - away from Swan Bay; more along coast than Swan Bay. Nothing flew up - no birds. As helicopter departed, it again flew over Swan Bay where it came from - no egrets or herons went up this time, even though the helicopter was at similar height. No Swans put up at all.

Site	Helicopter movement	Time	Flight direction (helicopter)	What did birds do?
	After	10:38		Swans unchanged, white-faced herons unchanged. Little Pied Cormorant flew past, but did not land. Bird count made.
Lake Victoria	before helicopter arrival	12:00		another (unrelated) helicopter flew over the site at higher altitude. No birds disturbed. 12:06 prior to helicopter arrival, all birds roosting and quiet.
	1st pass	12:07	north to south	Approaching helicopter puts everything up at once - stilts, avocets, shorebirds, ducks, cormorants. Combination of noise and visual disturbance, possibly. Stilts and avocets group up and fly around in a large noisy flock. Shorebirds form small groups and re-settle first once helicopter has passed. Re-settle on saltmarsh island pretty quickly, all mixed in together - 50 Sharp-tailed Sandpipers, 10 Curlew Sandpipers, also Red-necked Stints and Red-capped Plovers. Ducks and cormorants took to the water to re-settle, about 30 m from the saltmarsh island. Banded Stilts and avocets re-settle in water near saltmarsh island. Swans did not go up.
	2nd pass	12:09	south to north	Some shorebirds have now settled on southern part of saltmarsh island. Teal still swimming. As helicopter approaches again, up go cormorants first, then ducks, then shorebirds, then banded stilts/avocets. Shorebirds wheel around to south (behind helicopter), then re-settle fast in original spot on saltmarsh island. Shorebirds separate out into groups of small and medium waders. Ducks went higher and further, but return to same spot also. ~20 Red-necked Stint flew off towards the north – mudflats? Everything else settled. Chestnut teal drifted on water – swimming away to deeper water?
	3rd pass	12:10	north to south	Helicopter approaches, getting louder and louder. Up go the stilt, up go the shorebirds. Shorebirds group up in flight into a flock of 50-100. Cormorants and teal up and wheeling around to the south, stilt back on the saltmarsh island. Most small shorebirds seen are curlew sands, sharpies, plus red-caps.
	4th pass (final)	12:11	south to north	Again, helicopter approaches. Up go the stilt, then up go shorebirds, fly around in two groups. Ducks up, cormorants up. Shorebirds re-settling, splitting off small squadrons (~15 birds) with each pass - possibly flying off to other parts of Lake Victoria. Ducks still flying – circling around, and out over the lake. Stilts and avocets re-settling. Then ducks return to re-settle on deeper water near golf course. One by one, small squadrons of small waders (Stint?) fly in to re-settle - these are likely to be the split off groups returning. Note: Species did not separate out cleanly into species specific groups. Birds re-settled on north and south parts of saltmarsh island. Helicopter now gone. Banded Stilts and avocets still agitated and walking to the south, still in the water. 6 Avocets at far northern end of group - one further south. Red-caps and red-necked stint back as they were - re-settled. Not really feeding. Cormorants back on posts. Teal swimming back to island from deeper water.
	After	12:25		Birds pretty much re-settled. Bird count made. Later saw one pair of Banded Stilts mating, after the 4 passes of the helicopter.
Hospital Swamps	1st pass	13:25	east to west	Nothing but Black Swans observable. Helicopter approaches from east. Heads go up, but nothing takes to the air. Swans swim slowly into the lake centre. Beneath the helicopter, we feel its presence as a major disturbance – noisy and angry, and presenting a threat that would be hard to ignore. West of us, out of sight, 10 swans go up when helicopter reaches that point. And flock of 20 teal, one Great Egret, 15 shelduck, one Yellow-billed Spoonbill. All flying up and out over the Hospital Swamps.

Site	Helicopter movement	Time	Flight direction (helicopter)	What did birds do?
	2nd pass	13:26	west to east	Spoonbill doubles back to where it was, and re-settles. Swans and great egret land in water on north side of Hospital Swamps, closer to where we are. Shelduck land on water behind reeds - can't see them now.
	3rd pass	13:28	east to west	helicopter passes over quite high. Perhaps too high. Would it be that high when dispersing seed/spray? 30 Shelduck go up, plus 1 spoonbill - fly west.
	4th pass (final)	13:29	west to east	4th pass is well south of us and well south of the water line. Shelduck re-settling on lake; one group of 15 still flying east towards Lake Connewarre. Swans still swimming, but not flying. Egret still standing in knee-deep water. One straw-necked ibis flies in. Swans then take off (not through disturbance) and settle on north side of lake.
	After	13:31		Pretty much back to settled. Bird count made.

4. Conclusions

The observations presented in this report bear strong resemblance to those reported in earlier years of monitoring (GHD 2018, GHD 2019). The numbers of migratory shorebirds in 2020 were lower than in 2019, which in turn were lower than in 2018. This is likely due to prevailing conditions at the sites and elsewhere, but may also reflect the survey timing with respect to the shorebird season. March is the tail end of the shorebird season in Victoria, and many shorebirds may have commenced their return migration to the northern hemisphere before the surveys began. That said, there are continued reports of 30+ Curlew Sandpipers across southern Victoria (including the Bellarine Peninsula) well into late March 2020 (eBird.org).

Generally, shorebirds and wetland birds are easily disturbed, and are routinely disturbed by a range of sources, including people (including birdwatchers), loud noises, wayward golf balls, dogs, foxes, birds of prey and low-flying aircraft. During the assessments each year, observations have been made of birds being disturbed by sources other than the treatment helicopter. The results were consistently similar to what was observed at all sites during the helicopter flyovers – birds took to the skies, then tended to resettle at or near the original location soon after the disturbance source had gone. Disturbed birds tend to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these species and these sites.

On-ground observations made here during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter. Black Swans and Australian Pelicans were the exceptions – generally, they took notice of the helicopter (i.e., raised heads), but did not take flight.

This assessment considered the potential disturbance to the birds due to the helicopter operations only. From this assessment and similar assessments in 2018 and 2019, it appears likely that larvicide application by helicopter results in short-lived disturbance of migratory shorebirds (and other species) at sites where they are present. The disturbance does not appear to be major or extraordinary for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance remains unknown. These migratory shorebirds are preparing for their return migration to the northern hemisphere, and where the threshold of tolerable versus excessive disturbance lies, is also unknown.

Larvicide application by helicopter is likely to meet with variable conditions with respect to birds. Wet conditions in March 2020, yet dry conditions in March 2019, are likely to have influenced waterbird, shorebird and wetland bird distributions and abundances generally, such that birds are not consistently in locations where the helicopter flies. Therefore, the effect of treatments/applications may vary in terms of bird disturbance.

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GHD 2021 - Desktop assessment of Orange-bellied Parrot, history of habitat use in proposed action area. Unpublished report to the City of Greater Geelong (updated December 2021)

Desktop review of Orange-bellied Parrot habitat use

City of Greater Geelong

15 October 2021



The Power of Commitment

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1. Introduction

The Orange-bellied Parrot is a small grass parrot that migrates each year between summer breeding areas in Tasmania and winter foraging areas in coastal Victoria and South Australia. In Tasmania, the parrots nest in November-December, using hollows of eucalypt trees near button grass plains in the south-west of the state. In Victoria and South Australia, the parrots are seen almost exclusively in coastal and sub-coastal areas, west as far as the Yorke Peninsula in South Australia, and east to Westernport Bay in Victoria (occasionally further). Historically, parts of the Bellarine Peninsula have been favoured locations for non-breeding Orange-bellied Parrots.

On the mainland, Orange-bellied Parrots primarily seek coastal saltmarsh habitats, as well as littoral heathlands and low scrublands. The parrots feed on seeds, berries and flowers of low shrubs or prostrate vegetation, and roost in dense shrubs, usually within 10 km of the coast (Ehmke 2009, DELWP 2016, Birdlife Australia 2019; Australian Museum 2019; Department of the Environment 2019). Food availability varies throughout winter, as different food plants seed at different times, and food at some sites in closed wetlands and estuaries becomes inundated and temporarily unavailable (Ehmke & Tzaros 2009, DELWP 2016). Possibly in response to the changing food availability, Orange-bellied Parrots appear to be semi-nomadic in winter, moving between food sources and locations (Ehmke & Tzaros 2009, DELWP 2016).

Alarming declines in the species' population size were reported before 1980, leading to the formation of the Orange-bellied Parrot Recovery Team in 1983, and implementation of the first Orange-bellied Parrot Recovery Plan in 1984 (Brown and Wilson 1984, Vine 2010). Fledging success each year is uncertain, making it difficult to determine current population size. According to Steven Davidson (Birdlife Australia, Project Officer for Birdlife Australia's Orange-bellied Parrot Project), the general consensus is that fewer than 30 wild birds exist currently (as of mid 2020), and that estimate has remained relatively unchanged over the last five or six years. According to DELWP (2016), all non-breeding locations occupied since 2000 are considered to be essential for the survival of the species.

The Orange-bellied Parrot is listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and listed as Critically Endangered under the *Flora and Fauna Guarantee Act 1988* (FFG Act).

2. Methods

2.1 Ecological databases

A desktop assessment was undertaken to understand the history of habitat use by the Orange-bellied Parrot within the area subjected to the aerial treatment of mosquitos. The following databases and information sources, which are mostly curated by the Australian and Victorian governments, were accessed:

– Victorian Biodiversity Atlas (VBA) administered by the Department of Environment, Land, Water and Planning (DELWP)
– Commonwealth Atlas of Living Australia (ALA) (managed by CSIRO) to capture additional records not included in the Victorian Biodiversity Atlas database. The ALA is a collaborative, digital and open infrastructure that aggregates biodiversity data from multiple sources throughout Australia, and includes records not contained within the VBA. The ALA receives support through the Australian Government's National Collaborative Infrastructure Strategy and is hosted by the Commonwealth Scientific and Industrial Research Organisation
– NatureKit administered by DELWP
– Aerial imagery.

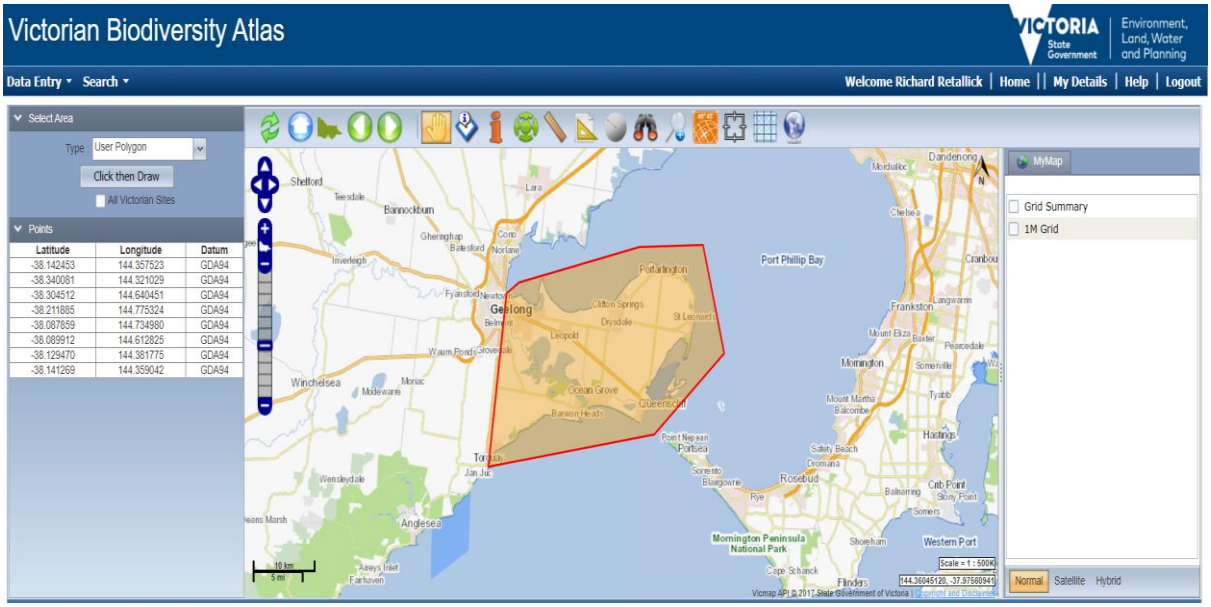
Not all locations of records in the VBA or ALA databases are precise; the actual accuracy of a record can range from ± 1 metre to ± 500 metres. Some databases present intentionally reduced location accuracy for 'sensitive species' in an effort to protect the species from unwanted attention. The validity of records accepted by the VBA or ALA has not been assessed as part of this report.

Two other relevant databases that were interrogated were:

– Birdata - The New Atlas database (1998 – present) administered by Birdlife Australia - available at **https://birdata.birdlife.org.au/** ;
– e-Bird data (<www.ebird.org>), administered by Audubon and Cornell Lab of Ornithology, USA – locational records of the Orange-bellied Parrot are suppressed in this database due to the species being considered a 'sensitive species' (i.e., in an effort to protect the species).

Note that there is some degree of overlap in these data sources (e.g., the ALA contains at least some records from VBA, Birdata and e-Bird sources).

Database records from VBA and ALA were obtained for the whole of Victoria, and for the Bellarine Peninsula only. For the Bellarine Peninsula search, an imaginary line connecting Geelong and Torquay was used as the arbitrary western boundary of the Peninsula, as shown below.



2.2 Existing literature review

A literature review was also completed of previous environmental studies by public or private entities. These included public authority management plans, recovery plans and action plans, and council and other administrative bodies' environmental investigations and environmental feature descriptions.

Internet searches were also undertaken in an effort to find additional recent observations of Orange-bellied Parrots that may not yet appear on government databases or in formally published literature.

The aim of the literature review and internet searches was to compile the findings of historical records, reports and information relevant to the Orange-bellied Parrot and this project.

Reports and other sources reviewed are shown in the reference list (section 4).

2.3 Orange-bellied Parrot Mainland Release Trial

Given the plight of the Orange-bellied Parrot, captive breeding programs have been undertaken successfully, and some of the fledglings have been released to the wild in a five-year (2019 - 2023) Mainland Release Trial. This is being undertaken as a partnership between DELWP and Zoos Victoria, and involves Corangamite CMA and Melbourne Water. The trial is seeking to establish whether Orange-bellied Parrots can be established in suitable mainland habitats during autumn and winter, to benefit birds naturally migrating between Victoria and Tasmania.

Internet searches were undertaken for information relating to the Mainland Release Trial.

A request for information was also made to Rachel Pritchard, DELWP Natural Environment Program Officer.

Captive-bred birds are also being released in breeding grounds in Tasmania.

3. Review findings

3.1 History of records

Victoria

Across the whole of Victoria, the ALA has 1355 records (1122 with accompanying locations and dates), with Orange-bellied Parrots recorded between the years 1857 and 2021 (Table 1). The VBA has 1586 records (all but one with accompanying locations and dates), between 1843 and 2019 (Table 1). The ALA records include 924 records from the VBA. The VBA records since 2010 include 520 records from monitoring at the Western Treatment Plant near Werribee, as part of the Mainland Release Trial.

Given the large overlap in OBP records across the two databases, we report mainly on ALA results.

Most records come from the 1980s and 1990s (Table 1), due to an increase in reporting and active searches as a result of the very high conservation concern for the species and the formation of the Recovery Team and associated management and monitoring actions. Reporting rates decrease after 2000 (Table 1), despite the fact that search effort and concern for the critically endangered species was likely to have been equal or higher than prior to 2000.

Bellarine Peninsula

For the Bellarine Peninsula alone, the ALA has 327 records (all with dates and locations), with Orange-bellied Parrots recorded between 1860 and 2019 (Table 1). The VBA has 312 records (all with dates and locations), between 1860 and 2018. The ALA records include 313 records from the VBA (Table 1).

Reporting over time at the Bellarine Peninsula followed a similar pattern as for the whole of Victoria – most records were made during the 1980s and 1990s, with a marked decrease in reports in since 2000 (Table 1, Figure 1), as the species becomes increasingly rare and the population size becomes smaller. The ALA contains just 16 records of the Orange-bellied Parrot on the Bellarine Peninsula in the past 10 years, which is approximately 10% of Victorian records over that period (Table 1).

Table 1 ***Counts of records in the ALA and the VBA databases for the state of Victoria and for the Bellarine Peninsula by decade.***

Source of Records	Pre-1980	1980-1989	1990-1999	2000-2009	2010-present	Total
ALA – all Victoria	113	362	331	142	174	1355**
VBA – all Victoria	122	362	307	106	688*	1586
ALA - Bellarine	14	133	136	28	16	327***
VBA - Bellarine	14	131	127	29	11	312

* includes 520 records from monitoring at the Western Treatment Plant near Werribee, as part of the Mainland Release Trial. ** includes 924 records from the VBA. *** includes 313 records from the VBA.

Mainland Release Trial

In April 2021, 12 captive-reared Orange-bellied Parrots were released at Lake Connewarre, another 12 were released at The Spit Nature Conservation Reserve near Werribee, and another 12 were released at a site on the northern shore of Western Port Bay. Since then, there have been a number of reported sightings of Orange-bellied Parrots at or near those sites.

DELWP (2021) reported in May 2021 that five wild birds have been seen to join the flocks of released birds. Two wild birds observed at Lake Connewarre were juveniles who migrated from Tasmania in autumn 2021, for their first mainland winter. One other wild juvenile bird and two adults were observed with released birds at the Spit Nature Conservation Reserve.

According to CCMA (2021), 11 of the released parrots at Lake Connewarre were known to be surviving 1 month after release. By the end of June 2021, five migrating Orange-bellied Parrots had been seen with released birds in Lake Connewarre - four wild-born birds and one captive-bred bird released in Tasmania in late summer. Moonlit Sanctuary (2021) reported a May 2021 sighting of a natural wild migrant bird (a juvenile from the 2020/21 breeding season) feeding in saltmarsh at the Westernport site alongside two captive-released birds from this year's release and another bird from last year's release. This is reportedly the first time a naturally migrating Orange-bellied Parrot has been confirmed at Westernport Bay for more than a decade.

In the most recent report, Birdlife Australia (2021) reported that flocks of Orange-bellied Parrots had been observed at all three sites, "consisting of individuals released this year, released last year and, most excitingly, individuals that have migrated from Melaleuca this year." Ten parrots were seen at The Spit and nine were seen at Lake Connewarre. Overall, ten naturally migrating birds have been observed with captive-bred released birds across the three sites.

3.2 Group size

Victoria

Most observations of Orange-bellied Parrots have been of more than one bird at a time. Across the whole of Victoria, the ALA records sum to 8665 Orange-bellied Parrots (Table 2). Most observations come from the 1980s and 1990s, then there is a marked decrease in reported numbers after 2000.

Maximum group size reported across Victoria shows that up to 121 Orange-bellied Parrots were reported in one record prior to 1980 (Table 3). After that, maximum reported numbers were lower, but remained relatively high (100 birds) until the 2000-2009 decade. Since 2010, the maximum reported group size across Victoria reported in the ALA has been 9 birds.

According to the OBP Recovery Plan (DELWP 2016), the estimated maximum number of birds sighted on the mainland has been 15 in 2009, 23 in 2010, 16 in 2011, 11 in 2012 and 11 in 2013, but it is acknowledged that those values may include double-counting of birds that were sighted in more than one location over the winter period.

Bellarine Peninsula

For the Bellarine Peninsula, the ALA records sum to 4371 Orange-bellied Parrots, which is approximately half of all Victoria historical observations (Table 2). There are no data on group size prior to 1980. Most observations come from the 1980s and 1990s, but the count in 1990-1999 (1551 birds) was approximately two-thirds of the count in the decade before (2460 birds). Then there was nearly a five-fold reduction from the 1990s to the 2000s, and a thirteen-fold reduction from the 2000s to the 2010s. Counts of Orange-bellied Parrots observed on the Bellarine Peninsula in the past 10 years (2010-present) amount to just 7% of the birds seen in the decade before (2000-2009), and just 1.6% of the birds seen in the decade before that (1990-1999) (Table 2).

The maximum group size reported across the Bellarine Peninsula is 100 birds in the 2000s (Table 3, Figure 1). Since then (i.e., in the past 10 years), the maximum number of Orange-bellied Parrots reported on the Bellarine Peninsula in one record has been 3 birds.

Comparing group size for Victoria with group size for the Bellarine Peninsula shows that the largest counts from Victoria historically come from the Bellarine Peninsula (Table 3). That pattern was not evident in the 2010-present decade.

Figure 2 shows the progressive decline in reported numbers of Orange-bellied Parrots on the Bellarine Peninsula. Progression through the decades sees a decrease in frequency of all counts, and a decrease in group size.

Table 2 ***Summed counts of Orange-bellied Parrot individuals in the ALA and the VBA databases for the state of Victoria and for the Bellarine Peninsula by decade.***

Source of Records	Pre-1980	1980-1989	1990-1999	2000-2009	2010-present	Total
ALA – all Victoria	188	4725	2627	549	326	8665**
VBA – all Victoria	190	4638	2587	550	1696*	9661
ALA - Bellarine	No data	2460	1551	335	25	4371***

Source of Records	Pre-1980	1980-1989	1990-1999	2000-2009	2010-present	Total
VBA - Bellarine	No data	2336	1511	342	24	4213

* includes records of 1382 birds monitored at the Western Treatment Plant near Werribee, as part of a Birdlife Australia captive release program. ** includes records of 7964 birds from the VBA. *** includes records of 4258 birds from the VBA.

Table 3 ***Maximum group size of Orange-bellied Parrots reported in the ALA and the VBA databases for the state of Victoria and for the Bellarine Peninsula by decade.***

	Pre-1980	1980-1989	1990-1999	2000-2009	2010-present	Overall
ALA – all Victoria	121	75	64	100	9	121
VBA – all Victoria	121	73	64	100	11	121
ALA - Bellarine	No data	75	64	100	3	100
VBA - Bellarine	No data	73	64	100	3	100

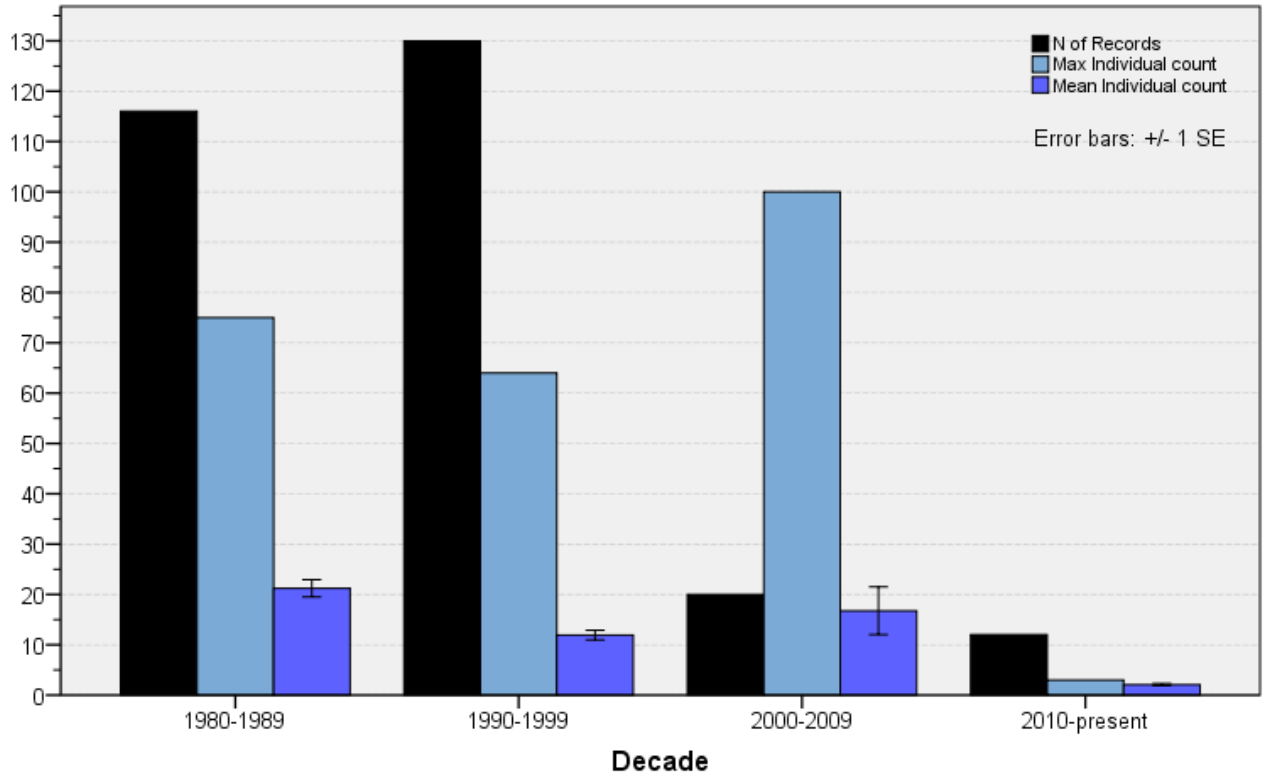


Figure 1 ***Counts of records, and mean and maximum group size of Orange-bellied Parrots reported in the ALA database for the Bellarine Peninsula by decade.***

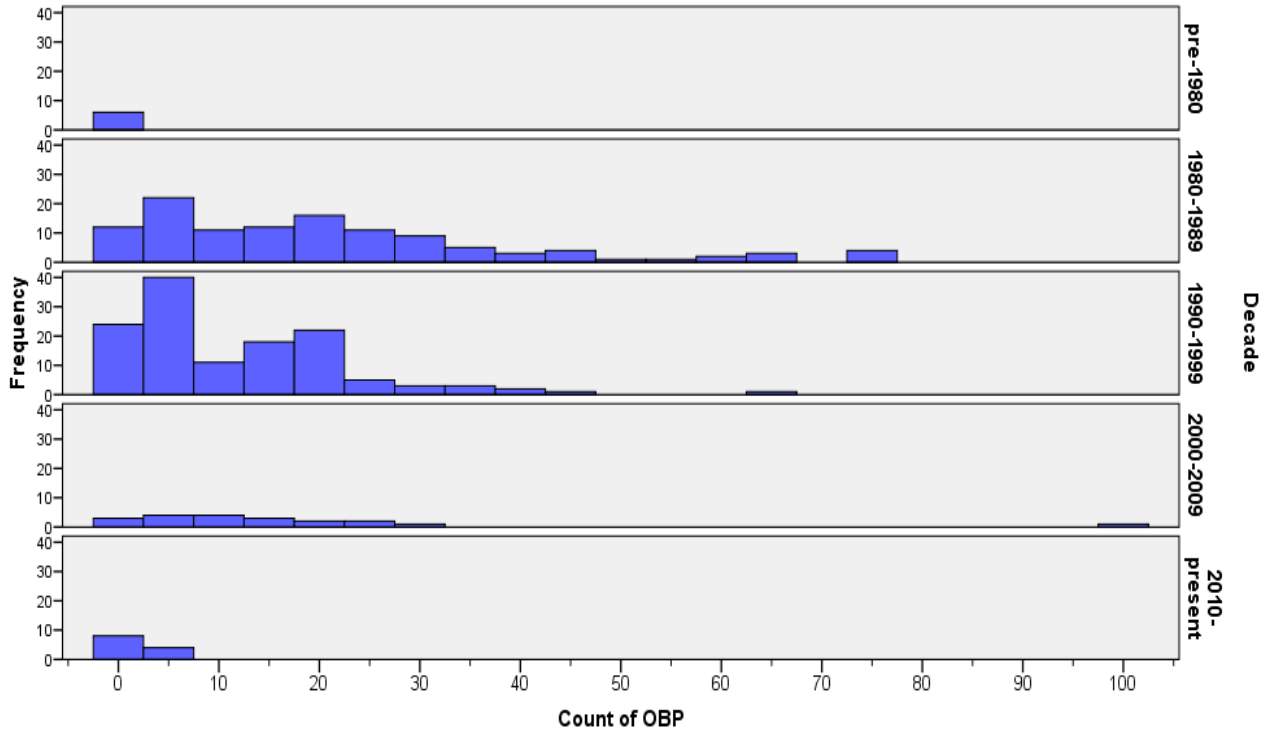


Figure 2 *Histogram of reported group size (ALA results only) of Orange-bellied Parrots on the Bellarine Peninsula by decade.*

3.3 Seasonal patterns - Bellarine

As a migratory species, historical records of Orange-bellied Parrots that visit the Bellarine Peninsula show a strongly seasonal pattern. The species is generally reported on the Bellarine Peninsula between April and October, with a peak between June and September. The species is typically absent from November to March, but there are small numbers of records.

Figure 3 shows the summed counts of Orange-bellied Parrots on the Bellarine Peninsula for each decade by month. Because the small counts of birds in the current era are dwarfed by the historical record, the same graph is shown below that for the 2010-present decade only (Figure 4).

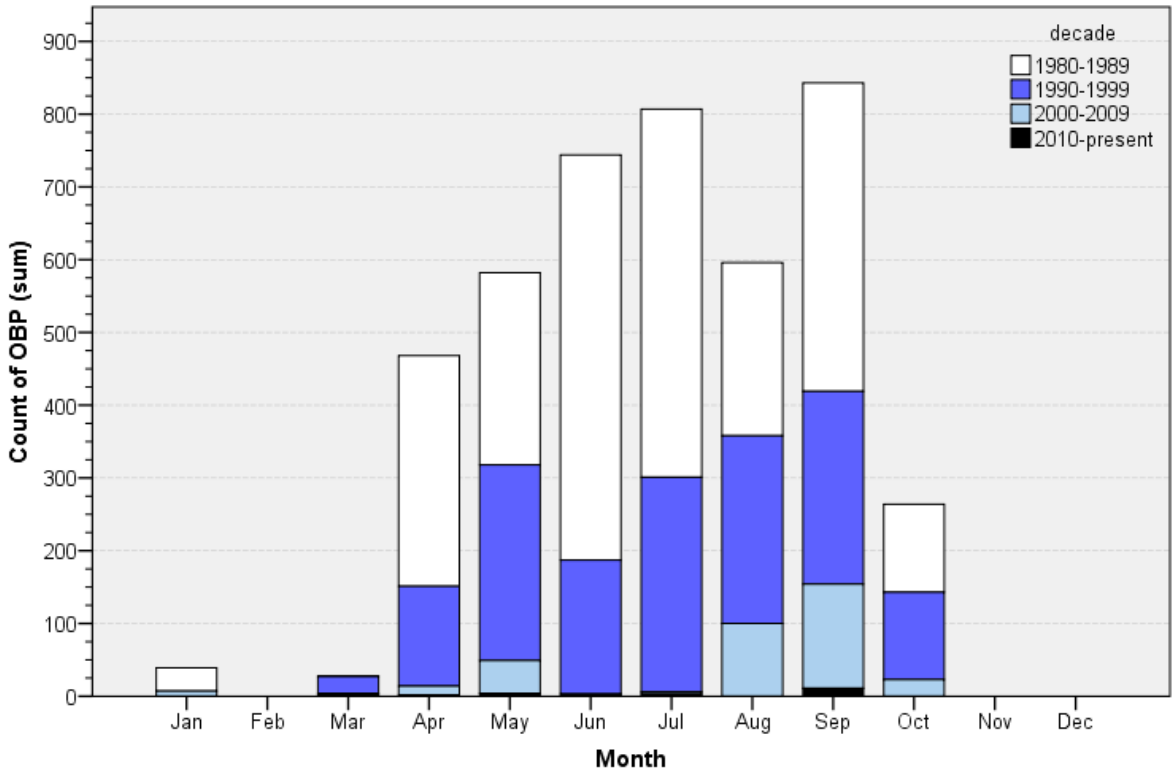


Figure 3 *Summed counts of Orange-bellied Parrots on the Bellarine Peninsula for each decade by month (ALA data).*

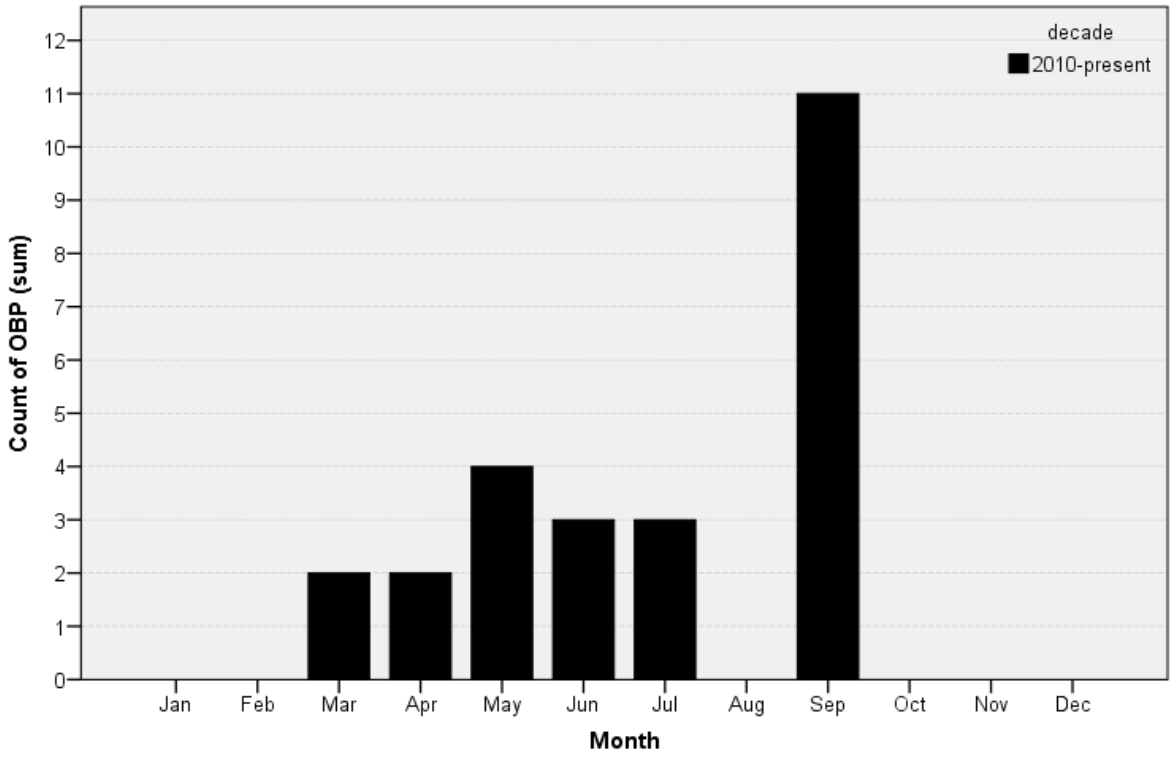


Figure 4 *Summed counts of Orange-bellied Parrots on the Bellarine Peninsula by month for the past ten years (ALA data).*

Higgins (1999) provides information on first and last dates of reported Orange-bellied Parrot presence at Queenscliff, on the Bellarine Peninsula:

– Dates of first arrival near Queenscliff (Higgins (1999), Table 2, p562): data for 15 years – 1983 – 1997. Arrival dates range from 24 March to 29 July. Birds arrived in March (1 year), April (1), May (2), June (3), and July (8).
– Dates of last departure near Queenscliff (Higgins (1999), Table 3, p563): data for 13 years – 1983 – 1996, but not 1990. Departure dates range from 10 Sept to 29 October. Birds departed in September (4 years), and October (9).

3.4 Habitat mapping

NatureKit, maintained by the DELWP was used to obtain Habitat Importance Models (HIM) which maps the modelled importance and extent of habitats for the species within the search area. The HIM reflects the relative importance of habitat in different places as determined by the amount of habitat available, its condition, and how much the habitat is connected across the landscape. HIMs indicate which patches of habitat may be relatively more important to a species' persistence than others. Most HIMs contain values ranked between 1 and 100, with higher values indicating a higher likelihood of important habitat. For the HIM used for this report the orange, then red areas indicate the habitat most likely to be of moderate to high importance for the species (DELWP 2018, NK 2021). For this assessment we reviewed the HIM against historical species records and aerial photography to provide comment regarding the accuracy of the modelling. We concluded that for this species the HIM probably overestimated the area of habitat available for each species within the search area and therefore made adjustments, allocating an overall area of up to 80% of the modelled habitat which is reported in the Preliminary Docuemntation Report to the City by GHD.

The habitat mapping shows the Bellarine Peninsula as a hotspot for Orange-bellied Parrot habitat, particularly around Reedy Lake, Lake Connewarre, the Barwon River estuary, around Point Lonsdale, Queenscliff and Lake Victoria (Figure 5 and 6). Other locations mapped as providing high value habitat include near Breamlee north-east of Torquay, Point Edwards Reserve at the north end of Swan Bay, the north-eastern coast near Portarlington, and on the north coast near Moolap.

The modelled habitat around Reedy Lake, Lake Connewarre and the Barwon River estuary coincides with boundaries of the *Port Phillip Bay Western Shoreline and Bellarine Peninsula* Ramsar site (Figure 5 and 6).

3.5 Locations of Orange-bellied Parrots

Victoria

ALA records show some unreliability in the Orange-bellied Parrot records. For example, one record labelled as Tasmania is shown well south of Tasmania in the Southern Ocean, another record is of a captive bird (an exhibit) at the Healesville Sanctuary, and a handful of records appear in arid north-western NSW and in southern NSW near Albury, which do not provide habitats that match those reportedly used by this species. None of the obvious discrepancies concern the records on the Bellarine Peninsula.

Since 1990, Orange-bellied Parrots have been reported mainly along the west coast of Tasmania, on King Island, and along the south-west coast of Victoria and south-east coast of South Australia, with records extending as far west as Adelaide. They have also been reported often along the western shoreline of Port Phillip Bay, the Bellarine Peninsula, and in the Western Port Bay area. Rarely, records extend into NSW.

Bellarine Peninsula

Figure 5 shows records (all historical ALA records) of Orange-bellied Parrots scattered across most of the Bellarine Peninsula. Locational inaccuracy of records (intentional and unintentional) likely accounts for some of this – at least some of the records shown in dispersed and isolated locations are likely to have been in areas that offer suitable habitat. Two hotspots of Orange-bellied Parrot observations are evident for the Bellarine Peninsula: Lake Connewarre and Swan Bay, particularly around Swan Island. Higgins (1999) and the Victorian FFG Action Statement (DSE 1993) also list Lake Connewarre and Swan Bay, including Swan Island, as being among the most important mainland sites for this species.

DSE (1993) proposes that it is necessary to find and protect roost sites for the Orange-bellied Parrot. At that time (1993), roost sites were not known at Lake Connewarre, but a number of sites were known at Swan Bay.

Figure 5 and 6 identified records since 2000, and the same pattern is evident: Lake Connewarre and Swan Bay are obvious hotspots, and a handful of records are scattered across other locations.

There are so few records in the past 10 years (i.e., since 2010) that no real pattern emerges for the most recent decade. There are two records from the Lake Connewarre hotspot, and one from the Swan Bay hotspot.

3.6 Locations for aerial treatment of mosquitos

Habitats sought by non-breeding Orange-bellied Parrots are also habitats that favour breeding by mosquitos, so there is no surprise that historical records of Orange-bellied Parrot observations overlap closely with areas targeted for aerial treatment of mosquito larvae, particularly in the Lake Connewarre area (Figure 5 and 6).

3.7 Identified threats to the Orange-bellied Parrot

According to the Orange-bellied Parrot Recovery Plan (DELWP 2016), the species is at risk of extinction in the wild in the near-term. DSE (1993) acknowledges that 'it is probable that not all the factors influencing the survival of the species have been determined', and lists the following threats for the Orange-bellied Parrot:

– loss and alteration of winter habitat, in particular destruction of its saltmarsh feeding grounds, by industrial and urban development, agricultural practices and recreation;
– its small population, making it extremely sensitive to sudden catastrophes such as disease and storms during migrations across Bass Strait;
– predation by introduced predators, especially foxes and cats;
– competition from introduced seed-eating birds; and
– loss of genetic variation because of its small population size.

Threats identified in the SPRAT database (DAWE) for Orange-bellied Parrot include predation by cats and foxes, and competition with and land degradation by rabbits. Other threats identified for the species include spread of weeds, death caused by collisions with manmade structures. Current knowledge (DELWP 2016) suggests that habitat loss and degradation, particularly in the non-breeding range, has caused the decline in this species.

The species appears to avoid areas with human developments and high disturbance rates, and modelling of sightings on the mainland has revealed that the species is less likely to occur in areas with high development intensity (Ehmke 2009). The gradual development of the Bellarine Peninsula in recent decades may have contributed to the decline in observations of Orange-bellied Parrot.

In DELWP (2016), *Disturbance from human activities* is given a moderate risk rating, and is given the potential to degrade otherwise suitable habitat by interfering with the behaviour of the birds. This threat is reportedly most common in developed and accessible areas (DELWP 2016 references visitor numbers recently increasing at the Western Treatment Plant, Werribee). Higgins (1999) lists two observed sources of disturbance: Feeding birds were sometimes disturbed by heavy traffic near Point Wilson/Werribee sewage farm, and disturbed by golfers at Swan Island.

Orange-bellied Parrots can be sensitive to noise disturbance, and may flee in response to noise from humans, vehicles and light aircraft including helicopters (Bezuijen et al. 2000, Quin & McMahon 2001, but see Bezuijen & Lane 1997). The threshold of disturbance that leads to abandonment of a site is not known.

The Recovery Plan (DELWP 2016) states the following: 'Actions that result in any of the following may result in a significant impact [*sensu EPBC Act*] on the Orange-bellied Parrot:

– Permanent loss or degradation of nesting, roosting or foraging habitat,
– Drainage or other significant hydrological alterations of wetlands associated with foraging habitat, or
– New industrial, urban or infrastructure developments that permanently affect Orange-bellied Parrot flight paths between sites, create disturbance that interrupts foraging, and/or introduces predators into habitats.'

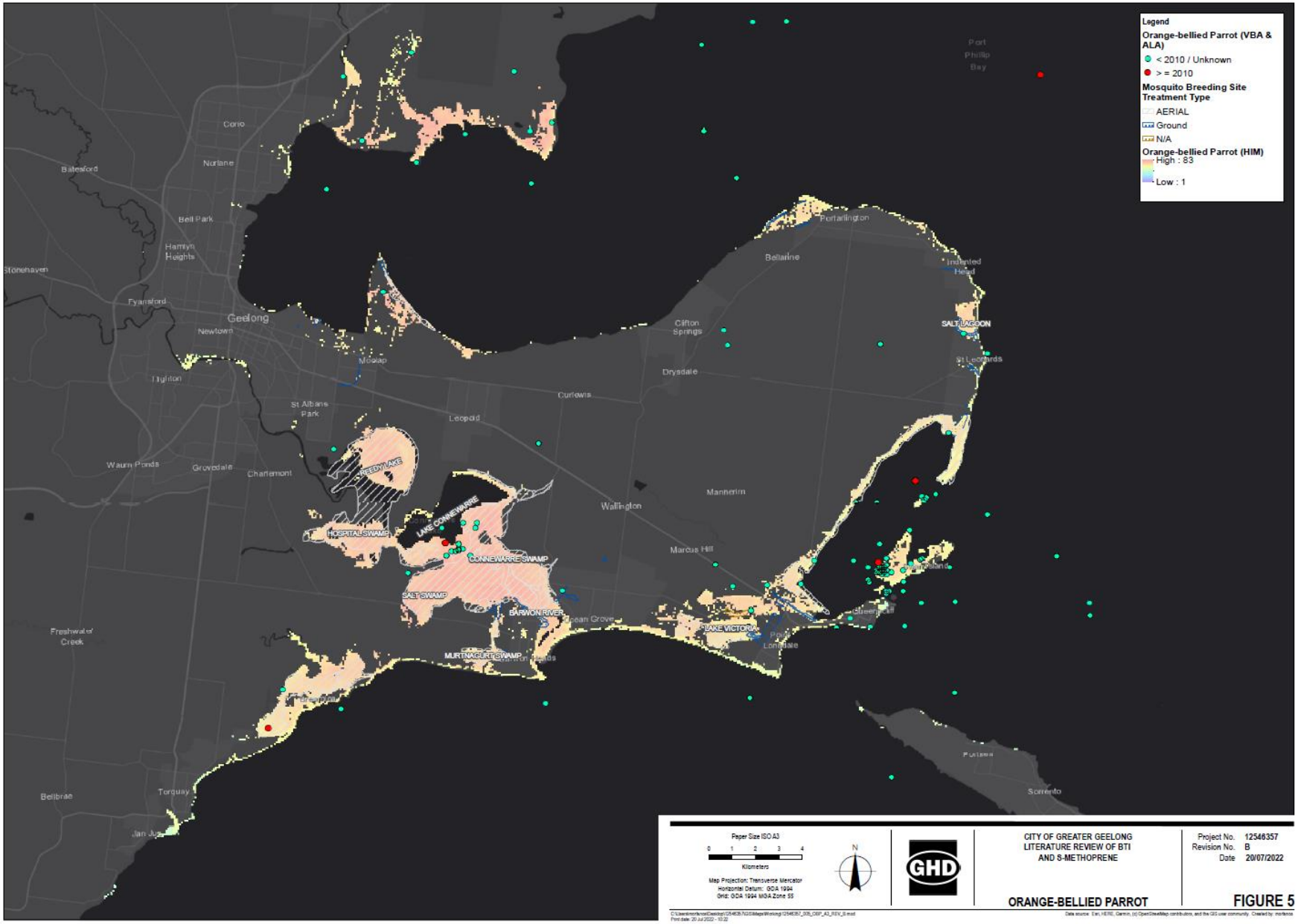


Figure 5 ***Orange-bellied Parrot records and HIM mapping region***

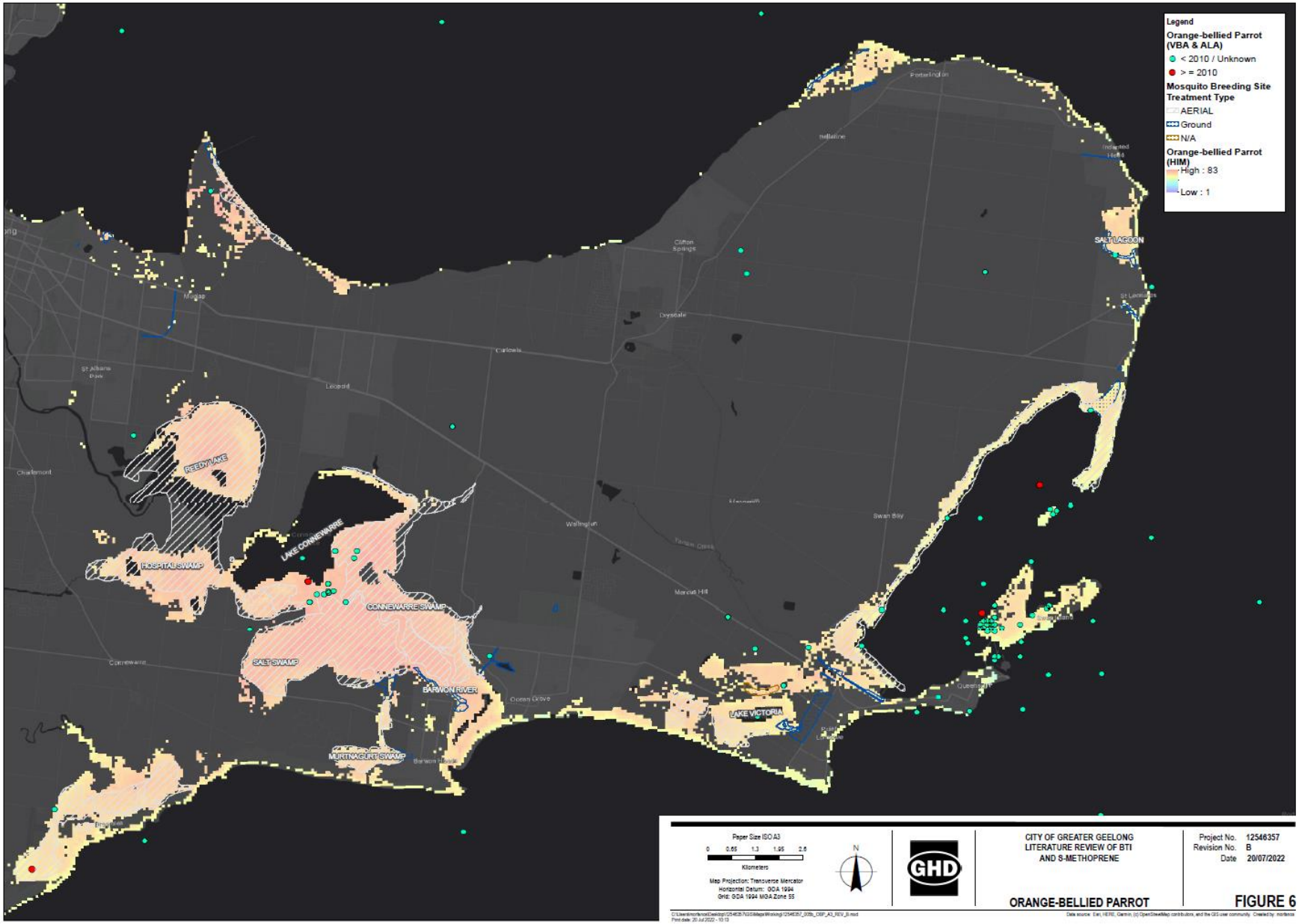


Figure 6 ***Orange-bellied Parrot records and HIM mapping project area***

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The Power of Commitment

GHD 2019 – Migratory bird monitoring March 2019. Unpublished report to the City of Greater Geelong, April 2019



City of Greater Geelong

Migratory bird monitoring 2019

August 2019

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1. Introduction

1.1 Project Background

The City of Greater Geelong (CoGG) monitors mosquitoes around the Bellarine Peninsula and Greater Geelong region on a weekly basis between August and March each year (CoGG 2016). Mosquito monitoring provides a better understanding of mosquito population dynamics in the Greater Geelong region, the potential public health risk from mosquitoes and aims to manage potential outbreaks before they occur. CoGG monitors both mosquito larvae and adults.

In response to the results of the monitoring, CoGG controls the abundance of adult mosquitoes in the Greater Geelong region with the use of ground and helicopter aerial treatments targeting mosquito larvae (CoGG 2016). The treatment areas include sections of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. The aerial treatments are conducted in accordance with an *Environment Protection and Biodiversity Conservation Act* (EPBC) approval 2005/2132.

The EPBC approval 2005/2132 lists a number of conditions to minimise the impact of the mosquito control project on the ecological character of the Ramsar site and listed migratory species. Condition 4D requires that *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour*.

A literature review of migratory shorebirds and a background review of migratory shorebirds in the study area were undertaken as part of the project last year, with the findings reported in GHD (2018).

An on-ground assessment was undertaken by GHD in February/March 2018 to directly document disturbance of birds (particularly migratory shorebirds) during an aerial application (GHD 2018). Due to the occupational health and safety risks for observers being beneath larvicide pellets as they are dropped, the assessment was made during a simulated aerial application (i.e., a dummy flyover by the helicopter, without the larvicide). This report presents the findings of similar monitoring undertaken in March 2019.

1.2 Project area

The project area for mosquito treatment consists of 37 sites from two areas, namely Swan Bay and Lake Connewarre that are subject to aerial application. These locations are identified by the EPBC approval conditions (EPBC 2005/2132) and shown in GHD (2018).

Six of the 37 sites were monitored for bird disturbance in 2018. Those same sites were used for the 2019 monitoring (Figure 1).

1.3 Purpose of this report

The federal Department of the Environment and Energy (DoEE) has advised that for a variation to the EPBC approval to be considered, information about migratory bird presence and behaviour in the treatment areas is required. The report stemming from bird monitoring last year (GHD 2018) included a review of current knowledge of the migratory shorebird species known or likely to occur in the aerial application treatment areas, and the findings of a field assessment of bird disturbance.

This report from 2019 builds on that information and presents the methods and results of a bird monitoring assessment during March 2019, including species and abundance at a range of sites before, during and after the simulated helicopter operations.

1.4 Legal Limitations

This report has been prepared by GHD Pty Ltd (GHD) GHD for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and the City of Greater Geelong, as set out in section 1.3 of this report. The assessment focuses on environmental risks to birds and does not consider risks to human health.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD, as described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by City of Greater Geelong and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.



Legend

- Migratory Shorebird Locations
- Highway
- Arterial
- Collector
- Tracks
- Ferry
- Watercourse
- Lake
- Swamp
- River
- Stream
- Drain/Channel/Ot...

Paper Size ISO A3

0 0.5 1 1.5 2

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

City of Greater Geelong
Mosquito Control Program
Assessment of impact of helicopter operations on migratory shorebirds

Migratory shorebird locations

Project No. **31-34129**
Revision No. **-**
Date **2018 April**

FIGURE 1

G:\31\34129\GIS\Maps\Working\3134129_001_Shorebird_Locations_3AL.mxd
Print date: 23 Apr 2018 - 16:37

Data source: DELWP, VicMap, 2017; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: tworth

2. Methods

To support the findings of GHD (2018), a five-day field assessment was undertaken in early 2019 to document observations of migratory bird disturbance caused by the helicopter flying over the treatment areas. The assessment was conducted between the 4 and 9 March 2019, before all of the migratory shorebirds had departed on their northerly migration.

Fieldwork was undertaken over 5 days: before (2 days), during (1 day) and after (2 days) a flyover event (a simulated larvicide application). For each phase of the assessment, observations recorded included species and abundance, and behaviour (e.g., foraging, roosting, preening).

The aim was to focus observations on migratory shorebirds. However, given the general scarcity of those species at most sites, observations were made of all birds listed as Migratory under the EPBC Act (i.e., including egrets, terns, etc.), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc.).

Six locations (tidal and non-tidal) were identified for the assessment, as was done for GHD (2018). Those sites were chosen to be representative of favoured shorebird locations in this region and to be relatively accessible to allow timely and repeatable observations of all sites all within one day. Sites chosen were based on past-10-year observations (using source: e-Bird.org) of species such as the Red-necked Stint and Sharp-tailed Sandpiper, which tend to be the most common Migratory shorebirds in Victoria.

The sites are shown in Figure 1 and include:

- Hospital Swamps (non-tidal)
- Lake Connewarre – Brinsmead Lane (tidal)
- Lake Murtnagurt (south of Lake Connewarre, north of 13th beach life saving club) (non-tidal)
- Lake Victoria – east end (non-tidal)
- Swan Bay Edwards Point Wildlife Reserve (tidal)
- Swan Bay Jetty (tidal)

The first site visit (day 1) determined that only four of the sites were suitable for the assessment under current conditions – Lake Murtnagurt and Hospital Swamps were completely dry, and currently supporting very few birds at all. Those sites were subsequently omitted from the study, and the before, during and after assessment was undertaken for the four remaining sites.

2.1 Pre-application assessment

The purpose of this phase of the assessment was to determine the presence and relative abundance of species at sites before helicopter operation occurred.

From the best available vantage point at each site, a point count of all wetland, waterbird and shorebird species was conducted on foot by two experienced observers using binoculars and, if deemed necessary, a high-powered spotting scope and tripod. The objectives were to:

- Determine species present and relative abundance, noting those that are listed as Migratory under the EPBC Act and those that are not.
- Determine habitat use of Migratory species at locations (roosting, foraging).

- Assess tide phase (tidal sites only), which may influence bird behaviour (e.g., high-tide roosting).

Each of the four sites was assessed twice (Day 1, then Day 2), with order of sites visited reversed for the second visit so that, as far as possible, every site was assessed once in the morning and once in the afternoon. Visiting sites twice reduced bias due to poor weather conditions, chance and time of day. Visits occurred on 4th and 5th March 2019 (days 1 and 2; before helicopter flyover).

A count of birds at each site on Day 3, prior to the helicopter flying over, effectively added another (third) pre-disturbance sample.

2.2 During-application assessment

The purpose of this phase was to determine whether the birds were disturbed by the helicopter flyover, and to gather information about the nature and magnitude of the disturbance.

On Day 3 (6 March 2019), using pre-arranged flight locations and times, two experienced observers watched the responses of birds at the four sites while the helicopter flew over the sites, as though it was applying larvicide (note – this was a simulated application, so that no larvicide was dropped). At each site, this was done after another full count of birds had been made – this effectively added another (third) pre-disturbance sample.

In keeping with what would be done for a normal larvicide application, the helicopter made repeated aerial passes over each site. Passes were made parallel to the shoreline, with each pass approximately 25 m towards the water relative to the previous pass, although in practice this was less structured in 2019 than in 2018.

The helicopter flew over at approximately 30-50 ft (10-17 m) above the ground, which is the normal height from which larvicide pellets are dropped. Helicopter speed was general slow, but strong prevailing winds made it difficult for the pilot to fly at the same speeds on all passes.

After flying over each site, the pilot landed the helicopter (at the Swan Bay Jetty Caravan Park) and waited for the ground-based ecologists to be in position at the next site, before flying over the next site. The flyover schedule was as follows:

- Swan Bay Jetty (10:00 am)
- Swan Bay Edwards Point (11:00 am)
- Lake Victoria (12:45 pm)
- Lake Connewarre (2:15 pm)

2.3 Post-application assessment

The purpose of this part of the assessment was to determine if species remain at or return to the site and in similar numbers. It was effectively a repeat of the pre-disturbance assessment, to allow for a before and after comparison.

This part of the assessment was undertaken on 8 and 9 March 2019 (assessment days 4 and 5; after helicopter flyover).

3. Results – Disturbance of migratory birds

3.1 Weather during the assessment

The weather on days 1, 2, 4 and 5 was relatively mild and calm and ideal for observing shorebirds. The weather deteriorated on day 3 (day of the helicopter flights), and conditions during the flight observations were far from perfect. Daily weather observations for the Geelong Bureau of Meteorology site (station 087184) during the assessment are shown in Table 1.

Temperatures at the time of the assessment were mostly mild to warm (low 20s), except for day 3, where the maximum temperature for Geelong did not rise above 18.8 ^{o}C.

During the assessment, days 1, 2, 4 and 5 were dry, while day 3 had squally passing showers, and 1.0 mm was recorded in Geelong. The assessment was done within a very dry period in southern Victoria. No more than 8.4 mm of rain was recorded in Geelong between 1 January and 4 March 2019 (62 days)(Jan: 2.0 mm; Feb: 6.4 mm; March 1-3: 0.0).

Winds were light and generally southerly on days 1 and 2, then increased strongly on the evening of day 2, as a cold front crossed the region. Day 3 was relatively windy and blustery from the west, with maximum recorded wind gusts of 54 km/h at Geelong, and 76 km/h at South Channel Island (BoM station). The intensity of squalls seemed to peak at the time of the assessment at Lake Connewarre, which was visited last that day. Winds returned to calmer conditions for days 4 and 5.

Table 1 Weather observations during the assessment

Date (2019) / Attribute	4 March	5 March	6 March	7 March	8 March	9 March
Day	1	2	3	-	4	5
Max Temp (^{o}C)*	24.7	25.2	18.8	21.9	25.3	24.1
Min Temp (^{o}C)*	14.6	15.4	12	8.3	11.5	12.8
Cloud cover (as observed by GHD) (x/8)	3 (high cloud)	4	7	-	6	1
Wind (max gust; km/h and dir)*	30 SSE	37 S	54 W	24 NE	31 S	35 S
Wind (max gust; km/h and dir)**	43 S	74 SW	76 W	50 SW	39 N	37 S
Rainfall to 9 am (mm)*	0	0	1.0	0.4	0	0

***BoM station 087184, Geelong; **BoM station 086344, South Channel Island.**

3.2 Representative images of sampled habitat at sites



Swan Bay (Edwards Point) (looking south)



Swan Bay Jetty (looking north)



Lake Victoria (looking southwest)



Red-capped Plover nest – Lake Victoria.



Lake Connewarre (looking east)



Hospital Swamps (looking north)

No image was taken at Lake Murtnaghurt, which was entirely dry at the time of assessment.

3.3 Waterbird species richness at sites

Over the five-day assessment, moderate numbers of waterbird species were observed at most sites (not including Lake Murtnaghurt or Hospital Swamps, which were dry at the time of assessment), ranging from 19 species at Lake Victoria and Swan Bay Jetty to nine species at Swan Bay Edwards Point. A total of 30 species were observed overall (Table 2). Not all of those species were Migratory species – most (23 of 30) were non-Migratory. Lake Victoria and Swan Bay Jetty were the only sites at which Migratory species were seen.

Only one species (Masked Lapwing) was observed at Lake Murtnaghurt, and no waterbirds were observed at Hospital Swamps, on two consecutive days (days 1 and 2).

Overall, species counts were lower in 2019 than in 2018, when 44 species were counted overall (39 of which were waterbirds).

Table 2 Counts of waterbird species (split into migratory and non-migratory) observed at each site during the assessment

Site	Migratory species	Non-Migratory species	Total species
Hospital Swamps*	0	0	0
Lake Murtnaghurt*	0	1	1
Lake Connewarre (Brinsmead Lane)	0	12	12
Lake Victoria	6	13	19
Swan Bay (Edwards Point)	0	9	9
Swan Bay (Jetty)	3	16	19
All sites	**7**	**23**	**30**

***visited on days 1 and 2 only.**

The waterbird species richness at most sites remained relatively consistent across the survey days (Figure 2). Generally, Lake Victoria and Swan Bay Jetty had more species present each day than the other sites, and this pattern was observed in 2018 also. Notable fluctuations in species richness occurred at Swan Bay (Edwards Point) (where only three species were observed on day 3, with up to six species on others days, before and after) and at Lake Connewarre (where no species were observed on day 4, with at least five species on all others days).

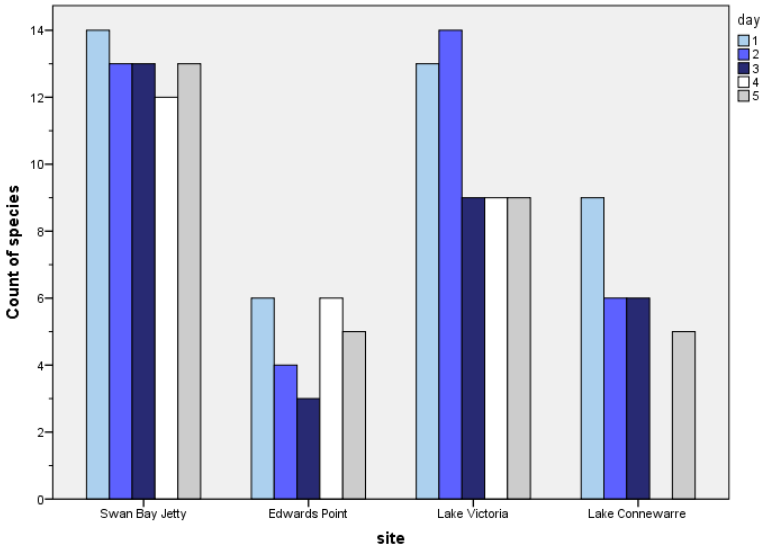


Figure 2 Total species counts at the five sites across the five-day assessment

Observations at Lake Victoria on days 1 and 2 (13 or 14 species) were notably higher than those on days 3, 4 and 5 (nine species each day), which superficially might indicate a change in bird distribution as a result of the helicopter flyover on day 3. However, closer examination of the species that were or were not observed show that a different mix of species was observed each day, and that it was mostly cormorants and ducks that were absent on latter days

(Table 3). There is no evidence that migratory species abandoned Lake Victoria as a result of the aerial flyovers.

Table 3 Waterbird species (migratory and non-migratory) observed at Lake Victoria during the five-day assessment

Species*	Day 1	Day 2	Day 3	Day 4	Day 5
Migratory					
Common Greenshank	✓	✓		✓	✓
Curlew Sandpiper		✓	✓	✓	
Double-banded Plover		✓		✓	✓
Marsh Sandpiper	✓				
Red-necked Stint	✓	✓	✓	✓	✓
Sharp-tailed Sandpiper					✓
Non-migratory					
Australasian Grebe	✓	✓	✓		
Australian Shelduck	✓	✓			
Black Swan	✓	✓	✓	✓	✓
Chestnut Teal	✓	✓	✓		
Great Cormorant	✓		✓		
Grey Teal	✓	✓	✓		
Little Black Cormorant	✓	✓			
Little Pied Cormorant		✓			
Masked Lapwing	✓	✓		✓	✓
Red-capped Plover	✓	✓	✓	✓	✓
Red-necked Avocet				✓	✓
Silver Gull	✓	✓	✓	✓	✓
Daily species count	13	14	9	9	9

*One additional species (White-faced Heron) was seen at this site on day 3 after the helicopter flyover – it is not included in this table.

3.4 Relative abundance of species at sites – all species

Waterbird and shorebird abundance at sites varied, but was generally large. This was to be expected, as the sites had been chosen on the basis of their bird history. At all sites, birds were engaged in a range of behaviours – foraging, roosting, rafting, preening, flying.

At Swan Bay Jetty (Figure 3, top), counts on all five days were consistently high, with more than 300 waterbirds observed each day. This matched the observations from 2018. The most abundant species were Little Pied Cormorant, Silver Gull, Black Swan, Grey Teal and Pied Cormorant. Again, this was similar to observations from 2018 (more Chestnut Teal were observed here in 2018). The Day 3 count (before helicopter flyover) resulted in the highest abundance of birds of any day, with nearly 700 birds counted. Counts on days 2, 4 and 5 were similar, with approximately 500 birds counted each day. For most species, post-disturbance counts (days 4 and 5) equalled or exceeded at least one of the pre-disturbance counts.

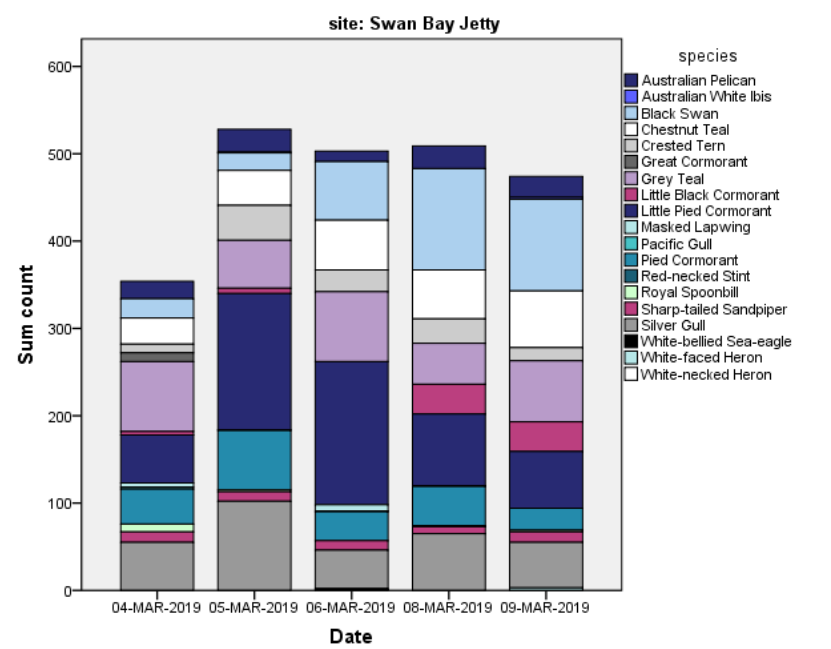
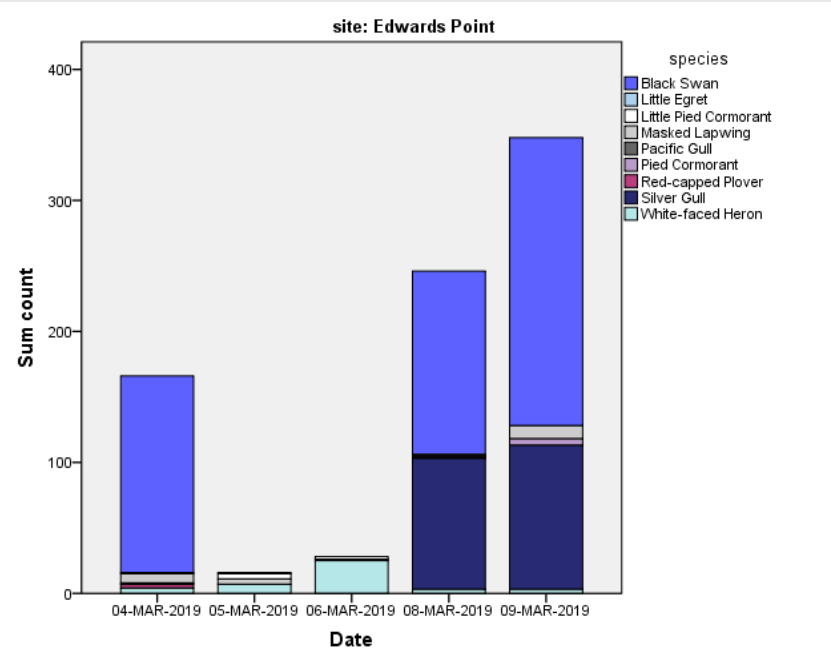
At Swan Bay Edwards Point (Figure 3, second from top), bird counts were lower than at the jetty site, and most birds counted (mainly Black Swans) were observed well off-shore. There were more than 150 birds observed on three of the five occasions, with nearly 350 observed on day 5. Lower bird counts were made on days 2 and 3. On Day 3, the wind was blowing strongly from the southwest (onshore, at that site). As was observed in 2018, the most abundant

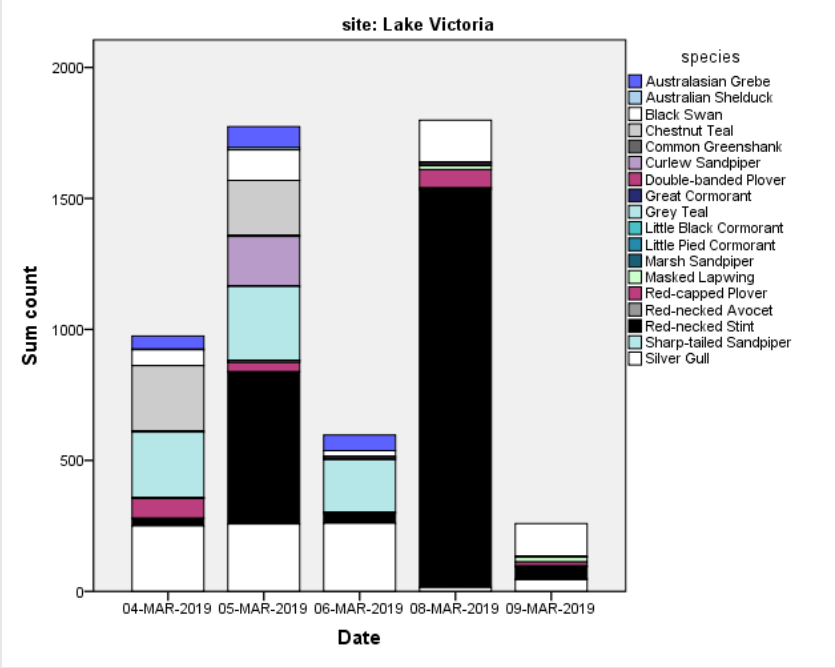
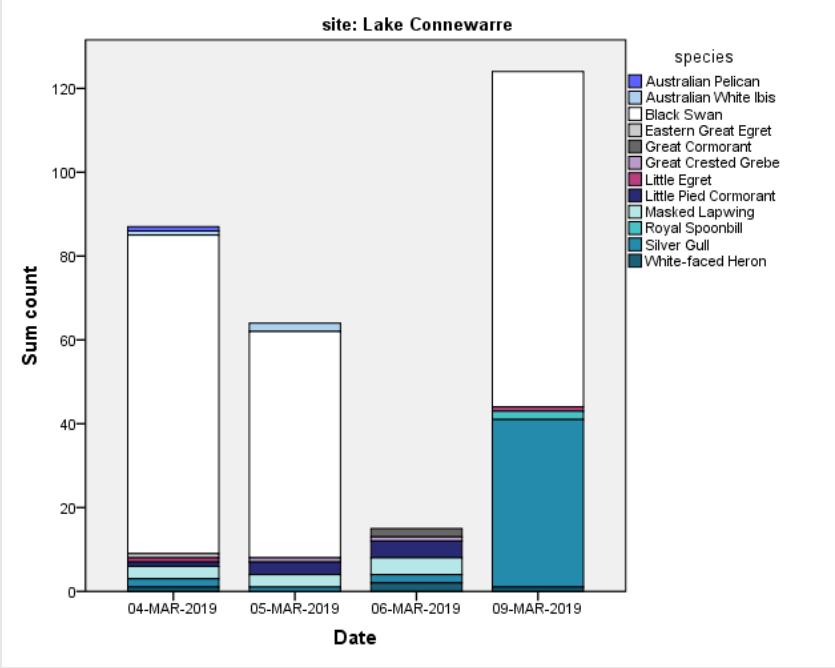
species was Black Swan (Days 1, 4 and 5), although in 2019, large numbers of Silver Gull were observed on days 4 and 5. For the two species that were observed in relatively large numbers, post-disturbance counts equalled or exceeded pre-disturbance counts. White-faced Heron was the exception, with 25 birds observed on day 3. These birds were not detected until they flew as a result of the helicopter disturbance – they may have been present on other days and not detected. In general, waterbirds other than Black Swans at this site appear to visit irregularly and temporarily (presumably to forage), rather than remain at the site for longer lengths of time – they may be present one day, then absent the next.

At Lake Victoria (Figure 3, second from bottom), bird counts varied widely across the five days, ranging from about 250 on day 5 to more than 1750 on day 4. Days with larger counts were similar to observations from 2018, where counts of 1000 to 2000 birds were made. The most consistently numerous species were Silver Gull, Red-necked Stint (particularly Days 2 and 4), Grey Teal, Chestnut Teal, and Black Swan. Other notable counts were of Curlew Sandpiper on Day 2, and huge numbers of Red-necked Stint on Day 4, but these observations were inconsistent across the days, and representative of fluctuating species' presence and abundance. Disregarding the species composition, the Day 4 count equalled the count on Day 2, while the Day 5 count was the lowest of all. The disparity in birds counts is at least partly explained by flighty foraging preferences of shorebirds and wind direction. On Day 3, the wind was strong and blowing the water (and therefore shoreline) of Lake Victoria away from the observers. Thus, the birds were present at Lake Victoria, but at more distant locations that were not considered part of the same site for the purposes of helicopter flyover observations.

At Lake Connewarre (Figure 3, bottom), bird counts were relatively small, from zero on day 4 and less than 20 on day 3 (immediately before helicopter flyover), to more than 120 birds on day 5. The most consistent and abundant species was the Black Swan, with Silver Gull and Australian Pelican also present on most days. For the Black Swan and Silver Gull, the post-disturbance counts exceeded any of the pre-disturbance counts.

Figure 3 Relative abundance of species (including Migratory and non-migratory) at the four sites during the five-day assessment

Site	Observations per day at each site – all waterbird species (Observations on day 3 are pre-disturbance)
Swan Bay Jetty	
Swan Bay (Edwards Point)	

Lake Victoria	
Lake Connewarre*	

*No waterbirds observed at this site on 8 March 2019 (day 4).

3.5 Relative abundance of species at sites – Migratory species only

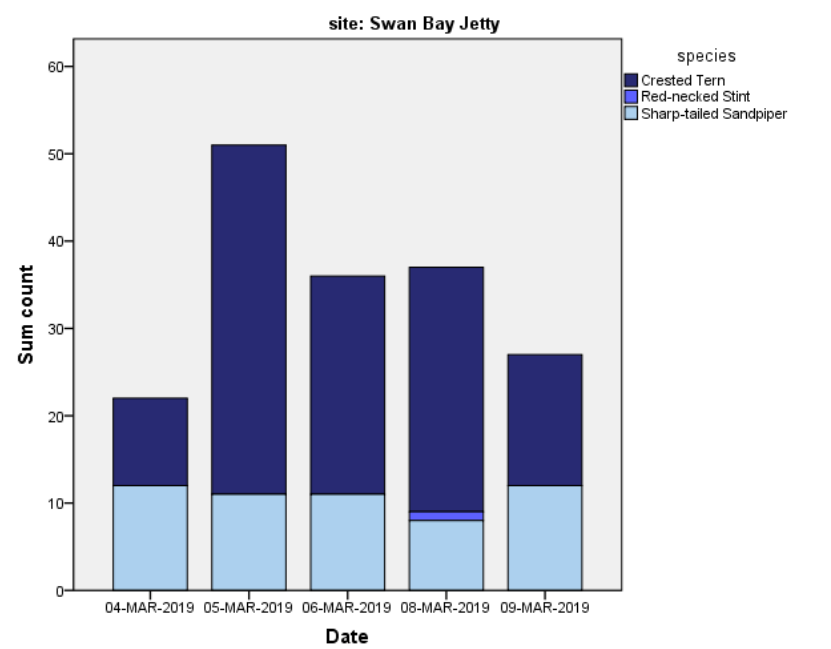
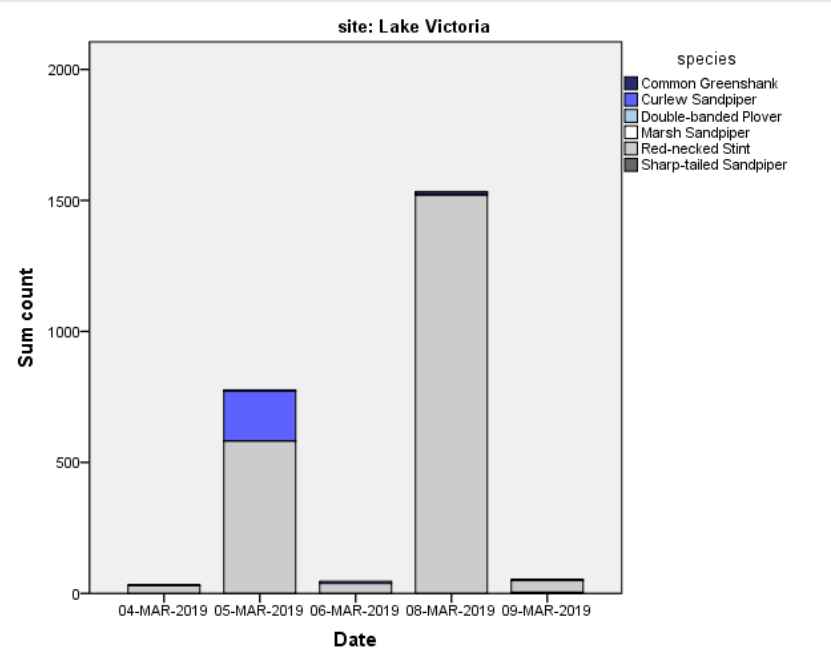
At most sites, richness and relative abundance of Migratory species was generally low. Migratory species (as listed under the EPBC Act) were only observed at two sites: Swan Bay Jetty and Lake Victoria. This reflects a fairly typical pattern for migratory species, which opportunistically exploit productive sites. Favoured locations can occasionally or regularly attract large numbers of migratory birds when conditions are suitable, but those species may be absent when conditions at those sites are less favourable or are favourable at sites elsewhere.

At Swan Bay Jetty (Figure 4 upper), three migratory species were observed, with two of those being migratory shorebirds: Red-necked Stint and Sharp-tailed Sandpiper. Counts of those species were relatively small; the Red-necked Stint was observed as a single bird on day 4 only. Interestingly, throughout the five day survey period, there was a small group of Sharp-tailed Sandpipers that were remarkably unfrightened by the presence of the observers, and that were barely disturbed by the helicopter flyover. Counts of birds pre- and post-helicopter disturbance were similar.

At Lake Victoria (Figure 4 lower), migratory shorebird counts near the chosen helicopter flyover site varied greatly between days, but maximum counts were markedly higher than at any other site, totalling more than 700 on days 2 and more than 1500 on day 4. Counts of migratory species at Lake Victoria were very much influenced by the prevailing conditions. With the very dry conditions in the months up to the survey period, the water level at Lake Victoria (rain fed and non-tidal) was low, and the shoreline was greatly receded, compared with 2018. Also, as explained above, on Day 3, the wind was strong and blowing the water (and therefore shoreline) of Lake Victoria away from the observers. Thus, the birds at Lake Victoria tended to be at more distant locations that were not considered part of the same site for the purposes of helicopter flyover observations. During the course of the five survey days, the birds appeared to have been moving around the lake more than they did in 2018, which accounts for the high variability in daily counts.

The most abundant species was Red-necked Stint (particularly Day 4), and Curlew Sandpiper (on Day 2 only). Interestingly, there were no Sharp-tailed Sandpipers observed at Lake Victoria on days prior to the helicopter disturbance, which is in strong contrast to the observations of 2018, where that species was one of the most common at that site.

Figure 4 Relative abundance of Migratory species at Swan Bay Jetty and Lake Victoria during the five day assessment

Site	Observations per day at each site – Migratory species only (Observations on day 3 are pre-disturbance)
Swan Bay Jetty	
Lake Victoria	

3.6 During-disturbance observations (Day 3)

As was observed in 2018, the helicopter flying repeatedly over the site resulted in high disturbance for all birds present at the site and near the site. Again, to the human observers, the noise was the most obvious sign of approaching disturbance, but whether it is noise or appearance (i.e., resembling an aerial predator) of the helicopter that disturbs the birds is unknown.

Descriptions of bird responses are shown in Table 4. As for 2018, species varied in how quickly they made the move to flee from the helicopter, and in how they fled. Some went early, and took to the skies; others went later and swam away. Species also varied in response behaviour – some flew off and landed in deeper water, others took to the skies and remained airborne. When disturbed, birds tended to group up with their own kind, then re-settle as a tight group, then commence spreading out again, once re-settled.

Species varied in how rapidly they returned to the site. Generally, soon after the helicopter disturbance, the species and numbers of birds present at the sites resembled the pre-disturbance observations.

It was noted that the helicopter, in both 2018 and 2019, was not carrying the larvicide bucket, so likely flew faster than it would have during normal application.

The pilot for 2019 was not the regular larvicide-applying pilot, and was not the same pilot as used for 2018. Consequently, there were subtle differences between the flight paths flown in the different years – in 2019, the flying was generally more distant from the observers. Given the generally small numbers of birds at most sites (not Lake Victoria), this was thought to not greatly influence the results. At Lake Victoria, it may have actually helped the 2019 results, because many of the birds that day were foraging in distant locations, and thus may not have been disturbed by the helicopter, had the helicopter flown the same flight path as it did in 2018.

At Swan Bay Point Edwards, too, it may have helped the results, because a large group of White-faced Herons was noticed because they were put up by the disturbance. Without that, they would have gone uncounted.

As was noted in 2018, the birds at these sites are generally easily disturbed by things other than helicopters. The coming and going of large numbers of birds appears to be normal and typical of these sites. Disturbance sources include people, dogs, noises, gunshots, golf balls, foxes, swamp harriers, whistling kites, low-flying aeroplanes and helicopters. In 2019, at Lake Victoria, there was a Whippet and a Greyhound walking off lead with owners as we arrived, and we noted at least one Swamp Harrier, Whistling Kite, Little Eagle, and White-bellied Sea Eagle.

Table 4 Disturbance responses by birds at each site during and after the helicopter flyover

Site	Helicopter movement	Time	Flight direction	What did birds do?
Swan Bay Jetty (pre-survey)	Helicopter arriving on site. Pre-surveys.	8:31	Helicopter arriving from the north. Pre-surveys.	To North: 3 Cormorants take flight. Then all cormorants from wooden structure go up. Pelicans from jetty all go up. 30 x Teal go up. 5 Sharp-tailed Sandpipers go up. 1 x White-necked heron go up. 20 teal remained, swam into water, didn't fly. Masked Lapwings did not fly. To south, 6 x sharp-tailed sandpipers near jetty did not fly. To north: Teal then re-settle in water 30 m off shore. Cormorants have not returned. Swans did not fly. To south: 2 minutes later, another 5 x sharp-tailed sandpipers land to the south of the jetty (~200 m). Presumably, these are the ones from the north side, put up by the helicopter. To north: 4 minutes after helicopter, 1 Masked Lapwing didn't fly, 2 Grey Teal didn't fly, a raft of Grey Teal swimming in the water having walked in, Silver Gulls, terns, cormorants still on jetty, To south: 6 sharpies, 10 Chestnut Teal, 7 Swans still there. Cormorants on southern wooden structure didn't fly.
Swan Bay Jetty	Take off	9:58	NA	Birds fly as helicopter takes off. All chestnut teal walk into water then swim gently, then stop, then return. All 80 Grey Teal take to the air, then circle back and land about 40 m out, near same area. White Ibis up. Masked Lapwing not up. 10-15 Silver Gulls not up. Black Swans to north not up, unperturbed. No sign of Sharp-tailed Sandpiper to north. 8 Sharp-tailed Sandpipers near Jetty (south side) did not fly - continue to forage. Cormorants on wooden structure north flew. Cormorants from jetty took off also, and now returning in 1s and 2s. Silver Gulls and Crested Terns from jetty did not fly. All birds south of jetty stayed put.
	First simulated seed drop	10:00	North to south	Helicopter flew to the north, and is now doubling back to do 1st seed drop simulation. Grey Teal in loose flock on water, 30 m out. 4 Swans took off. Masked Lapwings not up. Chestnut Teal not up. Sharp-tailed Sandpipers near Jetty did not fly. Helicopter flew over caravan park rather than shoreline, then south over saltmarsh habitat. Nothing put up, as far as observer can see. 2 Magpies and 2 White Ibis took to the air. Helicopter distant. Sharp-tailed Sandpiper to north is still there - did not fly when helicopter flew over.

Site	Helicopter movement	Time	Flight direction	What did birds do?
	Second simulated seed drop	10:02	south to north	Second pass. Sharpies under jetty cautious, running, but not put up. North: Chestnut teal swimming out to sea again, Grey teal also swimming out, but not taking off. Birds largely unfazed by that helicopter pass. 5 Masked Lapwings still there - not put up.
	Third simulated seed drop	10:04	north to south	Third pass. Chestnut teal still swimming in shallows, about 5 m offshore. Grey teal further out on water, about 30 m offshore. Silver Gulls and Masked Lapwings unfazed. Teal swim out when helicopter approaches, then swim back when helicopter departs. Sharp-tailed Sandpipers have grouped, under jetty, but not flown. Swans, birds on jetty and birds out to sea unfazed. Helicopter more over land than over sea.
Point Edwards	First simulated seed drop	11:02	north to south	Before helicopter arrived, 2 pelicans flew over, 2 chestnut teal flew over, 1 little egret flew past, no one landed. Helicopter wide of shoreline, east of us. No birds put up. Wind caused helicopter to fly through quite fast. To the south, helicopter puts up 25 white-faced herons and a Pacific Gull. Beyond boardwalk.
	Second simulated seed drop	11:04	south to north	White-faced Herons (WFH) settled in claypan area to north of where they were. Pacific Gull still flying. WFHs put up again by returning helicopter. WFHs swing around to east. Helicopter flying over us very fast. Nothing put up, nothing to fly.
	Third simulated seed drop	11:05	north to south	Helicopter further east - over coast/walking track. WFHs all up again. Wind picked up, rain on the way.
	Fourth simulated seed drop	11:06	south to north	Too distant to see. WFHs pushed from one claypan to another. Re-settled, didn't abandon whole area.
Lake Victoria	High flyover	12:47	north to south	Small numbers of birds today - windy and rainy. Very different conditions from yesterday. Birds are probably using other parts of the lake. Helicopter approaching from north-east, flying over us, but very high. No birds put up by that. Helicopter flies to other side of lake (south side), well away from where we are. Lots of distant shorebirds on lake flats, not put up.

Site	Helicopter movement	Time	Flight direction	What did birds do?
	First simulated seed drop	12:48	South to north	Helicopter in distance swings around and drops down, approaching from south to north. Shorebirds not put up, as far as eye can see (binoculars). Helicopter flies nearer us, puts shorebirds up - large numbers flying in small flocks, flying all over the place. Still distant.
	Second simulated seed drop	12:50	North to south	Helicopter doing transects in area away from us – probably the normal mosquito area. Shorebirds settle nearer us - 10 Red-necked stint settle. Most shorebirds settle on island in distance - site of preference today. Small numbers of shorebirds still flying around Flock of Chestnut Teal standing on lake shoreline near us. Small numbers of Stint.
	Third simulated seed drop	12:54	South to north	Helicopter now flying towards us, rather than further south. Flock Curlew Sands go up. Distant. All Red-capped Plover and all Red-necked Stint go up, flying towards the south, then landing nearby. Short-term disturbance, landing back into same habitat, haven't flown to other side of lake. Curlew Sands re-settled in group on island. One Greenshank seen also in flight - landed on island.
	Fourth simulated seed drop	12:56	North to south	Helicopter returning, flew right over us. Chestnut Teal disturbed from Golf course take to water, Chestnut Teal from Lake took off and flew towards golf course lagoon to re-settle. Swans not up. Silver Gulls not up. Large group of shorebirds still on island, now distant from helicopter. No sign of Red-caps on sand nearby. At 12:57, large group of shorebirds on island all put up and flying further west, not towards us. Teal from lagoon are up - 200-300 birds landing in lagoon again - must have been put up by helicopter when it flew over.
	Post helicopter	13:11		Helicopter now gone. Shorebirds - near island, flying and landing in groups. Red-capped Plovers on sand near us in small numbers. No Stint seen scanning to north. Marsh Terns seen flying out over Lake. Flock of teal (chestnut?) in lake, perhaps 200 birds, swimming. Chestnut teal in water in lagoon. White-faced heron seen also. Great cormorant on post - may not have even taken off.White-faced Heron - seen on other side of claypan. North section of lake. 4 Red-necked Stint foraging.

Site	Helicopter movement	Time	Flight direction	What did birds do?
Lake Connewarre	First simulated seed drop	14:16	East to west	Helicopter flying low. Magpies and Silver Gulls in east fly up. Masked Lapwings not flying. Then 1 Masked Lapwing put up. Super windy. To west, 2 Little Pied Cormorants put up, 2 Masked Lapwings put up, 3 Silver Gulls put up, 1 White-faced Heron put up. They wheel around behind the helicopter over the water, then re-settle fairly rapidly in similar location. Rain coming in - horrible conditions.
	Second simulated seed drop	14:18	West to east	Awful conditions. Seeking shelter behind bush. No birds seen flying or not flying. 1 White-faced Heron, 2 Masked Lapwing put up at east side. Helicopter settles temporarily in paddock to avoid weather. No birds nearby to observe during additional flyover. Exercise complete.

4. Conclusions

The observations presented in this report bear strong resemblance to those reported in 2018 (GHD 2018). The numbers of migratory shorebirds in 2019 were lower than in 2018, and limited to two sites only. This is likely due to the conditions being far drier in 2019 than in 2018 – wetlands were scarcer in 2019.

The weather conditions on day 3 (flyover day) in 2019 turned out to be worse than expected, and worse than on all other survey days. This may have influenced the results to some degree, but did not remove all value from the observations. The patterns observed in 2018 were again evident in 2019.

Generally, shorebirds and wetland birds are easily disturbed, and by a range of potential sources, including people (including birdwatchers), loud noises, wayward golf balls, dogs, foxes, birds of prey and low-flying aircraft. During the 2018 and 2019 assessments, observations were made of birds being disturbed by sources other than the helicopter. The result was similar to what was consistently observed at all sites during the helicopter flyovers – birds took to the skies, then tended to resettle at or near the original location soon after the disturbance source had gone. As was noted in 2018, disturbed birds tended to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Each major disturbance (i.e., when all birds flee) appeared to reset the distribution of birds at the site. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these sites. On-ground observations made here during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter.

One of the most interesting observations made during the 2019 survey period was of a small group of Sharp-tailed Sandpipers (migratory) at Swan Bay Jetty. These birds were remarkably unfrightened by the presence of the observers, and were barely disturbed by the helicopter flyover.

This assessment considered the potential disturbance to the birds due to the helicopter operations only. From this assessment and the similar assessment in 2018, it appears likely that larvicide application by helicopter results in short-lived disturbance of migratory shorebirds (and other species) at sites where they are present. The disturbance does not appear to be major or extraordinary for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance remains unknown. These migratory shorebirds are preparing for their return migration to the northern hemisphere, and where the threshold of tolerable versus excessive disturbance lies, is also unknown.

Larvicide application by helicopter is likely to meet with variable conditions with respect to birds. Dry conditions in March 2019 may have resulted in fewer birds generally, and not always distributed where the helicopter flies. Therefore, the effect of treatments/applications may vary in terms of bird disturbance.

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GHD 2018 – Mosquito Control Program, Review of migratory bird and seasonal behaviour including literature review and field assessment (February and March 2018). Unpublished report to the City of Greater Geelong, May 2018



City of Greater Geelong

Mosquito Control Program

Review of migratory birds and seasonal behaviour

June 2020

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Executive summary

Project background

The City of Greater Geelong (CoGG) monitors and treats mosquitoes in targeted locations around the Greater Geelong region and Bellarine Peninsula (the project area) on a weekly basis between August and March each year. The abundance of adult mosquitoes in the Greater Geelong region is controlled by ground and helicopter aerial treatments, which are aimed at targeting the larvae life stage (CoGG 2016).

The targeted project area includes 37 treatment sites from two broad areas of Swan Bay and Lake Connewarre. The aerial treatment areas are part of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. The aerial treatments are conducted in accordance with the *Environment Protection and Biodiversity Conservation Act* (EPBC) approval 2005/2132.

The EPBC approval 2005/2132 lists a number of conditions to minimise the impact of the mosquito control project on the ecological character of the Ramsar site and listed migratory species. Condition 4D states *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour.*

With assistance from GHD, CoGG has engaged with the federal Department of the Environment and Energy (DOEE) to revise the content of the EPBC approval to create conditions that are more valid and that better reflect the activities undertaken by CoGG in their aerial application.

To support a request to vary the approval, GHD prepared a desktop review of publically available literature and database information to identify the migratory shorebird species that are likely to be present within the project area. This has included reviewing information on species numbers, abundance and timing of occurrence, particularly during the approved annual aerial application period (16 August – 14 March). The majority of treatments occur from September to December, with fewer treatments generally in January to March.

To further support the request to vary the approval, GHD undertook a five-day assessment of bird behaviour during a simulated larvicide application event in February/March 2018. This assessment considered the potential disturbance to the birds due to the helicopter operations only. The methods and results of that assessment are included in this report.

Key review outcomes

There are 36 migratory shorebird species listed as protected in accordance with the EPBC Act, that breed in the northern hemisphere and migrate annually through the East-Asian-Australasian Flyway to nonbreeding areas in the southern hemisphere, including Australia. Based on the database searches, 33 of the 36 species were recorded within the project area during the assessment.

The desktop review revealed the following information:

- The review of the literature indicates that both Swan Bay and Lake Connewarre complex support a diverse and healthy population of migratory shore birds. The population of birds and their abundance is most pronounced in both areas between January and March. CoGG conduct the majority of their application between August and December, when the mosquito breeding season is most severe, with minimal applications in the latter months (January to March).
- The larvicide application between August and March each year is for a maximum cumulative period of 30 minutes at each treatment site (total of 37 sites) for the entire

season. The population and abundance of migratory birds is distributed across the wider Ramsar areas, and are not localised to areas that are within the flight path of the helicopter during aerial application. Observations made during the helicopter flights indicate that an insignificant number of birds are disturbed during the aerial applications.

- Information discussed in this migratory bird report does not allow for a review of the behaviour of migratory shorebirds and their abundance at the time of the treatment period. Also, as discussed further in the report, it was not possible to determine the presence/absence of migratory shorebirds recording video footage during the helicopter flights. Limitations exist that preclude the use of video footage, including:
  - Restrictions from CASA (Civil Aviation Safety Authority) to affix a camera to the helicopter or treatment bucket.
  - No other person is allowed in the helicopter during an application event due to occupational health and safety reasons as well as weight restrictions in the helicopter while applying the product.
  - Difficulty in getting quality footage from within the helicopter cabin.
  - The migratory shorebirds are often small and it is difficult to identify the species observed from the helicopter.

Key outcomes of shorebird disturbance monitoring

The helicopter operation over the wetlands almost certainly results in disturbance of migratory shorebirds at sites where they are present. However, the disturbance appears to be short-lived and does not appear to be major for the bird. On-ground observations found that most, if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance remains unknown.

When disturbed, birds tended to take to the skies, group up with con-specifics, then resettle as a tight group at or near the original location soon after the disturbance source had gone. Some birds re-settled some distance away, then made their way back to the original location in smaller groups. Each major disturbance (i.e., when all birds flee) appeared to reset the distribution of birds at the site. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these sites. Nearly all birds flew away from the approaching helicopter, which may explain why no migratory shorebirds were identified from the aerial video footage.

1. Introduction

1.1 Project Background

The *Framework for Mosquito Management in Victoria* (DSE 2004) forms the outline of mosquito management for Local Governments' throughout Victoria. Local Governments are responsible for mosquito management on council land under the *Public Health and Wellbeing Regulations 2009*.

The *Public Health and Wellbeing Regulations 2009 S.R. No. 178/2009 (1)* states:

> *For the purposes of section 235(a) of the Act, in order to prevent the breeding of mosquitoes which may be vectors of arboviruses, an authorised officer may give written directions to the owner or occupier of any premises to remove, or take steps to avoid, any condition on those premises conducive to the breeding of mosquitoes*.

The City of Greater Geelong (CoGG) monitors mosquitoes around the Bellarine Peninsula and Greater Geelong region on a weekly basis between August and March each year (CoGG 2016). Mosquito monitoring provides a better understanding of mosquito population dynamics in the Greater Geelong region, the potential public health risk from mosquitoes and aims to manage potential outbreaks before they occur. CoGG monitors both mosquito larvae and adults.

In response to the results of the monitoring, CoGG controls the abundance of adult mosquitoes in the Greater Geelong region with the use of ground and helicopter aerial treatments targeting mosquito larvae (CoGG 2016). The treatment areas includes sections of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. The aerial treatments are conducted in accordance with an *Environment Protection and Biodiversity Conservation Act* (EPBC) approval 2005/2132.

The EPBC approval 2005/2132 lists a number of conditions to minimise the impact of the mosquito control project on the ecological character of the Ramsar site and listed migratory species. Condition 4D requires that *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour*.

Due to the isolated nature of the wetlands, and the occupational health and safety risks involved in working with aerial larvicide applications, it has not been possible to conduct comprehensive bird surveys during the aerial application. As Bti and s-methoprene are not classified as Dangerous Goods or Hazardous Substances, the safety risks are not associated with using insecticides. Rather, the safety risk is due to OHS operational guidelines that non-essential personnel are not permitted in the helicopter during actual application of the product (when the bucket is slung underneath the helicopter). It is also associated with weight issues in the helicopter, making the treatment more difficult.

Consequently, the helicopter pilot has recorded observations of birds during the aerial application. Capturing aerial footage during flights has been suggested as a means to obtain more information about bird abundance and behaviour during aerial treatment of the target areas.

Given the limitations associated with interpretation of aerial footage, an on-ground assessment was undertaken by GHD in February/March 2018 to directly document disturbance of birds (particularly migratory shorebirds) during an aerial application. Due to the occupational health and safety risks for observers being beneath larvicide pellets as they are dropped, the assessment was made during a simulated aerial application (i.e., a dummy flyover by the helicopter, without the larvicide).

1.2 Project area

The project area consists of 37 sites from two areas, namely Swan Bay and Lake Connewarre that are subject to aerial application. These locations are identified by the EPBC approval conditions (EPBC 2005/2132) and are depicted in Figure 1 (Swan Bay) and Figure 2 (Lake Connewarre).

Figure 1 Treatment sites in the Swan Bay area


MAP 1 SWAN BAY
0 250 500 1,000 1,500 2,000
M
Figure 1
ANDERSONS RD
PORT ARLINGTON - QUEENSCLIFF RD
SWAN BAY RD
KNIGHTS RD
HELICOPTER LANDING SITE
Swan Bay Jetty
Edwards Point
SWAN ISLAND ARMY (prohibited area)
SWAN ISLAND GOLF COURSE
BELLARINE HWY
MURRAY RD
FELLOWS RD
Burrit Point
SEE INSET MAP 1
SEE INSET MAP 2
INSET MAP 1
INSET MAP 2



Figure 2

MAP 2 LAKE CONNEWARRE

0 250 500 1,000 1,500 2,000 M

Prepared by City of Greater Geelong - 17 August 2009 (Aerial Imagery - November 2007)
Although all due care has been taken to ensure that this document is correct, no warranty is expressed or implied by the City of Greater Geelong or Barwon Water in its use.

Figure 2 Treatment sites in the Lake Connewarre area

1.3 Purpose of this report

The federal Department of the Environment and Energy (DoEE) has advised that for a variation to the EPBC approval to be considered, information about migratory bird presence and behaviour in the treatment areas is required.

This report includes a review of current knowledge of the migratory shorebird species listed under the EPBC Act that are known or likely to occur in the aerial application treatment areas, and the findings of a field assessment of bird disturbance. The report:

- Provides a brief summary of migratory shorebird ecology in Australia.
- Identifies the migratory shorebird species listed under the EPBC Act that are known or likely to use the treatment areas.
- Documents the temporal patterns of usage of the treatment areas by these species.
- Documents the findings of a review of a sample of video footage collected by the CoGG staff during dummy flights to assist with understanding migratory bird behaviour and response to helicopter activity.
- Discusses the timing of the aerial application and historical occurrence of migratory bird species in the project area.
- Provides recommendations and potential next steps for the monitoring program.
- Presents the methods and results of a bird monitoring assessment, including species and abundance at a range of sites before, during and after the simulated helicopter operations.

1.4 Legal Limitations

This report has been prepared by GHD for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and the City of Greater Geelong as set out in section 1.3 of this report. The review focuses on environmental risks to birds and does not consider risks to human health.

GHD otherwise disclaims responsibility to any person other than City of Greater Geelong arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.5 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by City of Greater Geelong and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Literature review of migratory shorebirds

Migratory bird species which visit Australia receive protection within Australian territories as a matter of national environmental significance (MNES) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

There are 37 shorebird species (listed migratory species) protected as MNES under the EPBC Act that migrate to and from Australia each year (DoE, 2015a). Nine of the 37 species are also listed as vulnerable, endangered or critically endangered under the EPBC Act.

Migratory shorebirds are birds that inhabit the shorelines of coasts and inland water bodies during most of their life cycles. The majority of these birds are from two taxonomic families, the Sandpipers (*Scolopacidae*) and the Plovers (*Charadriidae*) (DoE, 2015a).

2.1 General ecology of migratory shorebirds

2.1.1 Movement patterns

Thirty-six of the 37 EPBC Act listed migratory shorebird species breed in the northern hemisphere and migrate annually through the East-Asian-Australasian Flyway (EAAF) to nonbreeding areas in the southern hemisphere, including Australia. The other species, double-banded plover, migrates between Australia and breeding grounds in New Zealand, rather than north-south through the flyway (DoE, 2015a).

Most migratory shorebirds make an annual return journey of many thousands of kilometres between their breeding grounds and foraging grounds via the EAAF. The EAAF extends from breeding grounds in the Russian tundra, Mongolia, Siberia and Alaska southwards through east and south-east Asia, to non-breeding foraging areas in Indonesia, Papua New Guinea, Australia and New Zealand (DoE 2015a, DoE 2015b).

Migratory shorebird species are mostly present in Australia during their non-breeding period, from as early as August to as late as April/May each year. The double-banded plover is different, and is generally present in Australia from March to September (DoE, 2015a).

Shorebirds that migrate from the northern hemisphere reach 'staging areas', such as Roebuck Bay in north-western Western Australia, by September. From these staging areas, the birds may disperse to other parts of Australia, typically reaching the south-eastern parts by October. Smaller numbers take advantage of ephemeral wetlands across inland Australia, while others spread along the coastline (DoE, 2015b). By March, birds begin to gather at staging areas, once again forming large flocks and feeding virtually round the clock to accumulate energy reserves for their northward migration (DoE, 2015b).

Flocks or individuals of some migratory species may remain in Australia during the winter months, such as first-year birds that lack the experience or physical condition to return to their natal sites until they are older and stronger, often in their second year (DoE, 2015b).

2.1.2 Areas inhabited by migratory shorebirds

After arriving in Australia at the end of their migration, birds tend to disperse to a wide variety of coastal and inland habitats within Australia, including:

- Coastal wetlands, estuaries, mudflats, rocky inlets, reefs and sandy beaches, often with mangrove populations.

- Inland freshwater wetlands, floodplains and grassland areas, often with ephemeral water sources.

Australia's coastal and freshwater wetlands are important habitat during the non-breeding season as places for migratory shorebirds to rest and feed, and accumulate energy reserves to travel the long distance back to their breeding grounds (DoE, 2015b). Areas commonly used by migratory shorebirds in Australia usually comprise networks of foraging and roosting habitats. Shorebirds move within these networks depending on the time of day, availability of resources, levels of disturbance and environmental conditions (DoE, 2015a).

The majority of migratory shorebirds mostly feed on intertidal mudflats and require safe roosting areas to rest during high tide periods. The high energy demands on migratory shorebirds resulting from their migratory lifecycle means that resting is critical when not breeding. Generally, migratory shorebirds prefer roosting areas in open habitat on slightly elevated ground so they remain alert for potential predators (DoE 2015a).

Migratory shorebirds at non-tidal wetlands such as inland systems tend to show more dispersive behaviour (DoE 2015a). Within estuarine environments, principal roosting areas include exposed sands at estuary mouths and on adjacent beaches, saltmarshes that are only marginally submerged during high tide, grassy areas adjacent to estuaries, mangroves, nearby freshwater wetlands, claypans, and occasionally, rock groynes and exposed reefs (DoE, 2015a).

2.1.3 Foraging habitat

Many migratory shorebirds have specialised feeding techniques that enable them to feed on specific prey within particular foraging areas. The distribution of prey species, generally invertebrates, crustaceans and small fishes, also depends on factors such as sediment type and particle size which influences foraging habitat selection. In coastal areas foraging habitats are typically found in soft substrate tidal areas exposed during low tide (DoE, 2015a).

Some Australian inland wetlands and grasslands are also important habitat for migratory shorebirds. Many of these inland areas are ephemeral due to variability in climate. For this reason, many inland areas may not be used for several years. However, when these areas receive rain they can provide extremely productive and important food sources for migratory shorebirds (for example, Lake Eyre in northern South Australia) (DoE, 2015a).

3. Migratory shorebirds in the project area

3.1 Data Review Method

In order to confirm the migratory species that could occur within the project area a review of the following databases was undertaken:

- The Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* Protected Matters Search Tool (PMST, 2017)[1]. – 5 km buffer search of project area.
- The Victorian Biodiversity Atlas (VBA, 2017), maintained by the Department of Environment, Land, Water and Planning (DELWP)[2] – 5 km buffer search of project area (all records for each species). The database search included a review of records from 1903 through 2015.

A list of species was identified in the project area using outputs from the VBA and PMST searches (see Section 2.2.2). A step-wise process was then undertaken to further refine the species considered for this project. The process involved a review of species records using the VBA data to determine species that regularly occur within the project area based on the number of observations (regardless of location and time of record) within the project area. On that basis, species were divided into two groups:

1. Species that regularly occur (50 or more historical observations) for the period of the database.
2. Species that occasionally occur (fewer than 50 historical observations), e.g. rare and vagrant species for the period of the database.

Data for each species that regularly occurs within the project area was then reviewed to consider the temporal distribution of records (e.g. how the records are distributed across the different months of the year, and particularly how the records are distributed from August through to March, the mosquito treatment period, of each year).

The review was also supplemented with information from Species Profiles and Threats Database (SPRAT, 2017) [3], maintained by the DOEE.

3.1.1 Data limitations

There are a number of limitations to this data review and approach including:

- The approach assumes all species have been surveyed equally and are equally detectable, i.e. same effort survey technique and appropriate timing. However, this is highly unlikely to be the case and there will be bias toward certain species.
- Given the sensitivity of the environment (e.g. a Ramsar wetland with some restricted access) there is likely survey bias regarding the location of survey points. It is unlikely that all areas have been surveyed equally for a variety of reasons (e.g. access); hence, data is assumed to be skewed towards locations that are publically and or easily accessible, and therefore that are surveyed more frequently.

[1] http://www.environment.gov.au/epbc/protected-matters-search-tool (accessed on 5/5/17)

[2] https://vba.dse.vic.gov.au/vba/ (accessed on 5/5/17)

[3] http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl (accessed on 5/5/17)

- Given the buffers applied to the search area and proximity of each project area (approximately 7-8 km apart) there may be overlap/duplication in data. We have attempted to sort and remove this data, where obvious.
- The data assessed includes species recorded since as early at 1900. This pool of data does not reflect bird counts for the last 2 to 3 years (i.e. 2015-2017) as data is not available.

3.2 List of recorded species

Thirty-three (33) species were recorded from the database searches in the project area (Table 1) of which:

- Historically 28 species have occurred within the Swan Bay project area throughout the year, of which 14 species are deemed to be regularly occurring species. The remaining species have few records and are considered to occasionally occur within the project area across the full time period assessed.
- Historically 31 species have occurred within the Lake Connewarre project area throughout the year, of which eight species are deemed to be regularly occurring species. The remaining species have few records and are considered to occasionally occur within the project area across the full time period assessed.

Table 1 Migratory shorebird species listed under the EPBC Act considered for this review.

Species name	Lake Connewarre (LC)			Swan Bay (SB)			Occurrence (LC or SB)
	PMST	VBA Records (observations)	VBA Year	PMST	VBA Records (observations)	VBA Year	(Regular or Occasional)
Latham's snipe, *Gallinago hardwickii*	Y	112	2013	Y	33	2006	**Regular (LC)**
Pin-tailed snipe, *Gallinago stenura*	Y	-	-	Y	-	-	Unlikely - No records
Swinhoe's snipe, *Gallinago megala*	Y	-	-	Y	-	-	Unlikely - No records
Black-tailed godwit, *Limosa limosa**	Y	22	2010	Y	45	2006	Occasional
Bar-tailed godwit, *Limosa lapponica**	Y	31	2012	Y	161	2009	**Regular (SB)**
Little curlew, *Numenius minutus*	Y	1	1891	Y	3	1984	Occasional
Whimbrel, *Numenius phaeopus*	Y	7	2007		34	2006	Occasional
Eastern curlew, *Numenius madagascariensis**	Y	93	2010	Y	144	2010	**Regular (LC & SB)**
Common redshank, *Tringa totanus*	-	1	2012	-	-	-	Occasional
Marsh sandpiper, *Tringa stagnatilis*	Y	112	2015	Y	16	1999	**Regular (LC)**

Species name	Lake Connewarre (LC)			Swan Bay (SB)			Occurrence (LC or SB)
	PMST	VBA Records (observations)	VBA Year	PMST	VBA Records (observations)	VBA Year	(Regular or Occasional)
Common greenshank, *Tringa nebularia*	Y	333	2015	Y	284	2010	**Regular (LC & SB)**
Wood sandpiper, *Tringa glareola*	-	5	2009		3	1979	Occasional
Terek sandpiper, *Xenus cinereus*	Y	7	2014	Y	2	2005	Occasional
Common sandpiper, *Actitis hypoleucos*	Y	27	2007	Y	42	2008	Occasional
Grey-tailed tattler, *Heteroscelus brevipes*	Y	3	1988	Y	55	2008	**Regular (SB)**
Ruddy turnstone, *Arenaria interpres*	Y	32	2006	Y	177	2008	**Regular (SB)**
Great knot, *Calidris tenuirostris**	Y	9	2010	Y	102	2009	**Regular (SB)**
Red knot, *Calidris canutus**	Y	25	2006	Y	173	2009	**Regular (SB)**
Sanderling, *Calidris alba**	Y	13	2008	Y	17	2005	Occasional
Red-necked stint, *Calidris ruficollis*	Y	306	2015	Y	543	2010	**Regular (LC & SB)**
Long-toed stint, *Calidris subminuta*	-	7	1986		2	1978	Occasional
Pectoral sandpiper, *Calidris melanotos*	Y	15	2010	Y	4	1989	Occasional
Sharp-tailed sandpiper, *Calidris acuminata**	Y	194	2015	Y	274	2009	**Regular (LC & SB)**
Curlew sandpiper, *Calidris ferruginea**	Y	200	2015	Y	305	2009	**Regular (LC & SB)**
Broad-billed sandpiper, *Limicola falcinellus*	-	2	1992	Y	3	1995	Occasional
Ruff, *Philomachus pugnax*	-	4	2010	-	-	-	Occasional
Red-necked phalarope, *Phalaropus lobatus*	Y	5	2002	-	2	1986	Occasional
Pacific Golden plover, *Pluvialis fulva*	Y	44	2008	Y	88	2006	**Regular (SB)**
Grey plover, *Pluvialis squatarola*	Y	5	2003	Y	115	2009	**Regular (SB)**
Little ringed plover, *Charadrius dubius*	-	1	1987		-	-	Occasional

Species name	Lake Connewarre (LC)			Swan Bay (SB)			Occurrence (LC or SB)
	PMST	VBA Records (observations)	VBA Year	PMST	VBA Records (observations)	VBA Year	(Regular or Occasional)
Double-banded plover, *Charadrius bicinctus*	Y	88	2011	Y	165	2009	**Regular (LC & SB)**
Lesser sand plover, *Charadrius mongolus**	Y	4	2008	Y	88	2006	**Regular (SB)**
Greater sand plover, *Charadrius leschenaultia**	Y	2	1996	Y	28	2004	Occasional

Table notes:
PMST = species predicted to occur within 5 km of project area
VBA records = number of observations from VBA database within 5 km of project area. Observations represent each occasion a species was documented in the VBA at a different date and by a different observer regardless of the number of individuals.
VBA year = year of last observation
* = Species also listed as threatened under the EPBC Act
Regular species = greater than or equal to 50 observations over the period of the database search
Occasional species = less than 50 observations over the period of the database search.
Observations represent each occasion a species was documented in the VBA at a different date and by a different observer regardless of the number of individuals.

3.3 Temporal distribution of records within the project area

3.3.1 Swan Bay area

The historical data from the Swan Bay area indicate that migratory shorebirds are present within the Swan Bay area for most of the year, although the number of individual records varies greatly from month to month (Figure 3). The majority of records of the regular migratory bird species appear to fall within October through March period (Figure 3), which coincides with the documented migratory bird movements within south-eastern Australia (e.g. various SPRAT profiles). It is worth noting that there is a drop in the number of individuals during the November period, although this also coincides with a drop in the number of recorded counts.

Fourteen regularly occurring species have been recorded in the Swan Bay area with a monthly average of approximately 18 species (all species for surveyed sites and years combined). Unlike the number of individuals, the number of species recorded each month appears to remain reasonably consistent from month to month (Figure 4). The lowest number of species is recorded during May, which coincides with the period that most species have returned to their breeding grounds. Lower numbers are also recorded during July, however it is worth noting that above average numbers have been recorded in June. Figure 5 displays the five most commonly recorded species during each month for the period of August through March. This is the period that aerial application is permissible within the project area.

The highest number of individuals was consistently recorded from January to March, which also corresponds with higher incidence of observations. The February through March period coincides with the time that most species are gathering at staging areas, to accumulate energy reserves for their northward migration at the end of March into early April.

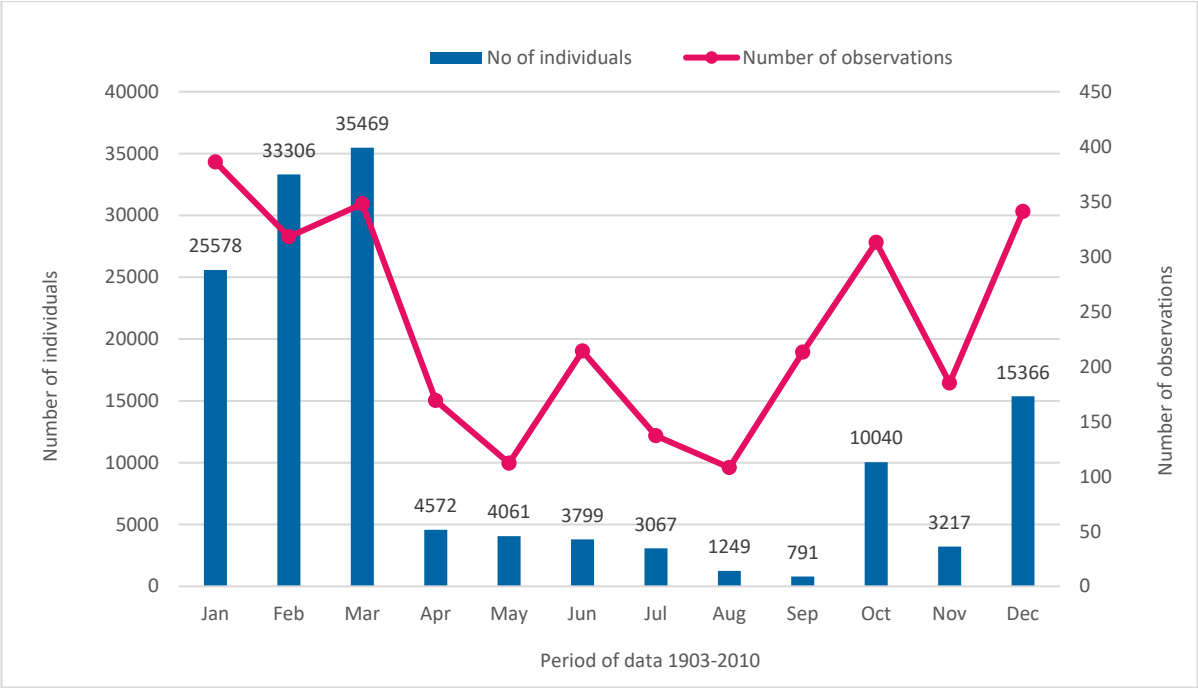


Figure 3 VBA records for sum of individuals and observations (all species combined) across different months (all years combined) – Swan Bay project area (all sites combined). Data presented includes only regular species. Note: the approved application period is between the 16 August and 14 March each year.

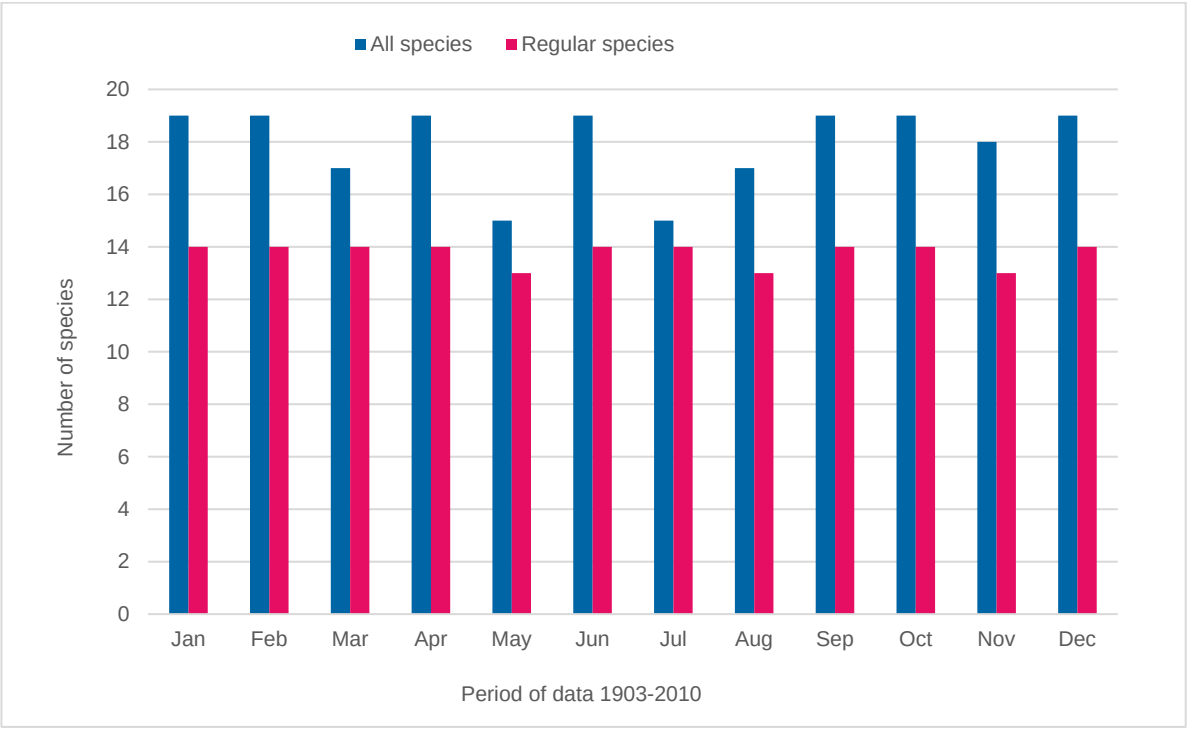


Figure 4 Number of species across different months (all years combined) – Swan Bay project area (all sites combined). Note: the approved application period is between the 16 August and 14 March each year.

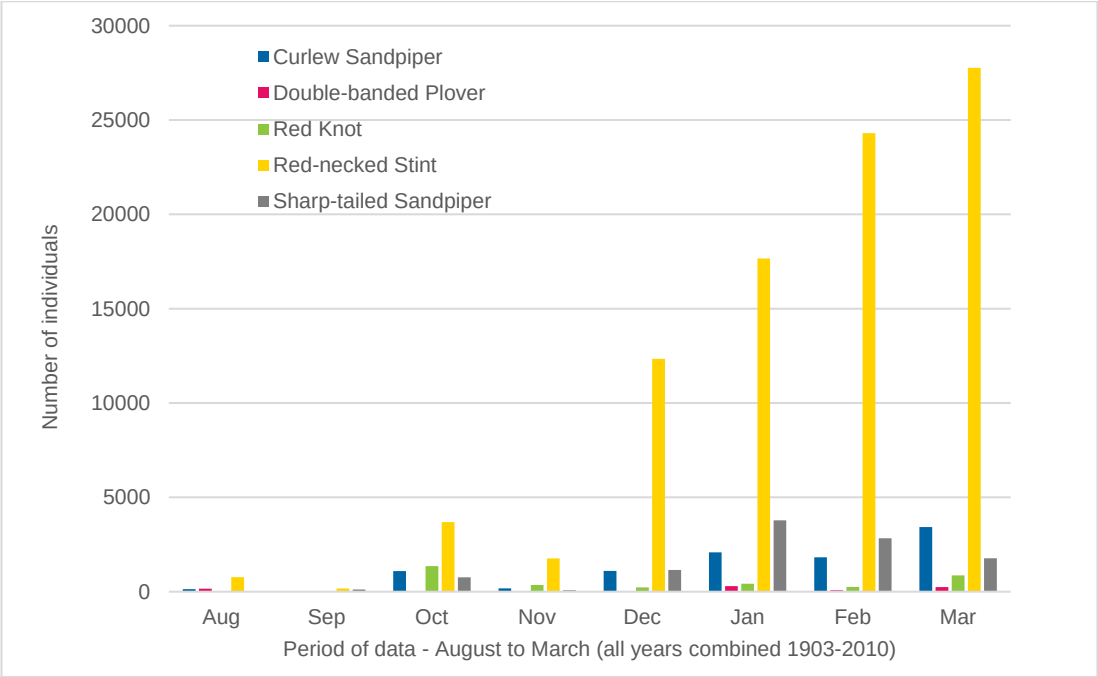


Figure 5 Five most commonly recorded species at the Swan Bay project area for each month within the mosquito application period (all years and sites combined). Note: the approved application period is between the 16 August and 14 March each year.

3.3.2 Lake Connewarre area

The historical data indicates that migratory shorebirds are present within the Lake Connewarre area throughout the year (Figure 6). The majority of records of the regular migratory bird species (Figure 4) appear to fall within the January through April period, which coincides with the latter part of the documented migratory bird movements within south-eastern Australia (e.g. various SPRAT profiles). The largest number of individuals has been recorded during January (more than 75% of all individuals recorded). A review of the data for the January period for all years revealed a large number of records for three species (Curlew Sandpiper, Red-necked Stint and Sharp-tailed Sandpiper- See Figure 8). It is also worth noting that these species were also well represented for most other months. There is also an increase in the number of individuals recorded during August (the arrival period for many species) and later in October.

Eight regular species have been recorded from the Lake Connewarre area with a monthly average of 17 species (all species for surveyed sites and years combined). The number of overall species recorded each month appears to fluctuate significantly (ranging from 11 to 25 species) (Figure 7). The lowest number of species were recorded during May and June, which coincides with the period that most species have returned to their breeding grounds. Figure 8 displays the five most commonly recorded species during each month for the period of August through March.

The highest number of individuals was consistently recorded from January through April, which also corresponds with high number of observations. The February through March period coincides with the time that most species are gathering at staging areas, to accumulate energy reserves for their northward migration at the end of March into early April.

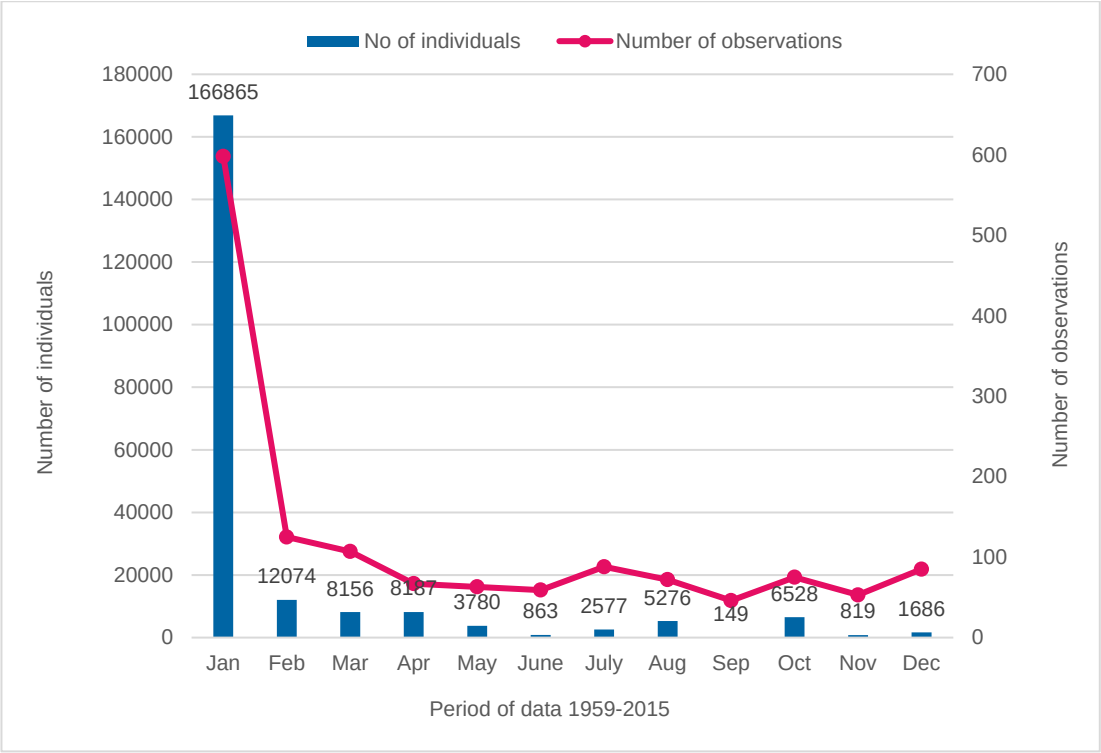


Figure 6 VBA records for sum of individuals and observations (all species combined) across different months (all years combined) – Lake Connewarre project area (all sites combined). Data presented includes only regular species. Note: the approved application period is between the 16 August and 14 March each year.

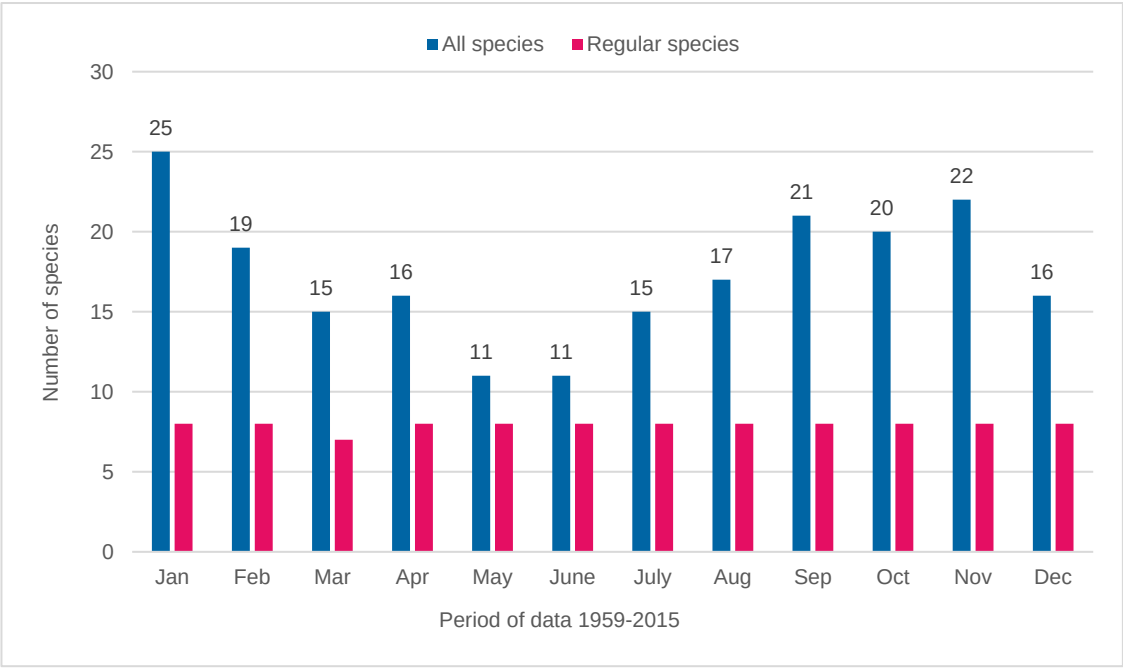


Figure 7 Number of species across different months (all years combined) – Lake Connewarre project area (all sites combined). Note: the approved application period is between the 16 August and 14 March each year.

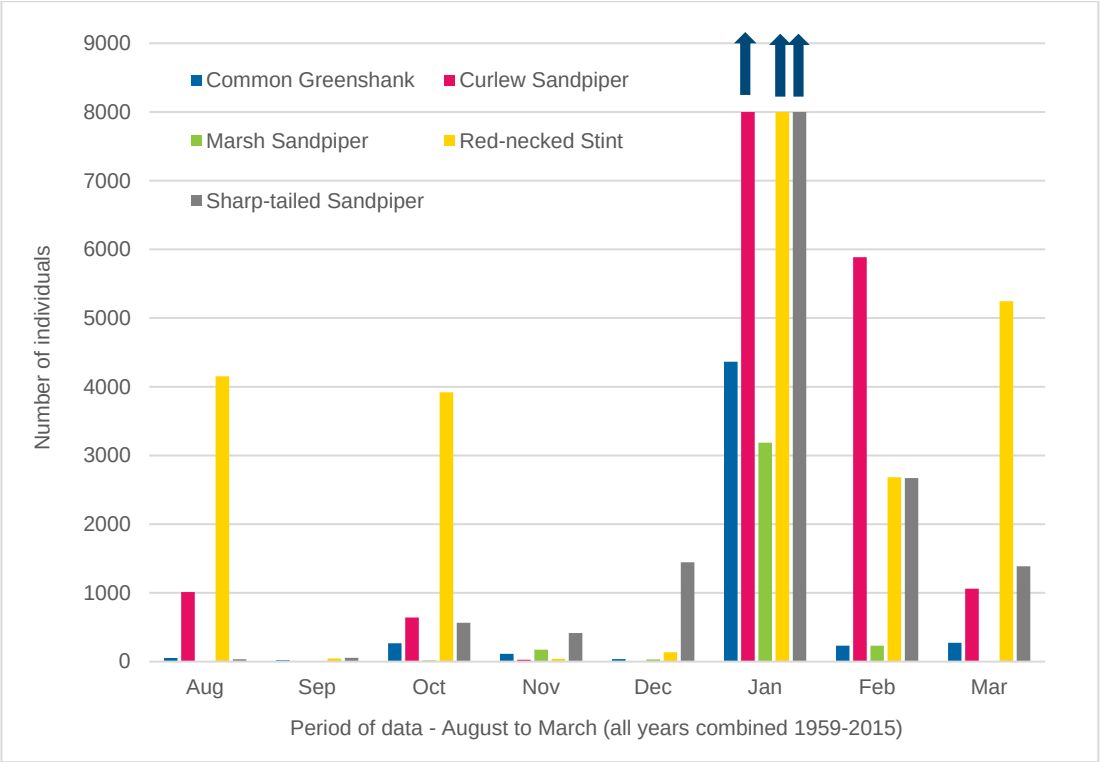


Figure 8 Five most commonly recorded species in the Lake Connewarre project area for each month (all years and sites combined). Actual records for January for Curlew Sandpiper = 31834, Red-necked Stint = 88307 and Sharp-tailed Sandpiper = 36395. Note: the approved application period is between the 16 August and 14 March each year.

4. Review of aerial video footage

4.1 Background

Aerial video footage recorded (see Table 2) during helicopter flights of the project area was reviewed by a GHD ecologist to assist with understanding the potential impacts of helicopter operations on migratory shorebirds present during the time of the survey. The footage was reviewed with the aim of:

- Identifying the presence/absence of migratory shorebird species
- Determine if the shorebird species were disturbed by the helicopter

4.2 Summary of results

No migratory shorebirds listed as MNES were identified when the aerial video footage was reviewed. Unfortunately, the poor quality of footage and narrow field of view prohibited confident identification of species that were observed, which were largely identified as larger wetland bird species (e.g. Mountain Duck, Swans and Egrets). Smaller species (e.g. Welcome Swallow and White-fronted Chat) were identified but these observations were confirmed from stationary footage and not from the helicopter.

It may be possible that birds removed themselves from the area when the helicopter was in close proximity, and flew out of the field of view of the camera prior to the flyover. Most birds were observed in flight by the time the helicopter passed through the area (see summary of results Table 2), hence it was difficult to determine if the absence of smaller birds (i.e. migratory shorebirds) is a result of the disturbance created by the helicopter, or the quality of the footage and field of view of the camera. It could also be a combination of all factors.

Table 2 Summary of analysis of aerial video footage supplied by CoGG

File name	Date and time	Duration hrs:mins:secs	Results
021116IMG_2003	5 December 2016, 10:38:24 AM	00:00:02	1 x white bird (egret species) in flight
021116-2IMG_2004	5 December 2016, 10:38:42 AM	00:00:03	-
021116-3IMG_2010	5 December 2016, 10:39:10 AM	00:00:05	2 x white birds in flight
021116-4IMG_2011	5 December 2016, 10:39:30 AM	00:00:05	1 x white bird in flight
021116-5IMG_2012	5 December 2016, 10:39:54 AM	00:00:02	1-4 x white birds in flight / 2-3 on water
021116-6IMG_2002	5 December 2016, 10:40:26 AM	00:00:10	1 x white bird in flight
021116-7IMG_2003	5 December 2016, 10:40:56 AM	00:00:02	1 x white bird in flight
021116-8IMG_2020	5 December 2016, 10:42:00 AM	00:00:02	3 x white birds in flight/ 1 x dark/black bird in flight

File name	Date and time	Duration hrs:mins:secs	Results
021116-9IMG_2024	5 December 2016, 10:42:46 AM	00:00:01	-
lake connewarre 071216	7 December 2016, 9:02:22 AM	00:00:04	-
071216 lconn	7 December 2016, 9:02:28 AM	00:00:16	1 x white bird in flight
lake conn 071216 (3)	7 December 2016, 9:04:46 AM	00:00:23	-
lake conn 071216	7 December 2016, 9:04:22 AM	00:00:01	6 x white birds/ grey birds in flight
lake conn 071216 (2)	7 December 2016, 9:04:30 AM	00:00:12	1 x dark bird in flight / 10 x dark birds on water
lake con birds	7 December 2016, 9:06:06 AM	00:00:07	10 x white birds/ grey birds in flight / 2 birds on water
lake con birds 071216	7 December 2016, 9:06:38 AM	00:00:02	6 x white birds/ grey birds in flight
lake con 071216	7 December 2016, 9:06:44 AM	00:00:16	4 x white birds in flight / 2 roosting
071216 lconn (2)	7 December 2016, 9:07:20 AM	00:00:01	1 x white bird in flight
071216 birds l conn	7 December 2016, 9:07:30 AM	00:00:02	6 x white birds in flight
071216 lake con	7 December 2016, 9:07:40 AM	00:00:02	2 x white birds in flight
071216 lake connewarre	7 December 2016, 9:08:18 AM	00:00:03	3-4 white/grey birds in flight
071216 birds	7 December 2016, 9:10:00 AM	00:00:03	1 x white bird in flight
071216 birds2	7 December 2016, 9:10:16 AM	00:00:03	-
lake conn- leopold 071216	7 December 2016, 9:05:28 AM	00:00:20	1 x white bird/ grey birds in flight / 1 bird on water
Lake Connewarre 20161125_091051	25 November 2016, 9:10:52 AM	00:00:50	-
Lake Connewarre 20161125_091645	25 November 2016, 9:16:46 AM	00:00:35	60 + ducks (different species) including 10 mountain ducks/ 5 x swan. Note many birds disturbed (started flying as helicopter flew over)
Lake Connewarre_20161125_091338	25 November 2016, 9:13:38 AM	00:01:19	35 x white birds in flight/ 1 x white bird in water/ 45 + swan in water / 2 x pelican in flight / 25 + smaller darker birds (duck species) in water

File name	Date and time	Duration hrs:mins:secs	Results
Lake Connewarre2 20161125_091422	25 November 2016, 9:14:22 AM	00:00:30	1 x white bird in flight
s ridge 071216	7 December 2016, 9:03:30 AM	00:00:07	-
saltwater ridge 071216	7 December 2016, 9:02:50 AM	00:00:39	-
Swan Bay landing site 150216 (2)	15 February 2017, 9:36:58 AM	00:01:27	Footage of landing site and helicopter. No footage taken during flight
Swan Bay Landing Site 150216	15 February 2017, 9:23:46 AM	00:00:20	Footage of landing site and helicopter. No footage taken during flight. 3 x sea gull in flight
Swan Bay landing site 150216-3	15 February 2017, 10:02:06 AM	00:01:40	Footage of landing site and helicopter. No footage taken during flight. 30 + birds mixed species of sea gulls, ducks and other species flying from water as helicopter passes over water. Some individuals appear to return to water after helicopter has passed through area.
Swan Bay landing site 191016	19 October 2016, 10:52:18 AM	00:00:59	Footage of landing site and helicopter. No footage taken during flight. 1 x lapwing plover foraging on ground nearby grounded helicopter.
Swan Bay landing site2 191016	19 October 2016, 10:55:10 AM	00:00:42	Footage of landing site and helicopter. No footage taken during flight. 1 x lapwing plover in flight as helicopter departs landing site.
Swan Bay landing site3 191016	19 October 2016, 11:02:04 AM	00:00:14	Footage of helicopter departing landing site. No footage taken during flight.
Swan Bay landing site4 191016	19 October 2016, 12:08:40 PM	00:00:26	1 x welcome swallow in flight/ 2 x white-fronted chat and 5 + other small birds in flight as helicopter returns to landing site. No footage taken during flight.
Total application time		**00:14:25 min**	

5. Summary of Review findings

5.1 Presence of migratory shorebirds during the proposed aerial application regime

In accordance with the EPBC approval 2005/2132 (4 November 2005), the following conditions apply to the Swan Bay and Lake Connewarre treatment sites regarding the approved application period:

- No aerial application at either site between 15 March and 15 August.
- Low level aerial application may occur between 16 August and 14 March at Lake Connewarre site.
- Low level aerial application may occur between 16 November and 14 March at Swan Bay (to avoid the Orange-Bellied Parrot).
- Low level aerial application may only be conducted at the Swan Bay site between 16 August and 15 November if surveys taken 24 hours prior to application confirm that the Orange-Bellied Parrot (*Neophema chrysogaster*) are not present at this site.

Table 3 provides a summary of the EPBC approval conditions and a summary of the historical presence of migratory shorebirds from within the project area. A review of the data indicates that:

- Thirty-one (31) of the 33 EPBC listed migratory shorebirds species have been recorded in the project area. The review suggests that migratory shorebirds are historically present within the project area for most months of the year for the period of the data reviewed, however the number of species and individuals records varies greatly from month to month.
- CoGG is permitted to spray the nominated treatment sites between the months of August and November, pending certain conditions. Documented records during this period indicate:
  - An average of 18 (ranging from 17-19) migratory bird species have historically occurred over these months within the Swan Bay area
  - An average of 17 (ranging from 15-21) migratory bird species have historically occurred over these months within the Lake Connewarre area
- The majority of individuals recorded occur during the months of October through March, with peak numbers occurring during January through March for each area, although large numbers have also been recorded during April, May and August. The majority of treatment occurs from September to December, with fewer treatments generally in January to March.

The desktop review demonstrates the historical presence of migratory shorebird species from August through March for the period of the data reviewed for the project area. This period coincides with the period CoGG is permitted to conduct low-level aerial application within the project area (Table 3).

5.2 Limitations to the data review

The data available on migratory shorebirds in the project area has limitations due to the high variability related to the data collected and its direct relationship with the helicopter treatment. The data available from the VBA database, for the purpose of understanding migratory birds in the project area, assumes all species have been surveyed equally and are equally detectable,

i.e. same effort survey technique and appropriate timing. However, this is highly unlikely to be the case and there will be bias toward certain species. The data reported includes recorded birds since 1900 and this further limits the relevance of the data for the purpose of understanding any potential impact to helicopter application for the duration of the EPBC approval (2005-2020).

Given the sensitivity of the environment (e.g. a Ramsar wetland with some restricted access) there is likely survey bias regarding the location of survey points. It is unlikely that all areas have been surveyed equally for a variety of reasons (e.g. access), hence data is assumed to be skewed towards locations that are publically and or easily accessible, and therefore that are surveyed more frequently.

Table 3 Review of EPBC conditions and presence of migratory shorebirds within the project area

Condition / Item	Key dates	Timeline											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low level application Lake Connewarre	16 Aug - 14 March												
Low level application Swan Bay	16 November - 14 March (also permitted 16 Aug - 15 Nov following OPB surveys)								Survey OPB	Survey OPB	Survey OPB		
Migratory bird presence within project area	October – March (core period)	X XX	X XX	X XX	X XX	X	XX		X XX	XX	X XX	X XX	X XX

Source of information regarding species occurrence - SPRAT profiles and VBA.

Table key:

	Indicate the period the treatment is permitted as a controlled action
	Indicates presence of migratory shorebirds
X	Indicates peak periods of migratory shorebird individuals for project area
XX	Indicates peak periods of migratory shorebird species for project area (number of species each month exceeds average record)

6. Field assessment – Disturbance of migratory birds

6.1 Background - restrictions to migratory shorebird monitoring

Through discussions with CoGG, it was understood that there are a number of restrictions to the monitoring method available in order to determine the impact of helicopter operation to the birds the area of application. In summary:

- CoGG has been advised that a camera cannot be adequately attached to the helicopter due to restrictions. The pilot needs to receive special permission from CASA (Civil Aviation Safety Authority) to affix a camera to the helicopter or treatment bucket. The aim is to prevent joyriding/dare devil helicopter pilots from filming 'extreme' actions.
- No other person is allowed in the helicopter during an application event due to occupational health and safety reasons as well as weight restrictions in the helicopter while applying the product.
- Migratory shorebirds are typically small and difficult to identify from the helicopter.
- It is difficult to get high quality footage from within the helicopter cabin.
- Most of the areas that are sprayed are difficult to access by foot or boat.
- On ground bird monitoring cannot be carried during treatments due to the remote nature of the wetlands and difficulty in accessing the area while treatment is occurring.

Within these limitations, GHD undertook a realistic and achievable compromise for migratory shorebird assessment during a single simulated aerial application.

6.2 Methods

To support the findings of the desktop review and to satisfy condition 4d which requires *a program to monitor the impact of helicopter operations on migratory shorebirds,* a five-day field assessment was undertaken in early 2018 to document observations of migratory bird disturbance caused by the helicopter flying over the treatment areas. The assessment was conducted between the 27th February and 6th of March 2018, before all of the migratory shorebirds had departed on their northerly migration.

Fieldwork was undertaken over 5 days: before (2 days), during (1 day) and after (2 days) a flyover event (a simulated larvicide application). For each phase of the assessment, observations recorded included weather conditions, species and abundance, and behaviour (e.g., foraging, roosting, preening).

The aim was to focus observations on migratory shorebirds. However, given the general scarcity of those species at most sites, observations were made of all birds listed as Migratory under the EPBC Act (i.e., including egrets, terns, etc), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc).

Six locations (tidal and non-tidal) were identified for the assessment. Those sites were chosen to be representative of favoured shorebird locations in this region and to be relatively accessible to allow timely and repeatable observations of all sites all within one day. Sites chosen were based on past-10-yr observations (using source: e-Bird.org) of species such as the Red-necked Stint and Sharp-tailed Sandpiper, which tend to be the most common Migratory shorebirds in Victoria.

The sites and shown in Figure 9 and include:

- Hospital Swamps (non-tidal)
- Lake Connewarre – Brinsmead Lane (tidal)
- Lake Murtnagurt (south of Lake Connewarre, north of 13th beach life saving club) (non-tidal)
- Lake Victoria – east end (non-tidal)
- Swan Bay Edwards Point Wildlife Reserve (tidal)
- Swan Bay Jetty (tidal)

The first site visit (day 1) determined that only five of the sites were suitable for the assessment under current conditions – Lake Murtnagurt was completely dry, and currently supporting very few birds at all. That site was subsequently omitted from the study, and the before, during and after assessment was undertaken for the five remaining sites.

Figure 9 Sites assessed for shorebird disturbance during the simulated aerial application.

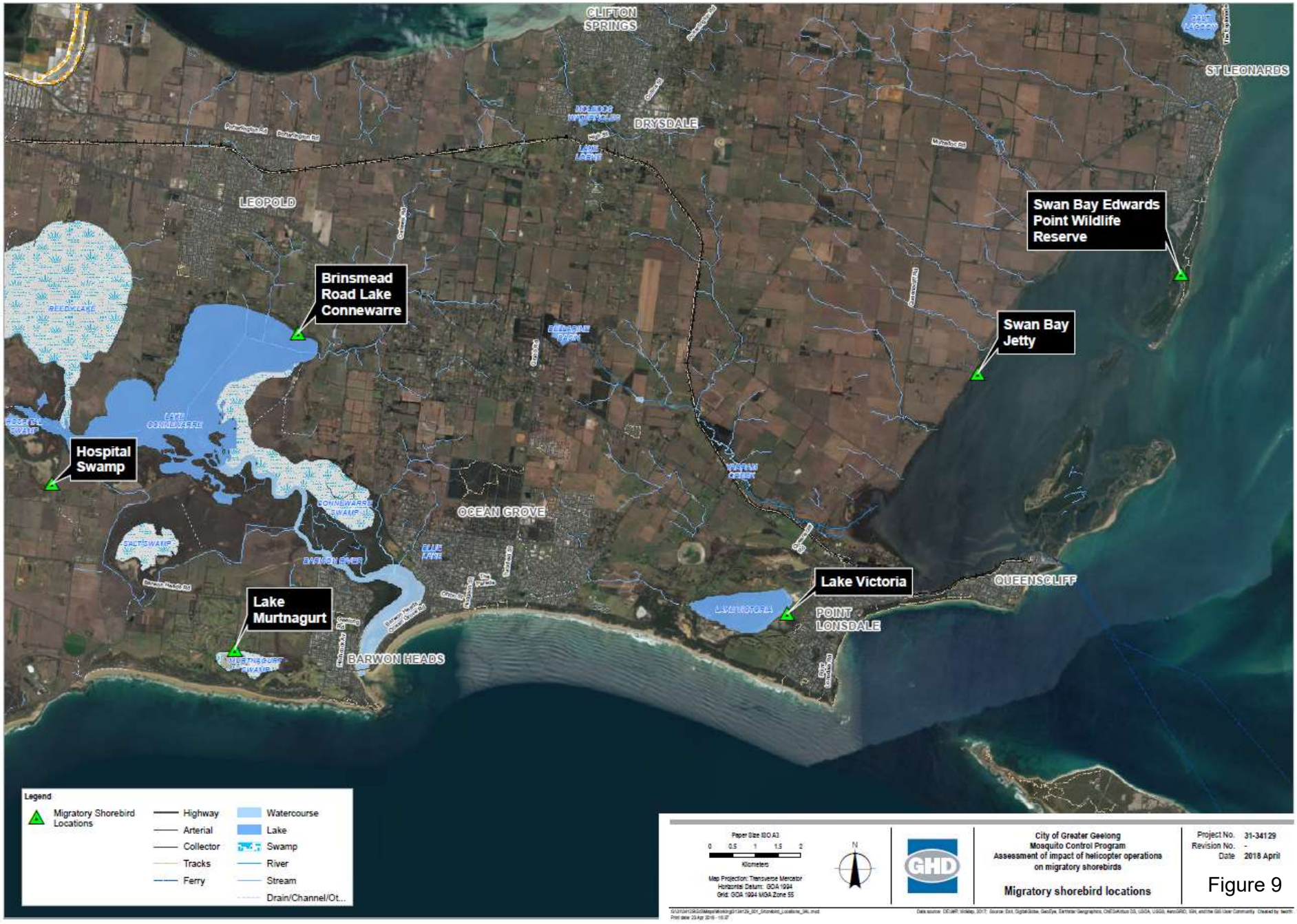

CLIFTON SPRINGS
DRYSDALE
ST LEONARDS
LEOPOLD
Swan Bay Edwards Point Wildlife Reserve
Brinsmead Road Lake Connewarre
Swan Bay Jetty
Hospital Swamp
OCEAN GROVE
Lake Victoria
QUEENSCLIFF
POINT LONSDALE
Lake Murtnagurt
BARWON HEADS
Legend
Migratory Shorebird Locations
Highway
Arterial
Collector
Tracks
Ferry
Watercourse
Lake
Swamp
River
Stream
Drain/Channel/Ot...
Paper Size ISO A3
0 0.5 1 1.5 2
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55
N
GHD
City of Greater Geelong
Mosquito Control Program
Assessment of impact of helicopter operations on migratory shorebirds
Migratory shorebird locations
Project No. 31-34129
Revision No. -
Date 2018 April

Figure 9

6.2.1 Pre-application assessment

The purpose of this phase of the assessment was to determine the presence and relative abundance of species at sites before helicopter operation occurred.

From the best available vantage point at each site, a 30-min point count of all wetland/waterbird/shorebird species was conducted on foot by two experienced observers using binoculars and a high-powered spotting scope and tripod. The objectives were to:

- Determine species present and relative abundance, noting those that are listed as Migratory under the EPBC Act and those that are not.
- Determine habitat use of Migratory species at locations (roosting, foraging).
- Assess tide phase (tidal sites only), which may influence bird behaviour (e.g., high-tide roosting).

Each site was assessed twice (Day 1, then Day 2), with order of sites visited reversed for the second visit so that every site was assessed once in the morning and once in the afternoon. Visiting sites twice reduced bias due to poor weather conditions/chance/time of day. Visits occurred on 27 and 28 February 2018 (days 1 and 2; before helicopter flyover).

A count of birds at each site on day 3 prior to the helicopter flying over effectively added another (third) pre-disturbance sample.

6.2.2 During-application assessment

The purpose of this phase was to determine whether the birds were disturbed by the helicopter flyover, and to gather information about the nature and magnitude of the disturbance.

On Day 3 (1 March 2018), using pre-arranged flight paths and times, two experienced observers watched the responses of birds at the five sites while the helicopter flew over the sites, as though it was applying larvicide (note – this was a simulated application, so that no larvicide was dropped). At each site, this was done after another full count of birds had been made – this effectively added another (third) pre-disturbance sample.

In keeping with what would be done for a normal larvicide application, the helicopter made repeated aerial passes over each site. Passes were made parallel to the shoreline, with each pass approximately 25 m towards the water relative to the previous pass.

The helicopter flew over at approximately 30-50 ft (10-17 m) above the ground, which is the normal height from which larvicide pellets are dropped.

After flying over each site, the pilot landed the helicopter and waited for the ground-based ecologists to be in position at the next site, before flying over the next site. The flyover schedule was as follows:

- Swan Bay Jetty (9:30 am)
- Swan Bay Edwards Point (10:30 am)
- Lake Victoria (12:30 pm)
- Hospital Swamps (2:00 pm)
- Lake Connewarre (3 pm)

6.2.3 Post-application assessment

The purpose of this part of the assessment was to determine if species return to the site and in similar numbers. It was effectively a repeat of the pre-disturbance assessment, to allow for a before and after comparison.

This part of the assessment was undertaken on 5 and 6 March 2018 (assessment days 4 and 5; after helicopter flyover).

6.3 Results

6.3.1 Species richness at sites

Over the five-day assessment, large numbers of species were observed at most sites, ranging from 26 species at Lake Victoria to 10 species at Swan Bay Edwards Point. A total of 44 species were observed overall (Table 4). Not all of those species were Migratory species – most were non-Migratory. Hospital Swamps and Lake Victoria had the highest count of Migratory species, with five species at those sites. All sites had at least one Migratory species.

The species richness at each site remained relatively consistent across the days (Figure 10). Generally, Lake Victoria and Swan Bay Jetty had more species present each day than the other three sites. That said, the species composition at some sites varied from day to day.

Table 4 Species counts (split into Migratory and non-migratory) at each site during the five day assessment.

Site	Species observed (total)	Migratory species observed	Non-Migratory species observed
Hospital Swamps	25	5	20
Lake Connewarre (Brinsmead Lane)	20	1	19
Lake Victoria	26	5	21
Swan Bay (Edwards Point)	10	1	9
Swan Bay (Jetty)	17	2	15
All sites	**44**	**8**	**36**

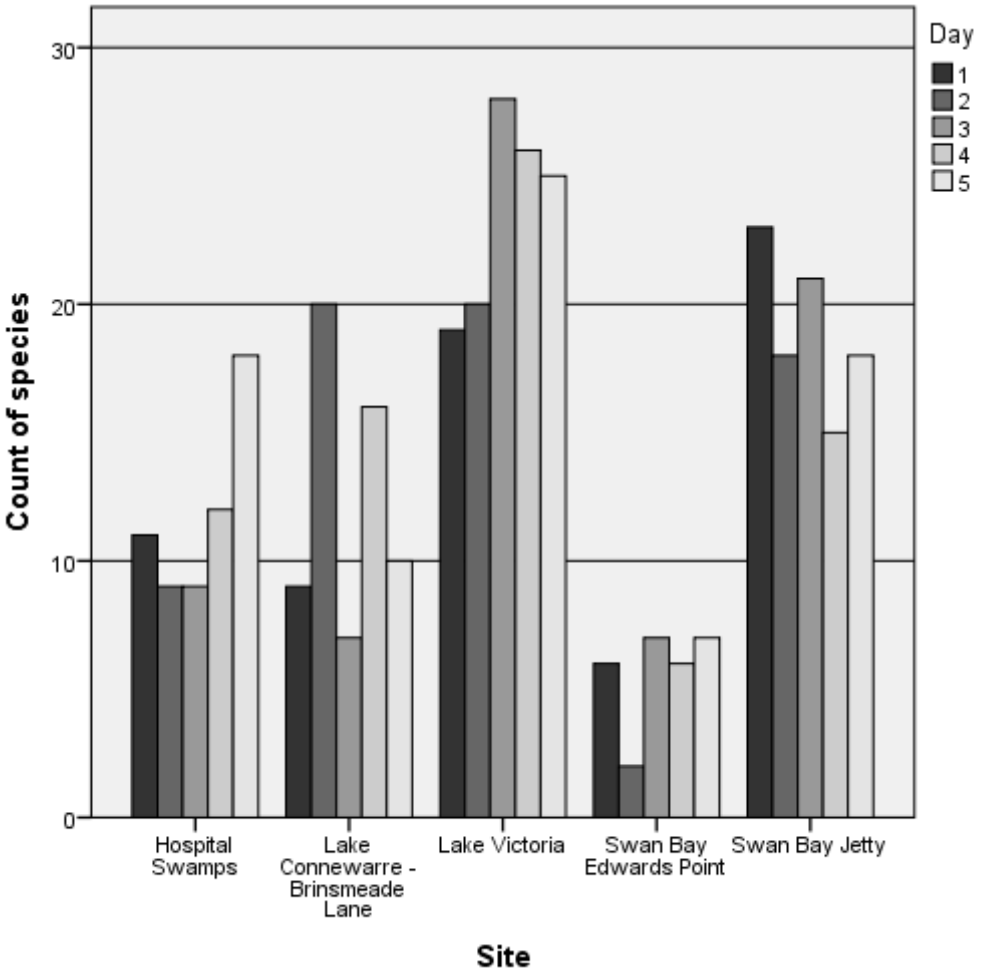


Figure 10 Total species counts at the five sites across the five-day assessment.

6.3.2 Relative abundance of species at sites – all species

Waterbird and shorebird abundance at sites was generally large. This was to be expected, as the sites had been chosen on the basis of their bird history. At all sites, birds were engaged in a range of behaviours – foraging, roosting, rafting, preening.

At Hospital Swamps (Figure 11A), there were 250 birds or more observed on three of the five occasions. Lower bird counts were made on days 2 and 3. The most abundant species were Grey Teal (Day 1), Black-winged Stilt (Days 1, 3, 4 and 5), Red-kneed Dotterel (Days 1 and 4), Black-fronted Dotterel (Day 5). Day 4 and 5 counts were similar to counts made on day 1, although the species composition differed. For most species, the post-disturbance counts equalled or exceeded at least one of the pre-disturbance counts. Grey Teal (a non-Migratory species) was the notable exception where pre-disturbance counts exceeded post-disturbance counts.

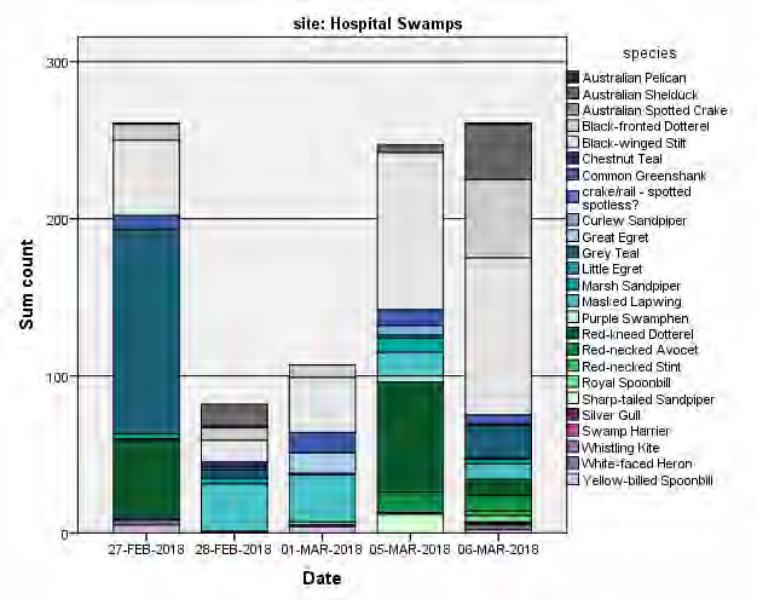
At Lake Connewarre (Figure 11B), there were 100 birds or more observed on four of the five occasions, with up to 500 observed on day 2. Lower bird counts were made on days 1 and 3. The most abundant species were Grey Teal (Days 2 and 5), Chestnut Teal (Days 2 and 4), and Black Swan (Day 2). Day 4 and 5 counts were considerably less than counts on Day 2, but considerably higher than counts on Days 1 and 3. For most species, the post-disturbance counts equalled or exceeded at least one of the pre-disturbance counts. Black-winged Stilt (a non-Migratory species) was the notable exception where the Day 2 pre-disturbance count exceeded both post-disturbance counts.

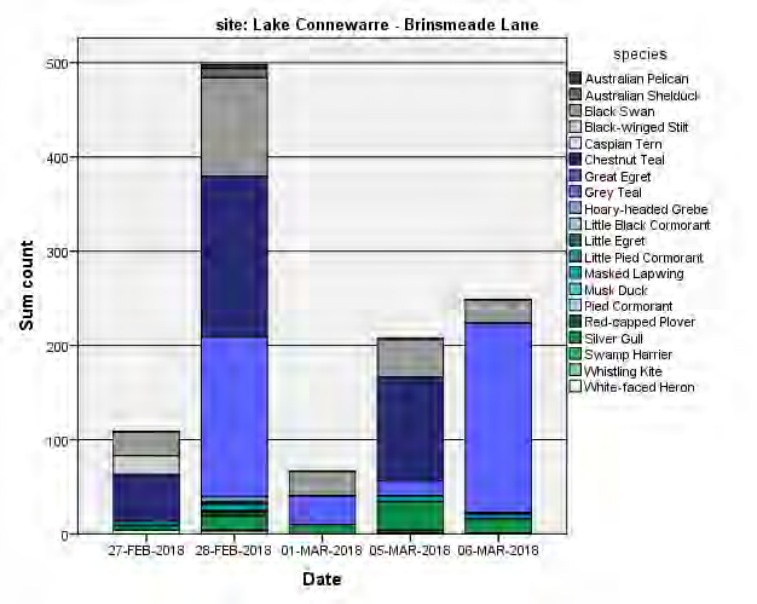
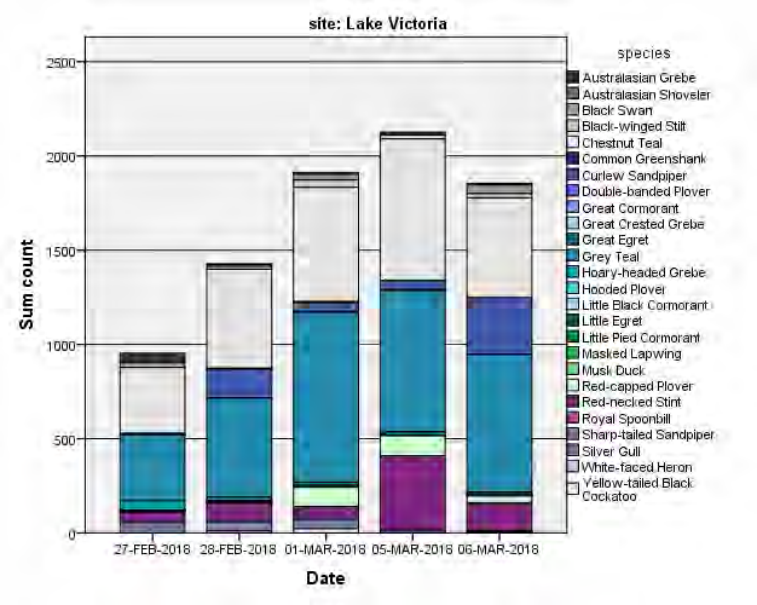
At Lake Victoria (Figure 11C), bird counts ranged from nearly 1000 to more than 2000; these numbers were buoyed by the presence of large roosting flocks of Chestnut and Grey Teal on all days. Other than Chestnut and Grey Teal, the most abundant species were Red-necked Stint (particularly Day 4) and Curlew Sandpiper (particularly Days 2 and 5). Day 4 and 5 counts were equal to or higher than counts on days 1, 2 and 3. For most species, the post-disturbance counts equalled or exceeded at least one of the pre-disturbance counts. Australasian Grebe (a non-Migratory species) was the exception where the Day 1 pre-disturbance count exceeded all subsequent counts.

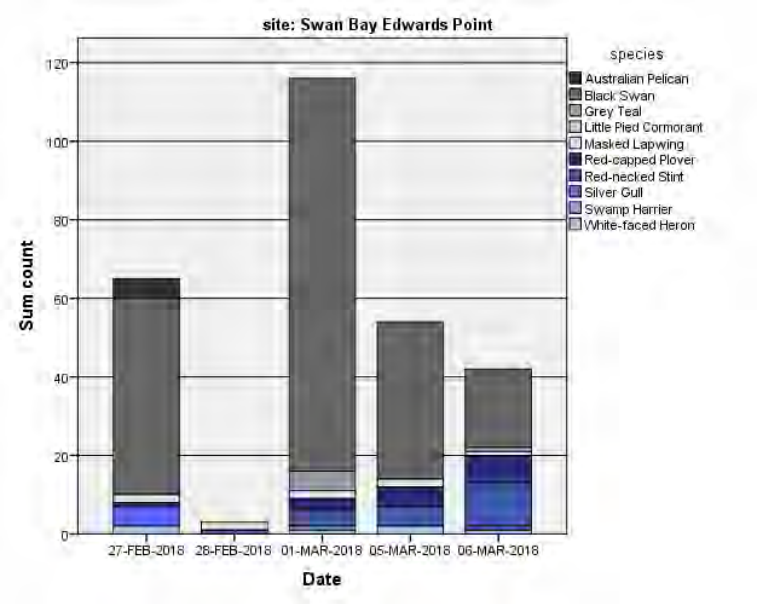
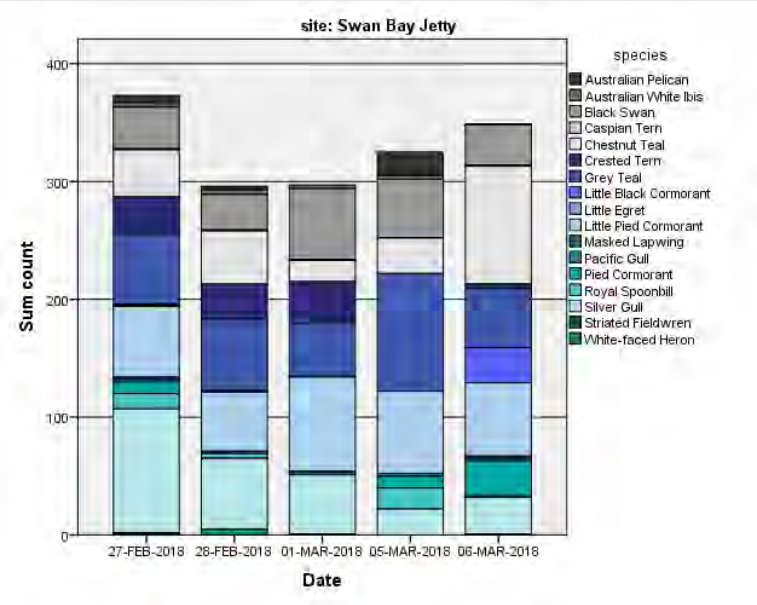
At Swan Bay Edwards Point (Figure 11D), bird counts were lower than at other sites. There were 40 birds or more observed on four of the five occasions, with nearly 120 observed on day 3. A lower bird count was made on day 2, when the wind was blowing strongly from the south (onshore, at that site). The most abundant species (albeit with relatively small numbers) were Black Swan (Days 1, 3, 4 and 5), Red-necked Stint (Days 3, 4 and 5) and Red-capped Plover (Day 5). Day 4 and 5 counts were considerably less than the count on Day 3, but similar to or higher than counts on Days 1 and 2. For most species, while the post-disturbance counts did not equal or exceed the pre-disturbance counts, they remained relatively high. Australian Pelican (a non-Migratory species) was the exception where the Day 1 pre-disturbance count exceeded all subsequent counts.

At Swan Bay Jetty (Figure 11E), counts on all five days were consistently high, with nearly 300 or more birds observed each day. The most abundant species were Silver Gull, Grey Teal, Chestnut Teal, and Little Pied Cormorant. Day 4 and 5 counts were less than the count on Day 1, but higher than counts on Days 2 and 3. For many species, the post-disturbance counts equalled or exceeded at least one of the pre-disturbance counts.

Figure 11 Relative abundance of species (including Migratory and non-migratory) at each site (A - E) during the five day assessment.

	Observations per day at each site – all species **(Observations on day 3 are pre-disturbance)**
A	

	Observations per day at each site – all species (Observations on day 3 are pre-disturbance)
B	
C	

	Observations per day at each site – all species (Observations on day 3 are pre-disturbance)
D	
E	

6.3.3 Relative abundance of species at sites – Migratory species only

At most sites (but not Lake Victoria), relative abundance of Migratory species was generally low. This reflects a fairly typical pattern for migratory species that opportunistically exploit productive sites – favoured locations can occasionally or regularly attract large numbers of migratory birds when conditions are suitable, but those species may be all but absent when conditions at those sites are less favourable or are favourable at sites elsewhere.

At Hospital Swamps (Figure 12A), there were five Migratory shorebird species observed, and nearly 40 birds in total on Day 4. All other daily counts resulted in less than 15 birds being observed. For all species, post-disturbance counts exceeded or were similar to at least one of the pre-disturbance counts.

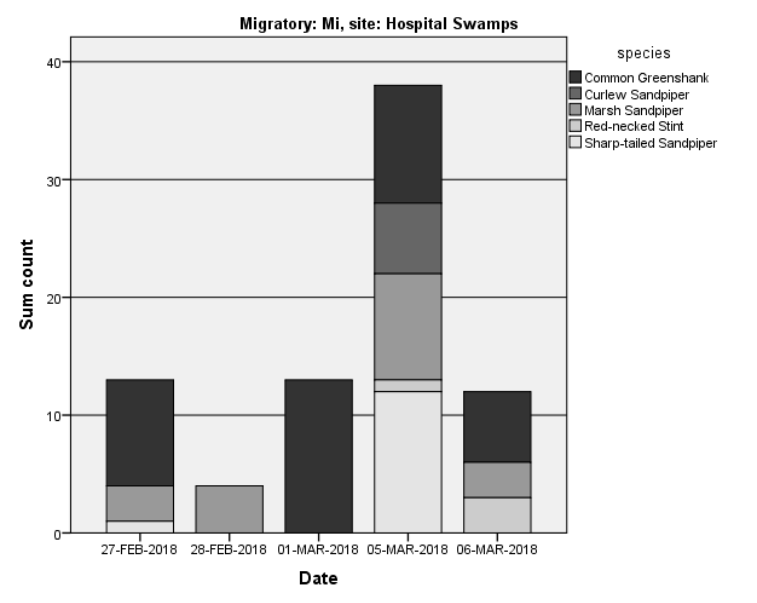
At Lake Connewarre (Figure 12B), Migratory birds were all but absent during the assessment. One Caspian Tern (a migratory species but not a migratory shorebird) was observed on Day 5.

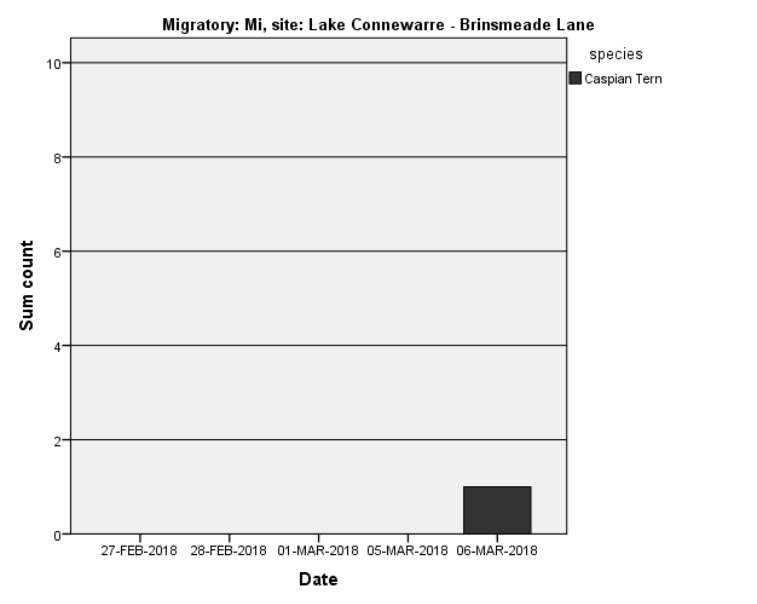
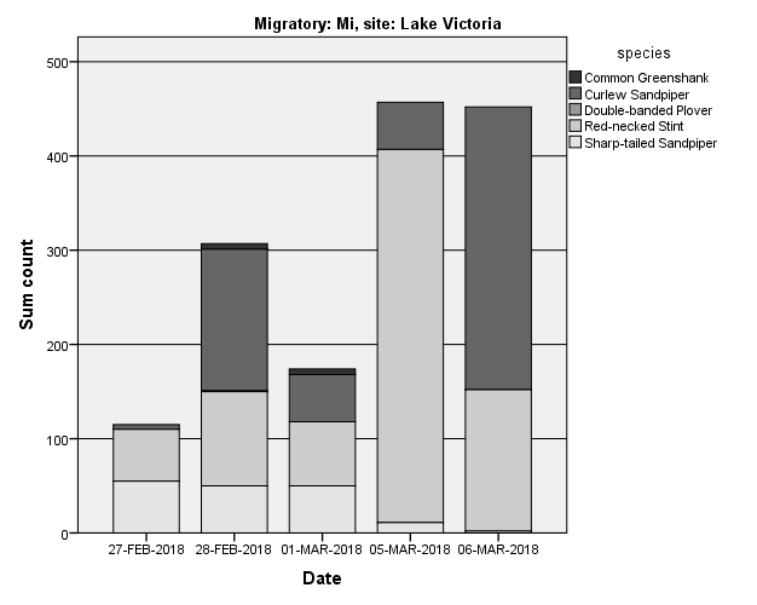
At Lake Victoria (Figure 12C), migratory shorebird counts were markedly higher than at any other site, totalling more than 400 on days 4 and 5. The most abundant species were Red-necked Stint (particularly Day 4) and Curlew Sandpiper (particularly Days 2 and 5). Day 4 and 5 total counts were higher than all earlier counts, but counts of individual species showed more variation.

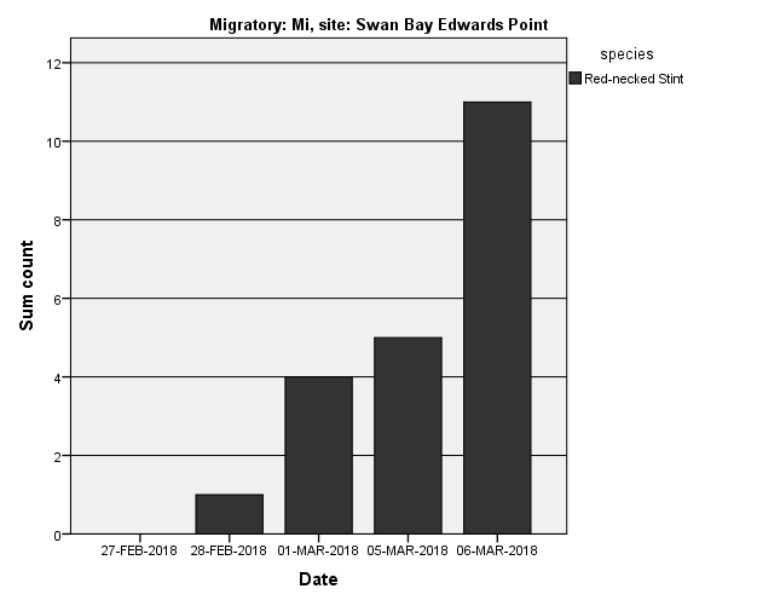
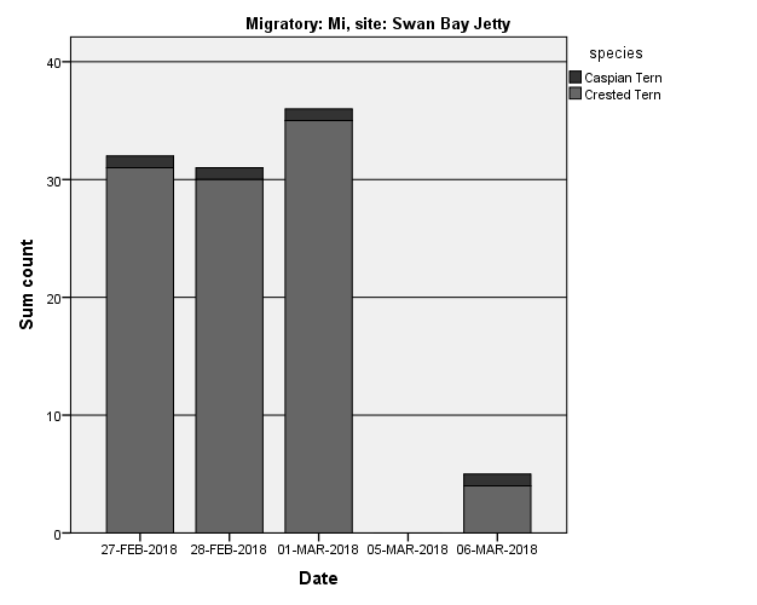
At Swan Bay Edwards Point (Figure 12D), only one Migratory species (Red-necked Stint; a Migratory shorebird) was observed. While the numbers of birds were generally small, Day 4 and 5 counts were higher than all earlier counts.

At Swan Bay Jetty (Figure 12E), only two Migratory species were observed, and neither is a Migratory shorebird. Day 4 and 5 counts of one these species (Crested Tern) were markedly less than earlier counts.

Figure 12 Relative abundance of Migratory species at each site (A - E) during the five day assessment.

	Observations per day at each site – Migratory species only **(Observations on day 3 are pre-disturbance)**
A	

	Observations per day at each site – Migratory species only (Observations on day 3 are pre-disturbance)
B	
C	

	Observations per day at each site – Migratory species only (Observations on day 3 are pre-disturbance)
D	
E	

6.3.4 During-disturbance observations (Day 3)

The helicopter flying repeatedly over the site resulted in high disturbance for all birds present at the site. The noise was the most obvious sign of disturbance for the observers, but whether it is noise or appearance (i.e., resembling an aerial predator) of the helicopter that disturbs the birds is unknown.

Species varied in how quickly they made the move to flee from the helicopter, and in how they fled. Some went early, and took to the skies; others went later and swam away. Species also varied in response behaviour – some flew off and landed in deeper water, others took to the skies and remained airborne. When disturbed, birds tended to group up with their own kind, then re-settle as a tight group, then commence spreading out again, once re-settled.

Species varied in how rapidly they returned to the site. Generally, with 5-15 minutes of the first helicopter disturbance, the species and numbers of birds present at the sites resembled the pre-disturbance observations. Descriptions of bird responses are shown in Table 5.

Table 5 Disturbance responses by birds at each site during and after the helicopter flyover.

Site	Helicopter pass	Time since first helicopter disturbance (mm:ss)	Observations
Hospital Swamps	1 (14:00 hrs)	0:00	East side first. Black-winged stilt up, all other birds up, flying west. Egrets not up. Egrets go up when helicopter goes over, spoonbills up, Masked lapwings not up. Teal fly in - put up from elsewhere.
	2	00:45	All up in the air, nothing on ground except Masked Lapwings
	3	01:05	Masked Lapwings up. Large numbers of teal (300-500) circling over swamp. Also Black-winged stilt
	4	01:40	Black-fronted dotterels up
	5	02:00	Nothing settled yet. Birds still in air. Large numbers of teal re-settle on swamp (water) @3:30, can see 4 Red-kneed Dotterels that weren't seen before, very large flock of Black-winged Stilt (100) seen on lake, masked lapwings back at site, 1 white-faced heron returned, egrets not returned, black-fronted dotterels back @4:30, Purple swamphens (x5) not up at all, cormorants in group, but not seen during flyover,
	After	Up to 13:00	5 mins after flyover; masked lapwings back, black-winged stilts back, black-fronted dotterels back, red-kneed dotterels remain, not seeing greenshank, spoonbills or egrets - perhaps gone to another wetland. Can't see teal easily - not sure where they settled. Seen later settled on swamp water itself - obscured by tall reeds/rushes. Large numbers of teal seen may have been pushed into site from Connewarre, brought in by helicopter, which approached from that direction. 10 mins after helicopter; 50 red-kneed dotterels returned to site - not seen prior. 13 mins after; 3 Greenshank seen - they still remain at Hospital Swamps. Further offshore, but still here.
Lake Connewarre	1 (15:00 hrs)	0:00	Flying over far east first - grey teal, great cormorant, little pied corms up, silver gulls, grey teal, up, swans not up, but walking into water. Silver gulls, teal and swans all landed again by 1:34; 1:40; silver gulls up, 1 masked lapwing up, nothing else flushed; 3 White ibis up (from far west); silver gulls straight back and landed.
	2	02:20	Silver gulls up, but landed again very rapidly, 2 masked lapwings up; also black-winged stilt (10), 1 white-faced heron, 1 great Egret, all up; teal up; another white-faced heron up; 1 pied cormorant up and flew towards lake to land,
	3	03:35	Nothing on ground, 1 great egret flying, frightened by helicopter; shorebirds flying back to join…(teal?) at far east;
	4	03:47	10 silver gulls up

Site	Helicopter pass	Time since first helicopter disturbance (mm:ss)	Observations
	After	08:00	9 silver gulls gone well east, looking west - no birds seen; looking east - nothing near; looking far east - 1 great egret foraging, lots silver gulls roosting, swans still there (did not fly), big group Grey Teal (100+, 1 White-faced heron roosting, pelican out on lake still there. All rest as before, except for near silver gulls and the black-winged stilt. small group of shorebirds seen as a result of chopper, but not seen before. group flew back to join teal, where they may have been before.
Lake Victoria	1 (12:30 pm)	0:00	First pass is seaward of us. Teal from north go up (200-300 birds), Little Egret goes up, red-necked stint, red-capped plovers, all up. Ducks, shorebirds, cormorants from lagoon go up, including chestnut teal, teal fly into lagoon near golf course
	2	00:35	All teal go up.
	3	01:15	All birds put up. Birds remain in sky while helicopter is present, or settle at more distant site, including in the lake proper. Teal trying to return (flying), but re-disturbed upon each pass.
	4	01:35	Nothing has re-settled
	5	02:10	Nothing re-settled at lagoon/roost site, still in air in big flocks.
	After	Up to 10:00	Shorebirds starting to return to area @ 3:45, flock of 4, plus teal flying in, more shorebird flocks fly in, Curlew Sand x 5, black-winged stilt coming back at 4:20, as helicopter disturbs birds on other side of lake, small shorebird squadrons flying around us, none re-settling yet. Royal Spoonbill re-settled (@ 5:00) - first to settle. 300 shorebirds (tight bunch, mixed flock) re-settled at@6:00, before ducks. Chestnut teal walking/swimming their way back from lagoon into roosting site. red-necked stint (100), sharp-tailed sand (50), curlew sand (150), returned by 12:35. Stint begin to forage as soon as they land. Curlew/sharp-tails clustered and preening. All red-caps in vegetation are gone - one has returned. Others have re-grouped on banks of lake. two red-caps returning at 12:36 birds (mainly shorebirds for this) returned to this site in larger numbers than before helicopter pass - helicopter flies around lake shore, putting up birds from everywhere. Birds then group up in the air, then settle en masse at best available location. 10 mins after flyover. Site appears very similar to situation seen yesterday. You would not know that a helicopter put all birds in the air 10 mins earlier. Large numbers of roosting grey teal/shorebirds on near shore of roost area,

Site	Helicopter pass	Time since first helicopter disturbance (mm:ss)	Observations
			150 stint returned to vegetation to roost, joined later by red-capped plovers. Stint continue to fly in from north (small sorties, 10 ish birds in each), and join birds in vegetation. teal on far north shore have returned (some time before 34 mins after flight). Swans not present now.
Swan Bay Edwards Point	1 (10:30 am)	0:00	Landward flyover. Nothing put up. Nothing to put up.
	2	01:00	No birds put up. No birds to be put up.
	3	02:00	White-faced heron not put up; 2 masked lapwings not put up; 1 small wader put up - red-capped plover; flew up and out of site to the north
	4	03:15	White-faced herons put up (6), masked lapwings put up, small plover put up, 4 stint put up and re-settled on same spot,
	After	06:00	5 white-faced herons have returned to their original spot; black swans have heads up, but did not fly;
Swan Bay Jetty	1 (09:30 am)	0:00	All birds took to the skies. 10 grey teal and 5 silver gulls remain. Silver gulls re-settle fast. All cormorants and teal have gone out to sea; teal arcing back to re-settle. Cormorants flighty, teal swimming out to sea, gulls up late. Teal arc around to fly back, or land at another site. Cormorants don't return as fast - land on nearby boat.
	2	01:15	All ducks and silver gulls up. Ducks go 30-100 m into water, some land, some keep flying. Local disturbance. Cormorants fly back in small numbers within 1-2 minutes.
	3	02:30	Cormorants, ducks and silver gulls go up. Swans not up. Ducks return immediately in small to moderate groups. Silver Gulls re-settle on jetty. Cormorants re-settle on distant perches
	4	03:45	Ducks up and fly seaward. Swans not disturbed. Egrets/ibis further south go up also.
	After	15:00	Swans undeterred, teal re-grouping and re-settling on land/water, cormorants gone, silver gulls and terns on jetty.

7. Conclusions

Historically, migratory shorebirds have occurred within the project area for much of the year. Their abundance is higher at both Swan Bay and Lake Connewarre between January and March each year. The desktop review indicates that peak numbers of migratory shorebirds occur within the project area during the period of aerial application.

The information reviewed to date does not allow for a review of the behaviour of migratory shorebirds and their abundance throughout the treatment period, other than for one simulated event. Also, as discussed in the report, it was not possible to determine the presence/absence of migratory shorebirds from the video footage recorded during the helicopter flights, but this was potentially explained by the on-ground observations during the helicopter flyover.

7.1 Concluding remarks – shorebird review

This review supports the request for the variation to the EPBC approval 2005/2132 condition 4D which requires that *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour*.

This request is supported by:

- The review of the literature indicates that both Swan Bay and Lake Connewarre complex support a diverse and healthy population of migratory shore birds. The population of birds and their abundance is most pronounced in both areas between January and March. CoGG conduct the majority of their application between August and December, when the mosquito breeding season is most severe, with minimal applications in the latter months (January to March) when the sites are generally drier due to warmer temperatures.
- The larvicide application between August and March each year is for a cumulative period of 30 minutes per site (37 in total) for the entire season. The population and abundance is distributed across the wider Ramsar areas, and are not localised to areas that are within the flight path of the helicopter during aerial application. Observations made during the helicopter flights indicate that an insignificant number of birds are disturbed during the aerial applications.
- Information discussed in this migratory bird report does not allow for a review of the behaviour of migratory shorebirds and their abundance throughout the treatment period – only for a single simulated event. Also, as discussed in the report, it was not possible to determine the presence/absence of migratory shorebirds recording video footage during the helicopter flights. Limitations exist that preclude the use of video footage, including:
  - Restrictions from CASA (Civil Aviation Safety Authority) to affix a camera to the helicopter or treatment bucket.
  - No other person is allowed in the helicopter during an application event due to occupational health and safety reasons as well as weight restrictions in the helicopter while applying the product.
  - Difficulty in getting quality footage from within the helicopter cabin.
  - The migratory shorebirds are often small and it is difficult to identify the species observed from the helicopter.

7.1 Concluding remarks - Field assessment of disturbance

Generally, shorebirds and wetland birds are easily disturbed, and by a range of potential sources. Sources of disturbance include people (including birdwatchers, e.g., walking), loud noises, wayward golf balls, dogs, foxes, swamp harriers, whistling kites, low-flying helicopters, etc. During this assessment, observations were also made of birds being disturbed by sources other than the helicopter– mostly by people walking nearby and raptorial birds of prey. The result was similar to what was consistently observed at all sites during the helicopter flyovers – birds took to the skies, then tended to resettle at or near the original location soon after the disturbance source had gone. When disturbed, birds tended to group up, then land as a tight group, then commence spreading out again, once re-settled. Some birds re-settled some distance away, then made their way back to the original location in smaller groups over the following period. Each major disturbance (i.e., when all birds flee) appeared to reset the distribution of birds at the site. Movements by large numbers of birds into, around and out of a site appears to be normal and typical of these sites. On-ground observations made here during the simulated aerial application showed that nearly all birds flew away from the approaching helicopter. This may explain why no migratory shorebirds were identified from the aerial video footage (Section 4.2).

This assessment considered the potential disturbance to the birds due to the helicopter operations only. From this assessment it appears that the helicopter operation results in short-lived disturbance of migratory shorebirds at sites where they are present. The disturbance does not appear to be major for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance remains unknown. These migratory shorebirds are preparing for their return migration to the northern hemisphere, and where the threshold of tolerable versus excessive disturbance lies, is also unknown.

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Migratory shorebird monitoring and drone disturbance trials in April 2023

City of Greater Geelong

30 October 2023



→ The Power of Commitment

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1. Introduction

1.1 Project background

The City of Greater Geelong (CoGG) monitors mosquitoes around the Bellarine Peninsula and Greater Geelong region on a weekly basis between August and March each year (CoGG 2016). Mosquito monitoring provides a better understanding of mosquito population dynamics in the Greater Geelong region, the potential public health risk from mosquitoes and aims to manage potential outbreaks before they occur. CoGG monitors both mosquito larvae and adults.

In response to the results of the monitoring, CoGG controls the abundance of adult mosquitoes in the Greater Geelong region with the use of ground and aerial treatments targeting mosquito larvae (CoGG 2016). The treatment areas include sections of the Port Phillip Bay (Western Shoreline, Bellarine Peninsula) Ramsar site, which provides habitat for threatened and migratory bird species. Until 2022, the aerial treatments were conducted by helicopter, in accordance with an *Environment Protection and Biodiversity Conservation Act* (EPBC) approval 2005/2132. The EPBC approval lists a number of conditions to minimise the impact of the mosquito control project on the ecological character of the Ramsar site and listed migratory species. Condition 4D requires that *the operational plan must include a program to monitor the impact of helicopter operations on migratory shorebird populations and their behaviour*.

A literature review of migratory shorebirds and a background review of migratory shorebirds in the study area were undertaken as part of the project in 2018, with the findings reported in GHD (2018). On-ground bird assessments were undertaken by GHD in February/March 2018, March 2019 and March 2020 to directly document disturbance of birds (particularly migratory shorebirds) during aerial applications (GHD 2018, GHD 2019, GHD 2020).

In 2022, CoGG began investigating the use of unmanned aerial vehicles (drones) to replace the role of the helicopter in delivering larvicide to selected wetland areas. CoGG identified factors for and against the use of drones rather than helicopters (Table 1).

Table 1 ***Factors for and against the use of drones rather than helicopters for larvicide application (as provided by CoGG)***

	Drone	Helicopter
For	Higher accuracy Further access to sites Lower overall cost Treatments conducted in-house	High-capacity load Longer flight times Capable of higher altitude
Against	Recharge times Smaller hopper Slower speeds	Limited access High costs for treatment No local operators

In terms of potential disturbance to birds, a drone differs from a helicopter in potentially important ways, particularly size, noise, speed and operating elevation. Therefore, the extent to which the results from earlier assessments with the helicopter transfer to the project's use of drones requires investigation. This report presents the findings of an assessment undertaken during a mock larvicide trial using a drone, undertaken in April 2023. As with the helicopter trials, no larvicide product was distributed during the trial.

1.2 Project area

Historically, the project area for mosquito treatment has consisted of 37 sites from two areas, namely Swan Bay and Lake Connewarre, that are subject to aerial application. These locations are identified by the EPBC approval conditions (EPBC 2005/2132) and shown in GHD (2018).

On the basis of historical shorebird observations, six sites were monitored for bird disturbance in 2018, 2019 and 2020 (Figure 1), although wetland conditions in 2020 meant that four sites, not six, were used for the 2020 aerial simulation. In this 2023 assessment, five of those six sites were selected again for the trial, and an additional site (Breamlea Wetlands) was added. Sites included in the aerial disturbance trials since 2018 are shown in Table 2.

Table 2 Sites assessed during the 2018-2020 trials and the 2023 trial

Site	2018	2019	2020	2023
Lake Connewarre, Brinsmead Lane	✓	✓	×	✓
Hospitals Swamp	✓	✓	✓	✓
Swan Bay Jetty	✓	✓	✓	✓
Point Edwards	✓	✓	✓	✓
Lake Victoria	✓	✓	✓	✓
Lake Murtnaghurt	✓	✓	×	×
Breamlea Wetlands	×	×	×	✓

1.3 Purpose of this report

This report for CoGG presents the methods and results of a bird disturbance assessment undertaken in association with a mock aerial treatment trial in April 2023 using an unmanned aerial vehicle (drone). It provides information on bird species and abundance at a range of sites on the Bellarine Peninsula before, during and after the simulated drone operations.

This report follows on from and provides a base for comparison with similar reports prepared in 2018, 2019 and 2020 that presented the methods and results of bird disturbance observations during mock aerial treatments using a helicopter.

This report is intended to provide information for CoGG that can be used to help gain project approvals under the EPBC Act.

1.4 Legal Limitations

This report has been prepared by GHD Pty Ltd (GHD) for City of Greater Geelong and may only be used and relied on by City of Greater Geelong for the purpose agreed between GHD and the City of Greater Geelong, as set out in section 1.3 of this report. The assessment focuses on environmental risks to birds and does not consider risks to human health.

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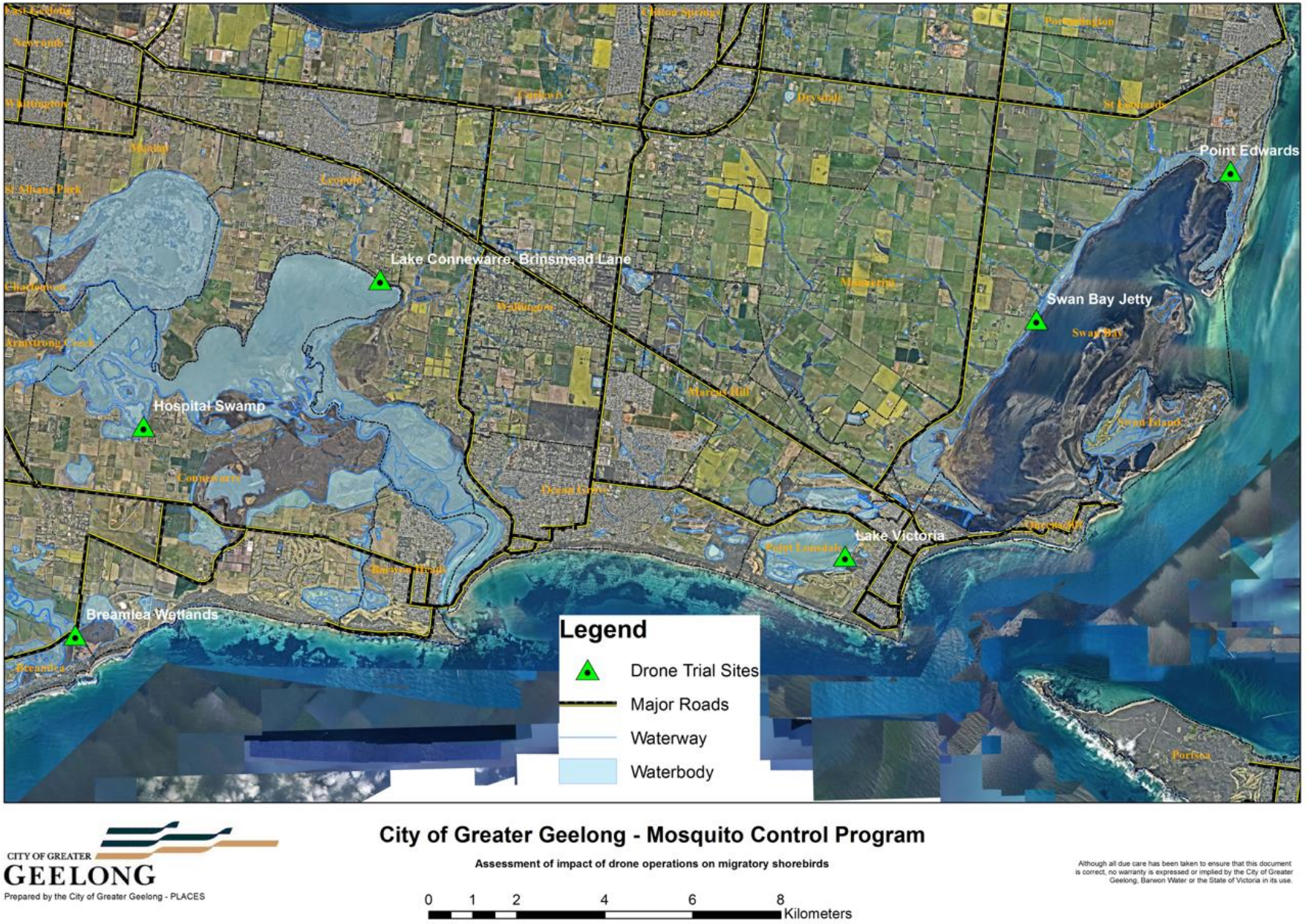


Figure 1 Sites assessed for shorebird disturbance during the simulated aerial application

2. Methods

To support the findings of previous monitoring, a three-day field assessment was undertaken in early 2023 to document observations of bird disturbance (including migratory species) caused by a drone flying over the treatment areas. The assessment was conducted between 18 and 20 April 2023, with the intention being that at least some migratory shorebirds would be detected and included in the observations, before they had all departed on their northerly migration. It is acknowledged, however, that mid-April is later than optimal in the migration season and many if not most birds are likely to have already departed south-eastern Australia.

Fieldwork was undertaken over three days: one day prior to the flyover event (a simulated larvicide application using a drone), one day during the event, and one day immediately after the event. The three days were consecutive. For each phase of the assessment, observations recorded included bird species and abundance, and behaviour (e.g., foraging, roosting, preening).

The aim was to focus observations on migratory shorebirds. However, given the general scarcity of those species at most sites, observations were made of all birds listed as Migratory under the EPBC Act (i.e., including terns, etc.), and all other birds that favour the habitats selected for larvicide application (including ducks, swans, grebes, large wading birds, etc.).

Six locations (tidal and non-tidal) were identified for the assessment. Those sites were chosen to be: i) representative of favoured shorebird locations in this region; ii) relatively accessible to allow timely and repeatable observations of all sites all within one day; and iii) within the area that CoGG would typically consider for aerial larvicide treatment. Sites chosen were based on past-10-year observations (using source: e-Bird.org) of species such as the Red-necked Stint and Sharp-tailed Sandpiper, which tend to be the most common Migratory shorebirds in Victoria.

The sites are shown in Figure 1 and include:

– Lake Connewarre – Brinsmead Lane (tidal)
– Hospitals Swamp (non-tidal)
– Lake Victoria – east end (non-tidal)
– Swan Bay Edwards Point Wildlife Reserve (tidal)
– Swan Bay Jetty (tidal)
– Breamlea Wetlands (tidal and non-tidal sections)

In previous assessments (2018, 2019, 2020), another site was considered: Lake Murtnaghurt (south of Lake Connewarre, north of 13th beach life saving club) (non-tidal). This site was the least reliable site for birds in the earlier assessments and was not included in the 2023 trial.

Visits to all sites on day one determined that, under current conditions and with the species and abundances present, sites were not equally suitable for the assessment using the drone. Lake Connewarre – Brinsmead Lane was currently attracting very few birds (and extremely few shorebirds) within observable range; that site was subsequently omitted from the aerial simulation. Swan Bay Edwards Point Wildlife Reserve was also attracting very few birds within observable range and provided no safe access for the drone from the launch site near the 4WD vehicle, so was also omitted from the trial. Breamlea Wetlands was omitted from the aerial simulation due to adverse weather conditions at the time of visit (too windy for safe operation of the drone).

Thus, observations associated with the aerial trial were limited to three sites: Hospitals Swamp, Lake Victoria and Swan Bay Jetty.

2.1 Pre-application assessment

The purpose of this phase of the assessment was to determine the presence and relative abundance of wetland, waterbird and shorebird species at sites before drone operation occurred.

From the best available and easily accessible vantage point at each site, a point count of all wetland, waterbird and shorebird species was conducted on foot by one or two experienced observers using binoculars. The objectives were to:

– Determine species present and relative abundance, noting those that are listed as Migratory under the EPBC Act and those that are not
– Determine habitat use of Migratory species at locations (roosting, foraging)
– Assess tide phase (tidal sites only), which may influence bird behaviour (e.g., high-tide roosting)

Each site was assessed twice (Day 1, then Day 2 before drone flyover). Visits occurred on 18 and 19 April 2023. A count of birds at each site on Day 2, prior to the drone being activated and flying over, provided a second pre-disturbance sample.

The order of sites visited was mixed up for the second visit so that, as far as possible, every site was assessed once in the morning and once in the afternoon. Visiting sites twice reduced bias due to poor weather conditions, chance and time of day.

2.2 During-application assessment

The purpose of this phase was to determine whether the birds were disturbed by the drone flyover, and to gather information about the nature and magnitude of the disturbance.

On Day 2 (19 April 2023), two experienced observers watched the responses of birds at the three treatment sites while the drone was flown over the sites, as though it was applying larvicide (note – this was a simulated application, so that no larvicide was dropped). At each site, this was done after a full count of birds had been made.

In keeping with what would be required for a typical larvicide application, the drone made repeated aerial passes over each site. Passes were made parallel to the shoreline, with each pass approximately 25 m towards or away from the water relative to the previous pass.

The drone flew at approximately 6 – 10 m above the ground, which is the typical operational elevation from which larvicide pellets would be dropped. Drone speed was slow (approximately 3 m/s), but even light winds (head or tail wind) made it difficult for the pilot to fly the drone at the same speeds on all passes.

The flyover trials at each site took place as follows:

– Swan Bay Jetty (9:27 – 9:52 am)
– Lake Victoria (11:26 – 11:47 am)
– Hospitals Swamp (2:14 – 2:22 pm)

2.3 Post-application assessment

The purpose of this part of the assessment was to determine if species remain at or return to the site and in similar numbers. It was effectively a repeat of the pre-disturbance assessment, to allow for a before and after comparison.

This part of the assessment was undertaken on 20 April 2023 (assessment Day 3; after drone flyover).

2.4 Drone specifications

The drone used for the trials is shown in the image below. Specifications of the drone likely to be used for larvicide application are as follows (refer to: https://www.xagaustralia.com.au/2020p30specs):

– Dimensions:
  - propeller folded – 1262 wide x 1250 long x 490mm tall
  - propeller unfolded – 2018 wide x 2013 long x 490mm tall
– Total Weight (Excluding Battery): 16.05 kg
– Maximum Take-off Weight: 38.5 kg
– Maximum Operating Speed: 12 m/s



3. Results – Disturbance of birds

3.1 Weather during the assessment

The weather on the three assessment days was generally mild, intermittently or mostly overcast, and still or slightly breezy. There were periods of stronger wind and occasional precipitation on Day 2, and sunny breaks on all three days. Daily weather observations for the Geelong Bureau of Meteorology site (station 087184) and made on site during the assessment are shown in Table 3.

Wind on Day 2 during the drone trial was variable; at one site (Breamlea Wetlands), a fresh prevailing wind prevented deployment of the drone. Maximum recorded gust wind speed at Geelong (BoM station) during the assessment period was 43 km/h at 14:35 on 18 April and at 12:17 on 19 April.

Table 3 Weather observations during the assessment

Date (2023) Attribute	18 April	19 April	20 April
Day	1	2	3
Max Temp (ºC)*	23.7	17.8	18.5
Min Temp (ºC)*	14.3	12.6	8.5
Cloud cover (representative of the day, as observed by GHD) (x/8)	4	6	6
Wind (max gust; km/h and dir)*	43 NNW	43 WSW	26 W
Wind (9 am; km/h and dir)*	11 NNW	13 WNW	7 NW
Wind (3 pm; km/h and dir)*	19 NW	24 W	15 W
Rainfall to 9 am (mm)*	0	0	0.2
Relative Humidity (%) (3 pm)	45	42	60
Prevailing conditions	Mild to warm, calm to breezy, sunny breaks	Cool, breezy to windy, sunny breaks, occasional rain	Cool, calm to breezy, sunny breaks

***BoM station 087184, Geelong**

Tides at St Leonards (east side of Bellarine Peninsula, within Port Phillip Bay) began as generally low in the mornings and evenings and high during the middle of the day (daytime high tide on April 18, 19, 20 respectively: 12:03 pm, 1:52 pm, 3:12 pm) (Figure 2). The lowest tide was 0.24 m on April 20, and the highest tide was 0.76 m, also on April 20. Thus, the inter-tide range was approximately 0.5 m or less. The maximum range during the observation period (0.52 m) is 65% of the maximum range at St Leonards (0.8 m; the tides in 2023 range from 0.04 to 0.84 m).

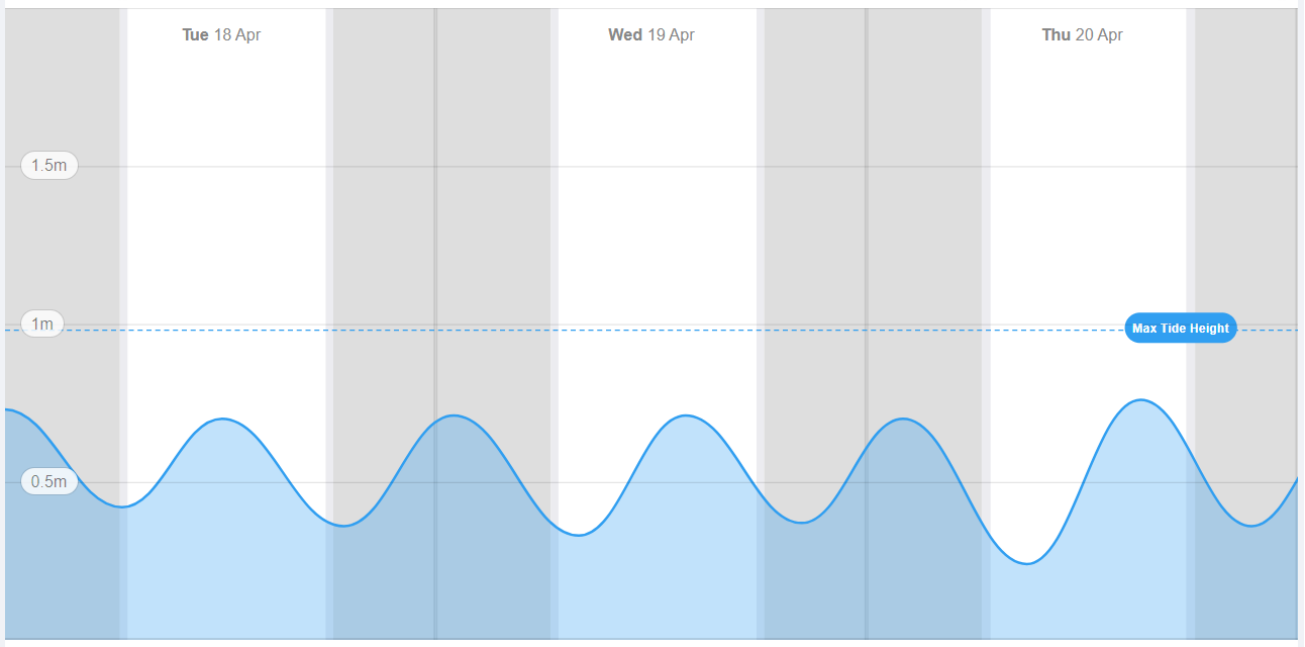


Figure 2 *Tides during the assessment period (St Leonards)*

Source:
https://www.willyweather.com.au/graphs.html?graph=outlook:3,location:13191,series=order:0,id:sunrisesunset,type:forecast,series=order:1,id:tides,type:forecast

3.2 Representative images of sampled habitat at sites



Coastal habitat and roosting birds at Swan Bay Jetty (looking north)



Coastal and saltmarsh habitat at Edwards Point, (Swan Bay side, looking south)



‘Saltmarsh island’ in the focal pond at Lake Victoria



Main shoreline, Lake Victoria 2020 (looking west)



Vegetated mudflats at Hospitals Swamp (looking west)



Breamlea Wetlands (looking west)



Lake Connewarre in 2023 (looking west)



Lake Connewarre in 2020 (looking west)

3.3 Waterbird species richness at sites

Over the three-day assessment, small to moderate numbers of waterbird species were observed at most sites, ranging from 29 species at Hospitals Swamp to four species at Breamlea Wetlands. A total of 35 wetland/waterbird species was observed overall (Table 4). Not all of those species were Migratory species – most (29 of 35) were non-Migratory. Migratory species were seen at five of the six sites (not at Breamlea Wetlands).

Overall, wetland, waterbird and shorebird species counts in 2023 (35 species) were similar to those in earlier assessments: 2020 (39 species), 2019 (30 species) and 2018 (39 species) (GHD 2020).

At all sites, species counts varied by day (Table 5; Figure 3). The most species seen at any one site on any one day was 21 species at Hospitals Swamp on days 1 and 2. The smallest daily species count at any site was four species at Breamlea Wetlands on day 1.

Table 4 ***Counts of waterbird species (split into migratory and non-migratory) observed at each site during the assessment***

Site	Migratory species	Non-Migratory species	Total species
Swan Bay Jetty	1	16	17
Lake Victoria	2	17	19
Hospitals Swamp	4	25	29
Breamlea Wetlands	0	4	4
Edwards Point	1	9	10
Lake Connewarre, Brinsmead Lane	1	18	19
All sites	6	29	35

Table 5 ***Counts of waterbird species observed on each day at each site during the assessment***

Site	Species count (day 1)	Species count (day 2, before drone)	Species count (day 3)
Swan Bay Jetty	13	12	10
Lake Victoria	12	13	16
Hospitals Swamp	21	21	12
Breamlea Wetlands	4	6	5
Edwards Point	6	not assessed	7
Lake Connewarre, Brinsmead Lane	15	not assessed	12
All sites	33	34	33

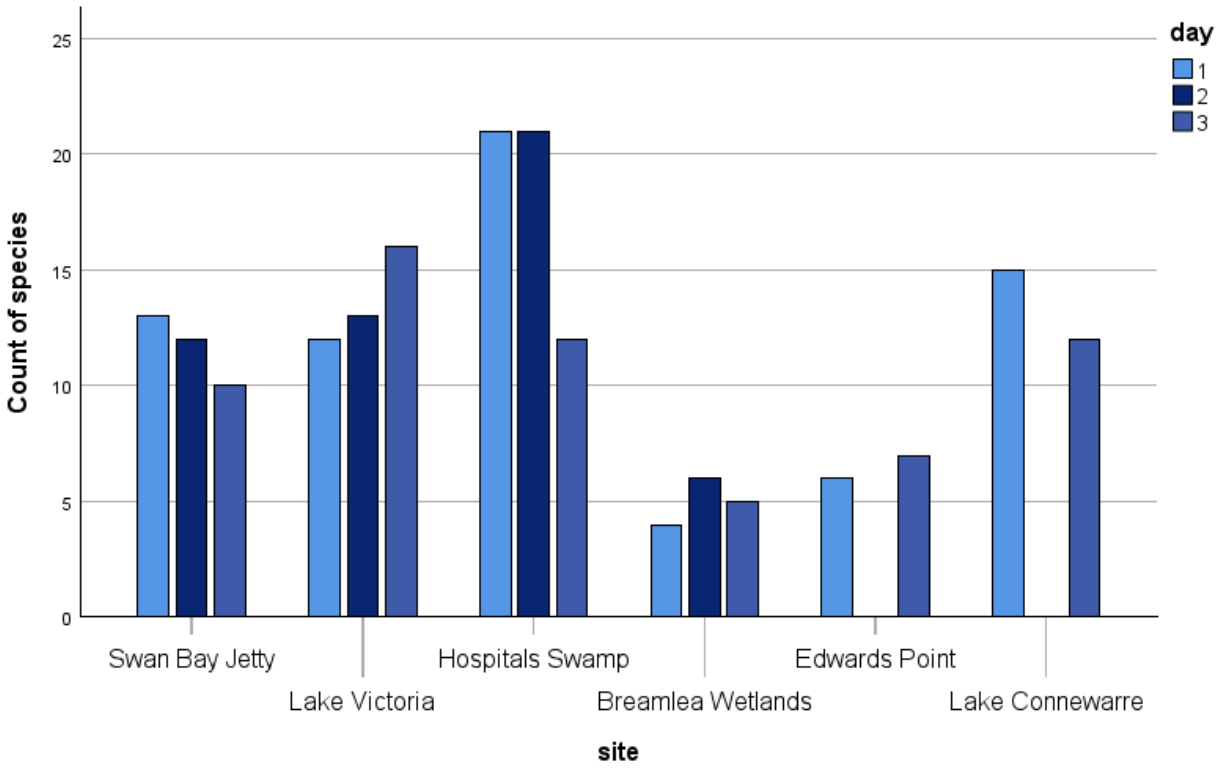


Figure 3 *Daily species counts at each site. Day 2 counts are pre-drone*

3.4 Relative abundance of species at sites – all species

Waterbird and shorebird abundance at sites varied, but most sites had relatively large numbers of wetland birds and waterbirds observable in the broader area, and a few had relatively small numbers of shorebirds. This was to be expected, as the sites were chosen partly on the basis of their bird history. At all sites, birds were engaged in a range of behaviours – foraging, roosting, rafting, preening, flying.

At Swan Bay Jetty (Figure 4, top), counts on all three days were consistently high, with approximately 150 or more waterbirds observed each day, and the total number counted increasing each day. Three species were consistently present in relatively large numbers: Silver Gull (particularly days 2 and 3), Pied Cormorant, Little Pied Cormorant, Crested Tern and Chestnut Teal. Overall, and for many species individually, the post-disturbance count (day 3) exceeded the pre-disturbance counts.

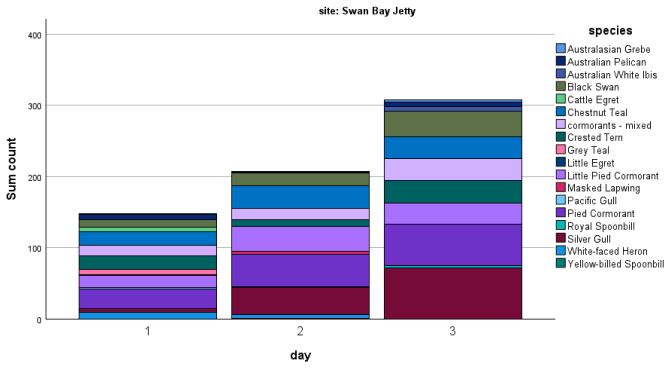
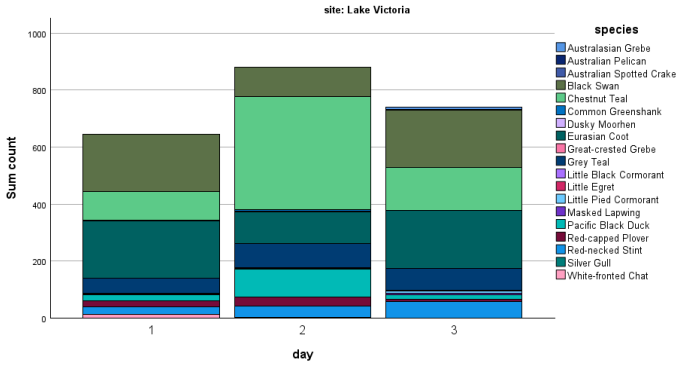
At Lake Victoria (Figure 4, second from top), bird counts were high across the three days, exceeding 640 birds on each day. The most consistently numerous species were Eurasian Coot, Chestnut Teal and Black Swan, with reasonable numbers also of Grey Teal, Pacific Black Duck (particularly on day 2), Red-capped Plover and Red-necked Stint. Overall, the post-disturbance bird numbers (day 3) were relatively similar to those in the pre-disturbance counts, with more birds counted on day 1 and fewer birds counted on day 2.

At Hospitals Swamp (Figure 4, third from top), counts on all three days were relatively high, with more than 200 waterbirds observed each day. The total number counted decreased each day, but not markedly. The most consistent and abundant species were Eurasian Coot, Purple Swamphen, and Black-winged Stilt, with Sharp-tailed Sandpipers also present in notable numbers. Overall, the post-disturbance bird numbers (day 3) were less than, but relatively similar to, those in the pre-disturbance counts. The slightly larger bird counts on day 1 and day 2 were due to variations in occurrence and abundance of some species (e.g., Eastern Great Egret and Australian Shelduck).

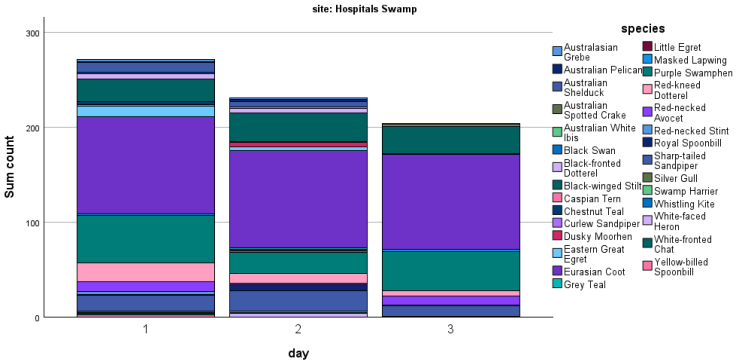
At Breamlea Wetlands (Figure 4, third from bottom), counts on all three days were generally smaller than at most other sites, with 120 birds on day 3 being the highest count. The total number counted each day varied, with the lowest count on day 2. The most numerous species was Pacific Black Duck, and bird counts at Breamlea were strongly influenced by the numbers of that species (i.e., 20 observed on day 2 and 100 observed on day 3). Other species seen at this site were Australasian Grebe, Black Swan and Chestnut Teal. There was no drone flyover at this site due to the excessively windy conditions experienced at the time of the visit.

At Edwards Point (Figure 4, second from bottom), nearly all birds counted were observed within Swan Bay itself, and most were well off-shore. No birds were observed within the flooded saltmarsh habitat typically targeted by the aerial treatment of mosquitos. Total counts were 87 birds on day 1 and 158 on day 3. White-faced Heron and Black Swan were consistently seen during both counts, although for both species, far more birds were observed on day 3 than on day 1. The smaller count on day 1 included a flock of 50 Red-necked Stint (a Migratory shorebird species) that were seen flying through the site. The Stint were not seen at this site on day 3. This site was not visited on day 2; the drone was not able to safely access this site, and given the observations of birds on day 1, a drone flight was not expected to provide useful results for the project.

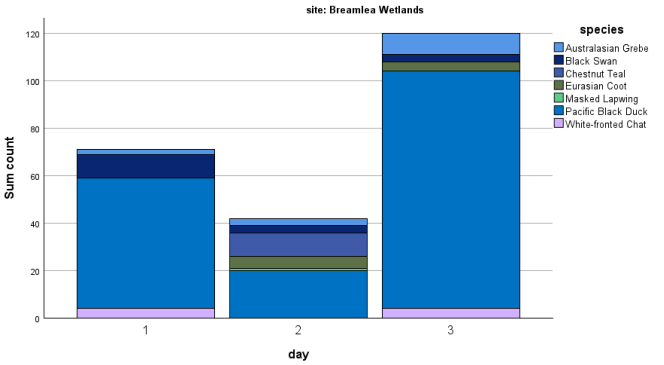
At Lake Connewarre (Brinsmead Lane) (Figure 4, bottom), nearly all birds counted were observed well off-shore, and few were observed within the shallowly inundated habitat typically targeted by the aerial treatment of mosquitos. Counts were dominated by two species (Black Swan and Eurasian Coot), which were swimming in large ‘rafts’ in Lake Connewarre itself. Far smaller numbers of numerous other species were observed on both days that this site was visited. This site was not visited with the drone on day 2; given the observations of birds on day 1, a drone flight was not expected to provide useful results for the project.

Site	**Observations per day at each site – all wetland-associated species** **(Observations on day 2 are pre-disturbance)**
Swan Bay Jetty	
Lake Victoria	

Hospitals Swamp

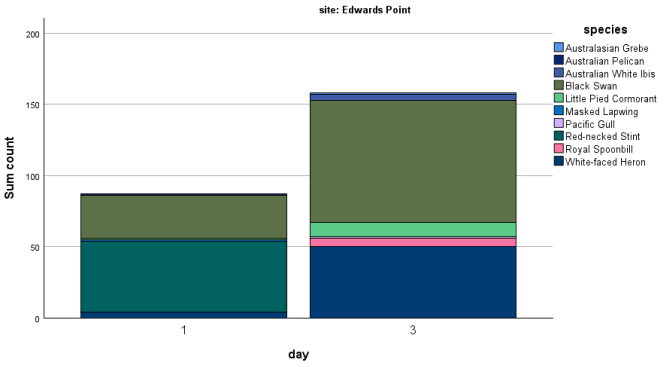


Breamlea Wetlands



Edwards Point

(not visited on day 2)



Lake Connewarre – Brinsmead Lane

(not visited on day 2)

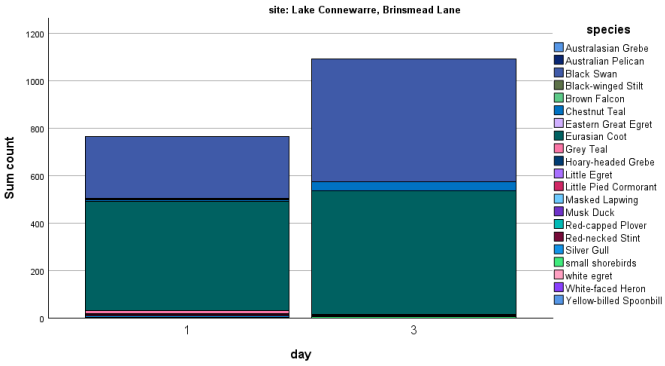


Figure 4 ***Relative abundance of wetland and waterbird species at each site during the three-day assessment***

3.5 Relative abundance of species at sites – shorebird species only

When the data are clipped to include shorebirds only (migratory and non-migratory), three sites had sufficient counts to present data.

Lake Victoria (Figure 5, top) had relatively large and consistent numbers of shorebirds, dominated by two species: Red-capped Plover and Red-necked Stint. Small numbers of Masked Lapwing and Common Greenshank were observed also. The numbers of Red-necked Stint observed increased each day, from 26 on day 1 to 57 on day 3. Counts of Red-capped Plover on day 3 (9) were smaller than on the other days (22 and 30), but this change is likely to reflect changes in detectability of these small birds rather than abandonment of the site by individuals. Overall, disregarding the differences for individual species, the post-disturbance shorebird numbers (day 3) were greater than those on day 1 and similar to those on day 2 (pre-disturbance counts).

Hospitals Swamp (Figure 5, middle) also had relatively large and consistent numbers of shorebirds, with a higher diversity of species (six or more species each day) than at Lake Victoria. Two species (Red-necked Stint and Curlew Sandpiper) were seen only on day 1, perhaps reflecting the dispersive and transient nature of habitat use by these species. All other species were observed at this site on all three days. Shorebird counts were progressively smaller each day of the trial, and overall, the post-disturbance shorebird numbers (day 3) were less than those in both pre-disturbance counts. This reduction is due to the accumulation of slightly smaller numbers of three species being observed on day 3: Black-fronted dotterel, Red-kneed Dotterel and Sharp-tailed Sandpiper. The habitat at this site is complex, however, with numerous patches of tall vegetation (*Typha, Phragmites*) obscuring parts of the shoreline, and it is possible that ‘missing’ individuals were present at the site but not within view.

At Lake Connewarre (Brinsmead Lane) (Figure 5, bottom), small numbers of shorebirds were observed, mostly at a distance. Three species were observed each day, with 10 birds seen on day 1 and nine birds seen on day 3 (this site was not visited on day 2). On day 3, a group of small shorebirds was seen at a distance, and identification was not possible. It is possible, or even probably, that those birds were Red-necked Stint, which tend to be the most common small shorebird in southern Victoria, and which were seen at this site on day 1.

At Swan Bay Jetty, Breamlea Wetlands and Edwards Point, too few shorebirds were recorded to present and discuss information here. At Swan Bay Jetty, four Masked Lapwings were observed on day 2; at Breamlea Wetlands, no shorebirds were observed; at Edwards Point, a flock of 50 Red-necked Stint flew through the site on day 1.

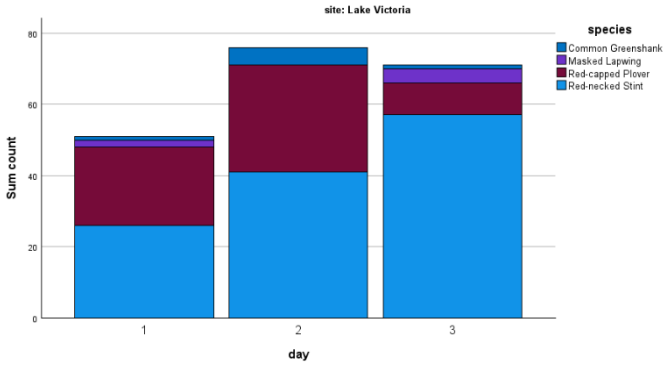
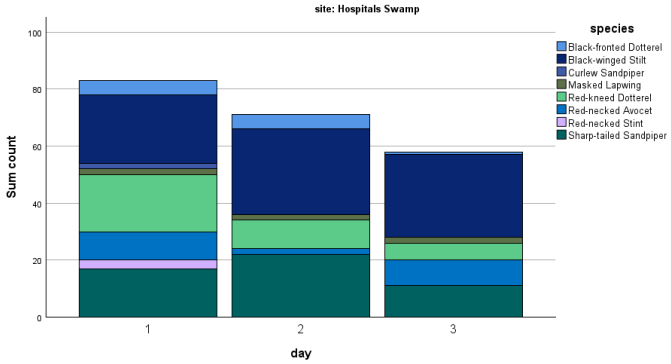
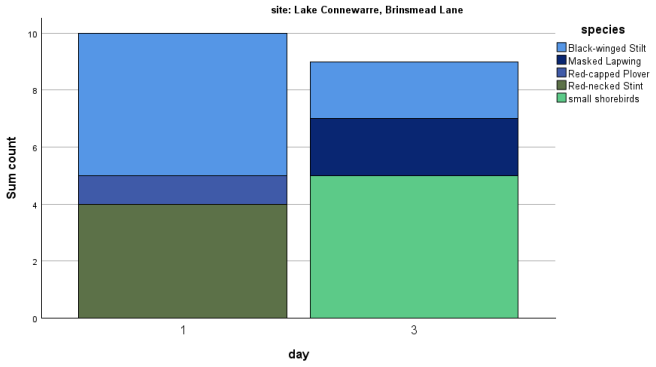
Site	Observations per day at each site – all shorebird species (Observations on day 2 are pre-disturbance)
Lake Victoria	
Hospitals Swamp	
Lake Connewarre – Brinsmead Lane (not visited on day 2)	

Figure 5 ***Relative abundance of shorebirds at sites during the three-day assessment***

3.6 Relative abundance of species at sites – Migratory species only

When the data are clipped to exclude non-migratory species, three sites had sufficient counts to present data. At Swan Bay Jetty (Figure 6, top), the only migratory species observed was Crested Tern, which commonly perch on the jetty at this site. The largest numbers of this species were observed on day 3 (32 birds), and the smallest numbers (10 birds) were observed immediately before the drone flyover on day 2.

At Lake Victoria (Figure 6, middle), two migratory species were observed: Red-necked Stint and Common Greenshank. The numbers of Red-necked Stint observed increased each day, from 26 on day 1 to 57 on day 3. Counts of Common Greenshank were consistently small, with the maximum count of 5 birds seen on day 2 before the drone flyover. Overall, the post-disturbance numbers of migratory birds (day 3) were greater than those during pre-disturbance counts.

Hospitals Swamp (Figure 6, bottom) had the largest counts of migratory birds of any of the sites, with 11 or more birds seen each day, and a maximum count of 23 birds seen on day 2. The counts were dominated by Sharp-tailed Sandpipers, and it is thought that it was likely the same group of birds remaining at the site for the survey period. Two other migratory species (Red-necked Stint and Curlew Sandpiper) were seen only on day 1, perhaps reflecting the dispersive and transient nature of habitat use by these species. Migratory bird counts were smallest on day 3 (post-disturbance), mainly due to the observable group size of Sharp-tailed Sandpiper being smaller. As said above, the habitat at this site is complex, with numerous patches of tall vegetation (*Typha, Phragmites*) obscuring parts of the shoreline, and it is possible that 'missing' individuals were present at the site but not within view.

At Breamlea Wetlands, Edwards Point and Lake Connewarre (Brinsmead Lane), too few migratory birds were recorded to present and discuss information here. At Breamlea Wetlands, no migratory birds were observed; at Edwards Point, a flock of 50 Red-necked Stint flew through the site on day 1, and at Lake Connewarre (Brinsmead Lane), four Red-necked Stint were observed on day 1.

Table 6 ***Counts of individuals of migratory species observed on each day at each site during the assessment***

	Hospitals Swamp			Lake Victoria			Swan Bay Jetty			Brinsmead Lane	Edwards Point	Breamlea Wetlands	Total
Day^ Species	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**1**	**1,2,3**	
Caspian Tern		1											1
Common Greenshank				1	5	1							7
Crested Tern							19	10	32				61
Curlew Sandpiper	2												2
Red-necked Stint	3			26	41	57				4	50*		181
Sharp-tailed Sandpiper	17	22	11										50
Total	**22**	**23**	**11**	**27**	**46**	**58**	**19**	**10**	**32**	**4**	**50**	**0**	**302**

* a flock of 50 birds flew through the site without stopping.

^ Day 2 counts are pre-drone disturbance.

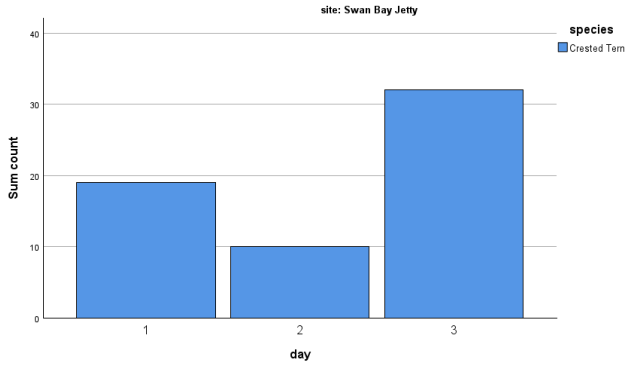
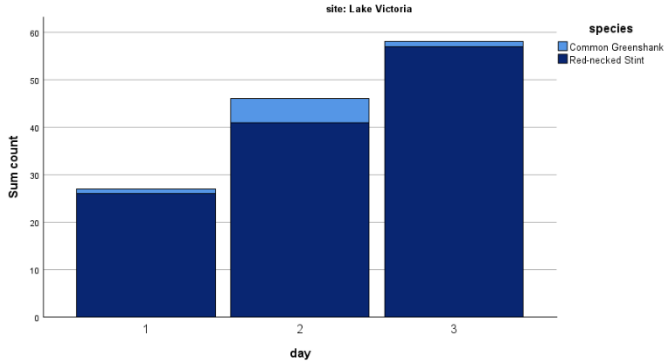
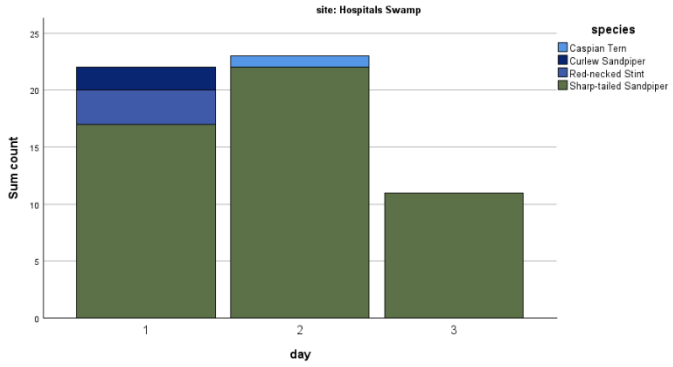
Site	Observations per day at each site – migratory species (Observations on day 2 are pre-disturbance)
Swan Bay Jetty	
Lake Victoria	
Hospitals Swamp	

Figure 6 *Relative abundance of migratory species at sites during the three-day assessment*

3.7 During- and post-disturbance observations (Day 2)

At most sites, species richness of all waterbirds on day 2 (before drone) was similar to day 1. At Swan Bay Jetty, the species count was slightly lower. The relative abundance of waterbirds at sites on day 2 (before drone) was also similar to or higher than the observed abundance on day 1 at two of the main sites (Swan Bay Jetty and Lake Victoria), but not at Hospitals Swamp, where abundance on day 2 was approximately 15% lower (Figure 4).

Shorebird counts were higher on day 2 (before drone) than on day 1 at Lake Victoria, but lower on day 2 at Hospitals Swamp, and migratory bird counts were higher on day 2 than day 1 at Lake Victoria and Hospitals Swamp, but lower at Swan Bay Jetty, where Crested Tern was the only migratory species observed.

Overall, the observations made during the drone trial in 2023 resembled those from helicopter trials in previous years. The drone disturbed birds as did the helicopter, but with notable differences, which are identified and discussed below.

The drone was flown at a range of elevations, from approximately 4 m to 15 m above the ground. The drone sounded like a swarm of buzzing bees and did not appear to obviously raise dust in its downdraught of wind beneath it. The drone appears small enough to be mistaken for a large bird of prey (e.g., eagle, harrier), although it is actually far larger than that.

Species varied in how quickly they made the move to flee from the disturbance, and in how they fled. Some went early and took to the skies; others went later and walked or swam away. Generally, birds did not flee the drone until the drone was reasonably close to them (generally within 25 m), and flying towards them (i.e., the birds were in the direct flight path). Species also varied in their response behaviour when disturbed – some flew off and landed in deeper water, some flew off and re-settled in almost the same place very quickly, others swam or walked away quickly or slowly, others took to the skies and remained airborne for some time. When disturbed, birds tended to group up with their own kind, then those that re-settled tended to do so as a tight group, then commence spreading out again, once re-settled. Descriptions of bird responses are shown in Table 7 and Table 8.

Species varied in how quickly they returned to the site. Generally, soon after the drone disturbance, the species and numbers of birds present at the sites resembled the pre-disturbance observations (Table 8). Some species moved away from the location as a result of the drone disturbance (e.g., White-faced Heron, Swan Bay Jetty; Table 8), but most remained in the location or returned to the location. In most cases, the before-after composition of birds at a site reflected re-distribution of birds rather than mass exodus.

The main observed differences between the helicopter and the drone were noise and radius of the disturbance area surrounding the flying object. The drone flew slower, lower and quieter than the helicopter, and therefore created a much more localised source of disturbance. Birds allowed the drone to get far closer to them than they did the helicopter, and birds further away from the drone did not appear to be concerned at all by the presence of the drone, which differed greatly from observations with the helicopter. Where the helicopter could only get within 50 – 100 m before birds took flight, the drone could get much closer (within 15 – 25 m) before birds appeared to become concerned. Disturbance of ten White-faced Herons at Swan Bay Jetty approximately 50 m away from the drone was the greatest distance of disturbance observed.

For the helicopter, it was the noise that was the most obvious (to humans) sign of approaching disturbance, but whether it was noise or appearance (i.e., resembling an aerial predator) of the helicopter that disturbed the birds was unknown.

As was observed with the helicopter, all or nearly all birds within a reasonable distance of the drone's flight path fled the drone at some point – only a handful of birds were observed to remain where they were (i.e., did not swim, walk or fly away) even when the drone appeared to fly almost immediately overhead.

Birds on land appeared to be more afraid of the drone than birds in the water. Whether that observation reflects the habitat (i.e., land or water) or the species (i.e., some birds use both habitats, others do not) remains unknown. Birds that took to the water upon disturbance (e.g., teal) tended to be far less afraid of the drone when it flew close and they were in the water.

As was noted in helicopter trials, birds at these sites are generally easily and commonly disturbed by things other than helicopters or drones. The inbound, outbound and redistributing movements of birds appears to be normal and typical of these sites. Disturbance sources include people, dogs, noises, gunshots, golf balls, foxes, swamp harriers, whistling kites, low-flying aeroplanes and helicopters.

3.8 Post-disturbance observations (Day 3)

There was no consistent evidence that species counts or abundances reduced on or after day 2 as a result of the drone flyover. At Hospitals Swamp, where more species were observed than at any other site, there was an apparent reduction in species count from day 2 before the drone flight to day 3 after the drone flight (Figure 3, Figure 4, Figure 5, Figure 6). While this result suggests the drone may have caused a notable disturbance at that site, the pattern is not seen consistently across the sites, and most sites show variation in richness and abundance between days 1 and 2, before the drone was introduced. At Lake Victoria, where the second largest species counts were made and where the largest abundances were counted, the species count on day 3 exceeded that on days 1 or 2 (Table 5), and the relative abundance on day 3 was higher than it was on day 1 (Figure 4). At Swan Bay Jetty, the day 3 bird count was the largest of any day at that site (Figure 4). This pattern was observed in previous years with the helicopter trials also – richness and abundance of birds at sites varied from day to day with or without the disturbance (GHD 2020).

Generally, observations on days 2 and 3 showed that the disturbance of birds by the drone was localised and short-lived.

Table 7 Disturbance responses by birds at each site during the drone flyover (day 2; 19 April 2023)

Site	Time	Drone activity	Location	What did the birds do?
Swan Bay Jetty	9:27	Drone lift off from car park	Drone 30 m away from habitat, but no birds close by.	No birds seen to be disturbed by drone lift off. Most birds on north side of the jetty.
		Flyover – south of jetty	Drone flying over saltmarsh habitat south of jetty.	1 Grey Teal took off - disturbed by drone. Nothing else flew. Nothing was disturbed from the water's edge (30+m away). Black Swans, Chestnut Teal on water not put up by drone over land.
				10 x White-faced Herons flew up from the coast (~50 m away from drone). Drone over saltmarsh, and not that close to them. This is the highest sign of disturbance thus far.
				Masked Lapwings and Grey Teal on land - not put up. Grey Teal within 20 m of the drone's path. Walking away, but not flying.
				3 Australian White Ibis already flying across the path of the drone – did not alter course.
				1 Australian Magpie took flight when drone overhead.
	9:30	Flyover – north of jetty	Drone flying over saltmarsh habitat north of jetty.	Nearly all birds on land and water nearby put up or begin to move - chestnut teal, cormorants, spoonbills; all up. Pelicans swimming out to deeper water, not flying. 2 silver gulls and 1 masked lapwing did not move - standing on shoreline, nearly under drone. Everything else did move, took to the sea either in flight or swimming, but began their return quickly.
		After drone (drone flown further north)	North of jetty.	Ducks/teal tended to circle around in the sky, then settle on the water (not on land) in the same bay. 1 min later, 3-4 cormorants still flying, but most birds re-settled.
				Birds present 1.30 mins after - 1 pelican, 8 swans, 30-40 chestnut teal, 20 silver gull.
		Flyover – north of jetty	Coast habitat (water's edge). North of jetty.	Drone flies south again over the coast (nearer the water). All birds are in the water - no birds go up.
				Birds on wooden structures and abandoned boat (30 – 50 m away), jetty and pier (15 m away)- not put up by drone at the water's edge. Low disturbance.
				Drone flies directly over where birds were initially standing (but birds now in the water). 1 x teal took off from water, but landed 5 m away. Nothing else went up. Birds clearly aware of drone's presence, but once in the water, there does not seem to be so much alarm. Birds 15-20 m from flight path.
	9:35	Flyover – north of jetty	North of jetty.	10 ibis and 4 herons that were moved further north when first put up by drone (and re-settled in saltmarsh habitat) were not put up by the drone when it went back up there. Drone didn't get as close to them as before.
	9:38	Flyover – north of jetty	Coast habitat (water's edge). North of jetty.	Drone now flying over the water - silver gulls put up when drone was ~5m away. Ducks are still further out to sea (50 m from shore), and were not bothered by the drone.

Site	Time	Drone activity	Location	What did the birds do?
	9:40	Flyover – north of jetty	Open water habitat.	3 teal flew up when drone flew directly overhead. Birds on wooden structures, abandoned boat, jetty and pier not put up by drone flying over water at the water's edge.
	9:41	Drone landing	Car park	Nothing.
	9:44	After drone	North of jetty	1 pied cormorant took off from water and re-settled on perch where it was first observed, then began drying its wings.
				Teal in water and all faced shorewards and swimming back, as is pelican and juvenile pacific gull; 3 other pelicans currently flying in from north.
				Swans have continued to swim to the north and don't look like they want to return at this stage. Same with some teal.
	9:46	After drone	Above car park	2 wedge-tailed eagles flying over at moderate elevation (not high, not low). Masked Lapwings not happy with eagles. Not too concerned by the drone, but annoyed by the eagles.
		After drone	North of jetty	Pelicans have swum their way back to earth jetty. Ducks continue to return to land (swimming), but very slowly.
				10 ibis and 1 spoonbill (200 m north) took off, and then the ducks went up from the water. No apparent reason. Circling around to east, but re-settling. 2 wedgies to the north, but very high.
				Silver gulls, ducks all back to where they were.
	9:52	After drone	At jetty	Boat comes in and all birds on jetty and in nearby water (north of jetty) go up, only to re-settle soon after. This site is frequently disturbed.
				To recap at the end of the drone trial at Swan Bay Jetty: numbers of birds in the area at the end are similar to those at the beginning, but birds have moved around. Most birds have moved off the shoreline and into the water, but most of those are slowly returning. Disturbance at this site (public jetty) is commonplace.
Lake Victoria	11:21	Before drone lift-off.	Throughout site	Drone day: relatively few birds on 'Saltmarsh Island' to begin with (they were there yesterday), but there are birds present, including shorebirds.
	11:25	Drone lift off	Sand flat ponds, west of path, near cars	Nothing
	11:26	Flying along sand flat ponds- north to south	Sand flat ponds, west of path	Drone flying over sand flat ponds, between path and Lake Victoria shoreline. Flying 8-10 m high. Small numbers of red-necked stint (6) put up by drone, 4 circled back and re-settled nearby, 2 flew up and over into the focal pond near Saltmarsh Island.
				Drone continues to south, flushing small numbers of birds (red-capped plovers, white-fronted chats) further forward.

Site	Time	Drone activity	Location	What did the birds do?
	11:27	Drone flying along ridge of path - south to north.	Along ridge of path.	4 red-necked stint flying west across the path and out to Lake. Another 4 circling around away from drone, coming back to lake shore, but did not settle immediately - settled 100-200 m from where they took off.
				No birds in focal pond (Saltmarsh Island) put up yet. Red-capped plovers on island still there, as are teal and other birds there.
	11:29	Drone flying east of path – north to south.	East of path.	Drone now flying nearer focal pond and Saltmarsh Island - over water between path and island.
				Red-necked stint (5) put up from Saltmarsh Island, then re-settled on island. Another 10 stint have flown in to land on island.
	11:30	Drone flying east of path – north to south.	Over Saltmarsh Island (focal pond)	Drone over Saltmarsh Island proper. Roosting ducks in shallow water and on island all still there - then they all go up when drone approaches. Shorebirds all up also.
				4 Common Greenshank took off and flew west across to Lake Victoria. 30 red-necked stint flew up and west over to Lake Victoria, then flew north over the water. Ducks/teal re-settled on water nearby almost immediately. Then began swimming back to where they appear to want to be - shallow water for roosting. Red-capped plovers - all gone. Must have flown with the stint, but not noticed.
	11:31	Drone flying east of path – north to south.	Drone flying over water beyond island.	Drone south of island, flying where lots of ducks/teal are. All ducks/teal put up again when drone is within 25-30 m from them. Pretty close. Ducks circle around behind the drone in two large flocks. One group of perhaps 100 birds re-settles rapidly in same spot - within 10 seconds. Another group continues circling and then flies off over Lake Victoria.
				Stint have not returned - gone to the north shore of the lake.
	11:33	Drone flying over focal pond – south to north.	Over Saltmarsh Island (focal pond)	4 chats put up as drone flies over island again.
	11:34	Drone flying over focal pond – south to north.	Over far side of Saltmarsh Island (focal pond)	Drone flying over the far part of the island (golf course side) - All (~150) ducks/teal put up - no birds remain on island. Many ducks/teal flying off to Lake Victoria. Very small numbers returning. Repeated flyovers may cause longer-term disturbance (i.e., convince birds to move out of the area rather than re-settle in same location).
	11:35	Drone flying back to landing location.	West of path	Drone flying along path back to operator.
	11:36	After drone	Saltmarsh Island	No sign of shorebirds returning. 1 red-capped plover still on island! No swans or coots took flight as a result of the drone. Cormorants took off during drone flights - not sure when or where to, but no longer roosting on posts. Probably when ducks went up. Swans near golf course didn't go up, nor did the more distant teal.
				Really just birds under the drone (within 30 m) get disturbed. Single pass may be short-term disturbance (birds immediately return to same location), but repeated passes may cause birds to move further afield.

Site	Time	Drone activity	Location	What did the birds do?
	11:41	After drone	Saltmarsh Island	Ducks/teal starting to return to roosting spot - now 20 birds back there. Likely to continue to re-group in ensuing hours.
	11:43	After drone	Saltmarsh Island	6 red-necked stint flew in to join ducks in roosting location. Birds starting to return.
	11:47	After drone	North shore of Lake Victoria	No stint or greenshank seen on northern shores of Lake Victoria as we walked out.
				To recap at the end of the drone trial at Lake Victoria: numbers of birds in local areas (e.g., roost site at Saltmarsh Island) have changed, and birds have moved around. But, there are early signs of birds returning – not immediately, but soon after. Single drone flyover may not cause too much disturbance, but repeated flyovers may push birds to find new locations.
	15:33	No drone – later in day	Saltmarsh Island	After-drone visit later in the day to see how birds have returned/resettled. Ducks and teal have returned, but perhaps not in quite so high numbers as before drone. Small numbers of Red-capped Plovers and Red-necked Stint on island.
Hospitals Swamp	14:14	Drone lift off	At vehicles	Drone pilot and take-off location not in view of bird observers. Pilot and observers communicating via live phone call.
	14:14	Drone flying slowly east to west along southern shoreline from carpark to mudflats	Car park	Drone approaching wetland area where birds congregate. Approaching from east. 2 Black-winged Stilts wading in the water fly up, but re-settle immediately a few metres in front.
		East to west transect	mudflat habitat (south)	Drone flying over eastern section of mudflats, where bird observers are and where Sharp-tailed Sandpipers were yesterday. No birds here currently, so nothing to put up. All birds are more west of our location.
				Drone now heading further west over core habitat - across central part of mudflat. Nothing flying up - all birds just sitting watching it. Purple Swamphens not concerned at all.
	14:16	East to west transect	mudflat habitat (south)	As drone flies over far side of mudflat, birds start to take flight: 2 Royal Spoonbills go up, 1 Australian White Ibis, 3 Black-fronted Dotterels, 7 egrets go up; swamphens do not. Black-winged Stilts flew 10-20 m before settling down again.
				Black-winged Stilts and Red-necked Avocets in distance did not fly up at first, but did take flight when drone got close to them (~100 m west of us).
				2 Black-fronted Dotterels took off, then landed about 2 m from where they were.
				Haven't seen any Red-kneed Dotterels fly yet, but they are present.
	14:17	West to east transect	mudflat habitat (south)	Drone returning to east and flying over core areas now - drone puts up 20 Sharp-tailed Sandpipers from far side - birds not previously seen! Sandpipers re-settle nearby.

Site	Time	Drone activity	Location	What did the birds do?
				Drone flying east, following edge of water. Red-kneed Dotterels present but not moving, same for Sharp-tailed Sandpipers, now under drone again. Drone appears to be right over the top of them, at ~15 m high.
	14:20	Drone returns to landing location	Car park	Nothing.
	14:20	after drone		To recap at the end of the drone trial at Hospitals Swamp: numbers of birds in the area at the end are similar to those at the beginning, but birds have moved around and then re-settled as the drone disturbs them. Few birds seen to vacate the area. Drone had to be really quite close before birds took off, and even then, some birds (e.g., Purple Swamphen) didn't fly.
				Most flighty species: 20 sharp-tailed sandpipers, 15 Red-kneed Dotterels, 5 Black-fronted Dotterels, 30+ Black-winged Stilts, 5 Red-necked Avocets – all took flight repeatedly, but re-settled nearby.
	14:22	after drone		All birds in the immediate area have now settled back down. Egrets and spoonbills have not returned - likely settled in another location around the swamp. Those two species WERE displaced from local area by the drone.
	14:22	after drone		After the drone disturbance, birds seem to be roosting/standing rather than foraging - they are not spreading out fast. Perhaps waiting to regain confidence in the area before that.

Table 8 Post-disturbance observations of each species at drone trial sites (day 2; 19 April 2023)

Site	Species	Shorebird/Migratory	Observations after disturbance	Displaced from local area?
Swan Bay Jetty	Grey Teal	-	Post-disturbance count remained similar to pre-disturbance - few birds seen to vacate area. Birds generally moved (flew) to land in water ~50 m offshore, but then slowly returned (swimming) to roosting site. Small numbers kept swimming away from disturbance site.	some
	White-faced Heron	-	Disturbance caused birds to fly off and re-settle on land ~200 m north	yes
	Masked Lapwing	Shorebird	Seemingly undisturbed.	no
	Australian White Ibis	-	As for White-faced Heron	yes
	Black Swan	-	Birds swam away slowly, rather than taking flight. Some kept swimming away from disturbance site even after drone had landed.	some
	Chestnut Teal	-	As for Grey Teal	some
	Little Pied Cormorant	-	Took flight when drone close and stayed in sky longer than teal did. Eventually (not too long after) re-settled on water or on wooden structures/boat/jetty.	no
	Pied Cormorant	-	As for Little Pied Cormorant	no
	Silver Gull	-	Took flight when drone close - some birds flew to settle on nearby structures, others to water nearby then returned slowly by swimming back	no
	Crested Tern	Migratory	As for Silver Gull	no
	Royal Spoonbill	-	As for White-faced Heron	yes
	Yellow-billed Spoonbill	-	As for White-faced Heron	yes
	Australian Pelican	-	As for Black Swan	no
	Pacific Gull	-	As for Silver Gull	no
Lake Victoria	Red-necked Stint	Shorebird/Migratory	Easily disturbed by drone – took flight. Some circled around and re-settled rapidly nearby, but generally they flew off in small groups to other less-disturbed locations nearby. Small groups observed to fly in 13 mins later – not known if they are new or returning individuals.	some
	Red-capped Plover	Shorebird	Most birds disturbed by drone when drone reasonably close – took flight. Most birds re-settled rapidly nearby, but some flew off to other less-disturbed locations nearby. One bird not disturbed by drone at all, even when drone apparently overhead.	some
	Chestnut Teal	-	Disturbed by drone (took flight) when drone very close (within 25 m). Some birds circled around and re-settled on water nearby immediately. Others flew off to Lake Victoria and re-settled on water there. Some remained in the sky for longer, and then re-settled at or near original location.	some
	Grey Teal	-	As for Chestnut Teal	some
	Common Greenshank	Shorebird/Migratory	Disturbed by drone when drone close – took flight. Flew off to Lake Victoria shoreline	yes

Site	Species	Shorebird/Migratory	Observations after disturbance	Displaced from local area?
	Black Swan	-	Not disturbed by drone – most birds too far away to be disturbed.	no
	Eurasian Coot	-	As for Black Swan	no
	Little Pied Cormorant	-	Disturbed by drone when drone close and when other birds took flight, but not sure where they went. Possibly re-settled on water nearby.	Unsure, but unlikely based on other observations of this species
	Little Black Cormorant	-	As for Little Pied Cormorant	Unsure, but unlikely based on other observations of this species
	Pacific Black Duck	-	As for Chestnut Teal	some
	Dusky Moorhen	-	Not seen to be disturbed by drone at all	no
	Great-crested Grebe	-	Not disturbed by drone – too distant from flight path	no
	Silver Gull	-	As for Little Pied Cormorant	Unsure, but unlikely based on other observations of this species
Hospitals Swamp	Australasian Grebe	-	Not disturbed by drone – too distant from flight path	no
	Australian Pelican	-	Not disturbed by drone – too distant from flight path	no
	Australian Shelduck	-	Not disturbed by drone – too distant from flight path	no
	Australian White Ibis	-	Disturbed by drone – took flight. Flew off to another suitable perching location on land - far side of wetland.	yes
	Black-fronted Dotterel	Shorebird	Disturbed (took flight) when drone close. Mostly re-settled nearby behind drone. Otherwise, flew to nearest undisturbed part of same area.	no
	Black-winged Stilt	Shorebird	Easily disturbed when drone close – took flight, then flew around for a while, re-settling in same location when disturbance gone. Some re-settled at suitable location nearby. More distant birds not disturbed.	no
	Caspian Tern	Migratory	Not disturbed by drone - too distant from flight path	no
	Dusky Moorhen	-	Not disturbed by drone	no
	Eastern Great Egret	-	As for Australian White Ibis	yes
	Eurasian Coot	-	Not disturbed by drone	no
	Grey Teal	-	Not disturbed by drone	no
	Little Egret	-	As for Australian White Ibis	yes

Site	Species	Shorebird/Migratory	Observations after disturbance	Displaced from local area?
	Masked Lapwing	Shorebird	Not easily disturbed by drone at all. Occasionally took flight for short distant and re-settled almost immediately.	no
	Purple Swamphen	-	Barely disturbed by drone at all. Only observed to take flight if drone right overhead.	no
	Red-kneed Dotterel	Shorebird	Not obviously disturbed by drone. Some birds run quickly when drone approaches, but this species does that anyway in the absence of disturbance.	no
	Red-necked Avocet	Shorebird	As for Black-winged Stilt	no
	Royal Spoonbill	-	As for Australian White Ibis	yes
	Sharp-tailed Sandpiper	Shorebird/Migratory	As for Black-fronted Dotterel	no
	Swamp Harrier	-	Not disturbed by drone – not close to drone flight path at the time of drone flyover.	no
	Whistling Kite	-	Not disturbed by drone – not close to drone flight path at the time of drone flyover.	no
	White-faced Heron	-	As for Australian White Ibis	yes

4. Discussion and conclusion

The drone was observed to disturb birds. However, the drone's radius of disturbance was far smaller than that observed for a helicopter in previous years (GHD 2020), such that birds generally were disturbed only when the drone was relatively close, and most birds re-settled in the immediate area very quickly. Some birds appeared to be relatively unconcerned at all by the presence of the drone. There was no consistent evidence that species counts or abundances reduced on or after day 2 as a result of the drone flyover. Disturbance caused by the drone generally appeared to be less intense, less extensive and less prolonged than disturbance caused by the helicopter.

Aside from the differences in scale (i.e., the drone creates a smaller disturbance area than the helicopter does), the observations presented in this report bear strong resemblance to those reported in earlier years of monitoring during helicopter trials (GHD 2018, GHD 2019, GHD 2020). Generally, wetland birds at these sites (including migratory shorebirds) are easily disturbed, taking to the skies or walking and swimming away, then re-settling at or near the original location soon after the disturbance source had gone. Disturbed birds tended to group up in flight, then land as a tight group, then commence spreading out again, once re-settled. Birds at these sites are also routinely disturbed by a range of sources other than the drone, including people (including birdwatchers), loud noises, dogs, foxes, birds of prey. Movements by of birds into, around and out of these sites appears to be normal and typical of these species and these sites.

The numbers of waterbirds at sites were variable, but the number of migratory shorebirds was generally low, which is likely to be due to prevailing conditions at the sites and elsewhere, but for shorebirds, may also reflect the survey timing with respect to the shorebird season. April is very much the tail end of the shorebird summer season in Victoria, and many migratory shorebirds are likely to have commenced their return migration to the northern hemisphere before the surveys began.

Aerial larvicide application is likely to meet with variable conditions with respect to birds. Particularly windy, wet or dry conditions are likely to influence waterbird, shorebird and wetland bird distributions and abundances, such that birds are not consistently found in the same locations all the time. Therefore, the effect of treatments/applications are expected to vary in terms of bird disturbance.

From this assessment and similar assessments in 2018, 2019 and 2020, it appears likely that larvicide application by helicopter or drone would result in localised and short-lived disturbance of wetland birds (including migratory shorebirds) at sites where they are present. The disturbance observed did not appear to be major or extraordinary for the birds; on-ground observations found that most if not all birds returned to the site of disturbance, and resumed pre-disturbance behaviour, relatively quickly. Whether there is a cumulative or long-lasting effect of disturbance, particularly for migratory shorebirds, remains unknown. Migratory shorebirds in Victoria tend to be preparing for their return migration to the northern hemisphere, and where the threshold of tolerable versus excessive disturbance lies, is also unknown.

Because the drone is smaller than the helicopter and carries a smaller larvicide load, it would require more refills (i.e., return to base) than a helicopter does to treat the same area. Therefore, treatment of an entire site may take longer overall using a drone than using a helicopter, and birds at a wetland site may experience disturbance over a more prolonged period (hours rather than minutes). Also, because the drone is smaller and flies lower, the area it treats with each flyover is narrower, which means it requires more repeated sweeps over a site than a helicopter would to treat the same area. However, because the drone is smaller, lower, slower and more manoeuvrable than a helicopter, it has the potential to treat a site with more precision, resulting in less product redundancy or wastage; it may require less larvicide than the helicopter does to effectively treat the same area.

If use of the drone results in a longer duration of stress and/or more repeated flying over a site, then it may result in higher and more significant disturbance for birds than the occasional once-only flyover. Birds may re-settle nearby after one disturbance or even two, but there will come a time when the disturbance is too great and the birds decide not to remain at that location. This needs to be investigated.

5. Recommendations

Further mock drone trials are recommended with the following changes:

– Undertake trials during the peak migratory shorebird season in Victoria (ideally November-January) to get disturbance observations for larger numbers and potentially more species of shorebirds.
– Undertake trials using the actual drone model proposed to be used for larvicide treatment, to observe noise and disturbance caused by that drone.
– Undertake trials with the drone pre-programmed to treat different sites, to get information on disturbance caused by repeated flyovers and actual flight paths, rather than a pilot-controlled flight path. This may also allow trials to be done in additional sites that were not considered accessible or safe by the drone pilot in this assessment.

6. References

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