ECOLOGY AUSTRALIA

Anglesea Borefield Ecological Monitoring and Assessment Program 2022

Prepared for: Barwon Water

Document information

This is a controlled document. Details of the document ownership, distribution, status and revision history are listed below.

All comments or requests for changes to content should be addressed to the document owner.

Owner	Ecology Australia Pty Ltd	
Project	19-038	
Author	Halliday B.T, Kerr N, Goodman B, and Bloink C.	
File	REPORT Anglesea MAP 2022_Ecology Australia 19-038_FNL01 13Jun23	
Bioregion	Otway Plain	
Distribution	Tom Scarborough	Barwon Water

Document History

Status	Changes	Author	Reviewer	Date
Draft 1	First Draft	Halliday B.T, Kerr N, Goodman B, and Bloink C.	Bloink C., Palmer G. and Preston T.	23/3/2023
Final	Nil	Halliday B.T, Kerr N, Goodman B, and Bloink C.	Bloink C., Palmer G and Preston T.	13/06/2023

Citation: Halliday B.T, Kerr N, Goodman B, and Bloink C. (2023). Anglesea Borefield Ecological Monitoring and Assessment Program 2022. Report to Barwon Water, Ecology Australia Pty. Ltd., Fairfield, Victoria.

Cover photo: Male southern pygmy perch showing breeding colours, captured from Salt Creek during the 2022 fish surveys – Bryce Halliday

ECOLOGY AUSTRALIA
88B Station Street, Fairfield VIC 3078
T: (03) 9489 4191
E: admin@ecologyaustralia.com.au
W: ecologyaustralia.com.au

Contents

Tables

Figures

Appendices

Acknowledgments

We gratefully acknowledge the assistance of:

- Tom Scarborough	Barwon Water
- Jared Scott	Barwon Water
- Gary Palmer	Ecology Australia
- Matthew Linn	Ecology Australia

All works were completed under the following permits:

- Animal ethics: WSIAEC #09.22
- Fisheries general research permit 1142
- DELWP research permit 10010421–2
- Scientific Procedures Fieldwork License 20097

Summary

Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE) to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). The BE requires data to be collected to monitor the impacts of water drawdown under a Monitoring and Assessment Program (MAP) established in 2009.

Per the updated MAP (revised in 2014) (Victorian Government 2014), Ecology Australia was commissioned to undertake both the aquatic and terrestrial ecological monitoring in 2022. The 2022 aquatic ecological monitoring included the annual macroinvertebrate survey of three sites and fish survey at two sites. The terrestrial monitoring, which is typically biennial and last conducted in 2021, was required again in 2022, as the borefield was operated in 2022, triggering the requirement for the terrestrial monitoring. Ecology Australia has undertaken terrestrial monitoring (vegetation and frogs) since 2009 and aquatic monitoring since 2017.

Methods

Vegetation monitoring was undertaken along 6 permanent transects in the Anglesea Swamp and 4 permanent transects in the Anglesea Estuary. The data collected included:

- Plant species lists
- Ecological Vegetation Class (EVC)
- Plant Functional Group
- Bare ground cover
- Water depth (in the swamp only).

Frog survey data was collected at 8 sites in the Anglesea Swamp and 4 sites in the Anglesea Estuary and included:

- Species richness
- Abundance
- Water quality
- Habitat attributes.

Aquatic monitoring consisted of the one-in-three-year spring macroinvertebrate surveys undertaken at 11 sites as well as targeted surveys for southern pygmy perch and Otway bush yabby at 2 sites. Fish and macroinvertebrate monitoring included:

- Taxonomic diversity (macroinvertebrates)
- Abundance
- Biometrics (fish and crayfish)
- Water quality
- Habitat attributes.

Findings

Vegetation

The number of plant species present in the wetland communities remain largely unchanged within the Anglesea Swamp and Estuary. Overall, frequency of the aquatic plant functional group has decreased across both the Anglesea Swamp and Anglesea Estuary since monitoring commenced, however has remained stable at this lower frequency since 2019. The average frequency of the amphibious functional groups has remained relatively consistent across the Anglesea Swamp and Anglesea Estuary. In the Anglesea Swamp, the dry functional group has remained the least frequent functional group in the swamp and continues to display a slightly decreasing trend across all monitoring years. In the Anglesea Estuary, the dry functional group makes up a higher proportion of all functional groups and has remained relatively consistent across all monitoring years.

Standing water was recorded at all sites in the Swamp. The number of sites containing algal mats has increased to 5 sites compared to 3 sites in 2021. No algae was detected across the Estuary sites in 2022.

Frogs

One or more frog species were recorded within 100 m from 7 of 8 sites within the Anglesea Swamp, with frogs heard calling from more than 100 m away at all 8 sites in 2022. Southern brown tree frog, common froglet and southern bullfrog were all recorded within the Anglesea Swamp. Frogs were only recorded at one of the Anglesea Estuary sites in 2022. Only southern brown tree frogs were recorded within 100 m of LAR1 at the Anglesea Estuary. All records in 2021 were from calling frogs with none visually sighted. Results of the 2022 frog surveys show that the number of frogs heard calling at the estuarine sites are as low as that recorded in 2016 and 2019. Conversely, the Anglesea Swamp sites show an increase in frog numbers compared to 2020 and 2021. As such, both sites showed different responses by different species each year. The high rainfall recorded in 2022 resulted in different responses by frogs within both the Anglesea Swamp and the Anglesea Estuary environment, with the Anglesea Swamp having an increase in frog species while the Angelsea Estuary having a reduction in frog species.

Southern pygmy perch & Otway bush yabby

Southern pygmy perch were again only detected from one of the 2 monitoring sites, the Salt Creek site, which has been a consistent result for the past 5 years. Recruitment was again not detected at the Salt Creek site, however fish appeared in breeding condition (breeding colours displayed and ripe fish present). This year’s sampling (2022) was the fifth consecutive year that southern pygmy perch were not recorded in the Breakfast Creek tributary. Based on this result, we suggest that this population may now be locally extirpated. It would be advisable to determine if there is a source population elsewhere in the Breakfast Creek catchment as a possible source of recolonisation into the Breakfast Creek tributary.

Otway bush yabby was detected at 2 sites in 2022 at the Breakfast Creek tributary and Salt Creek site. All Otway bush yabby collected in 2022 from both methods were recorded (measured, weighed, counted as appropriate), adding further knowledge and data for this threatened species. Otway bush yabby have been continually detected at the Breakfast Creek tributary and Salt Creek sites since 2017 (Ecology Australia 2018–2022). Otway bush yabby abundances were higher in 2022 compared with the previous year, however inconsistent methodology for this species since detection have made it difficult to accurately plot the trajectory of this species through time. A significant number of small, young-of-year/juvenile, individuals were detected in 2022, indicating this species is continuing to recruit successfully at the sites where it is present.

Macroinvertebrates

The macroinvertebrate monitoring results from 2022 were relatively consistent with the previous three years (Ecology Australia 2020–22). A slight improvement was evident in the present year. The overall trend for the macroinvertebrate assemblage for the study area has been decline since at least 2014. New environmental objectives, Environment Reference Standard (ERS) (Victorian Government Gazette, 2021), were used for comparison with the macroinvertebrate assemblage. Attainment of ERS objectives was low with SIGNAL2 (creek sites) and VLAKES (wetland site) being the only categories meeting relevant objectives. Low pH conditions within the more depauperate sites were the likely driver of the poor macroinvertebrate results.

1 Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). Groundwater pumping under the BE is permitted as long as it does not adversely affect environmental values and groundwater-dependent ecosystems in the Jan Juc Groundwater Management Area.

The BE requires data to be collected to monitor the impacts of water drawdown. At the commencement of the BE, a Monitoring and Assessment Program (MAP) was developed. The MAP has been revised and updated once, in September 2014 under the Bulk Entitlement (Anglesea Groundwater) 2014 (henceforth to be referred to as the 'BE' succeeding the previous version; Victorian Government 2014). The MAP includes groundwater and surface water monitoring, acid sulphate investigations, land-level surveying and aquatic and terrestrial ecological monitoring (Victorian Government 2014).

Ecology Australia has undertaken the terrestrial (vegetation and frogs) monitoring component of the MAP since 2009 and the aquatic component (fish and macroinvertebrates) since 2017 (Ecology Australia 2009–2022).

The current MAP requires aquatic ecological monitoring to be undertaken annually (with an increased number of sites every 3 years), and terrestrial ecological monitoring to be undertaken biennially in the absence of groundwater pumping, and annually during periods of groundwater extraction (Victorian Government 2014). Barwon Water operated the borefield in 2022 between January and October extracting a total volume of 1787.96 ML (Barwon Water 2023). As borefield extraction occurred during 2022 (i.e. during this present reporting period) the MAP requirement for terrestrial ecological monitoring was triggered.

The 2022 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic ecology

The Aquatic Ecological monitoring component included the annual spring monitoring of macroinvertebrates at 3 sites:

- Breakfast Creek tributary 1 (BCT1)
- Salt Creek (SC1)
- Lower Anglesea River wetland 2/3 (W2/3).

Additionally, this component included spring sampling of southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocherax tasmanicus* at 2 sites:

- Breakfast Creek tributary (BCT1)
- Salt Creek (SC1).

1.2 Terrestrial ecology

The Terrestrial Ecological monitoring component included spring monitoring of vegetation along established transects at 6 sites and frog monitoring at 8 sites in the Anglesea Swamp (Figure 1):

- AS1_2014 (vegetation and frog monitoring)
- AS2 (vegetation and frog monitoring)
- AS3 (vegetation and frog monitoring)
- AS4 (vegetation and frog monitoring)
- AS5 (frog monitoring only)
- AS6 (frog monitoring only)
- ASP7_2014 (vegetation and frog monitoring)
- AGP2_2014 (vegetation and frog monitoring).

Additionally, spring monitoring of vegetation was undertaken at established transects at 4 sites and frog monitoring was undertaken at the same sites in the Anglesea Estuary:

- LAR1
- LAR2
- LAR3
- LAR4.

Vegetation data collection included floristic species lists, Ecological Vegetation Classes (EVCs), plant Functional Groups, and other structural and physical attributes (water depth, bare ground and algal mats).

The frog monitoring data collection included species richness, abundance, water quality, and habitat attributes.

This report presents the monitoring methods and results, along with a discussion including a comparison of the 2022 data with annual data collected since the MAP review and update in 2014.

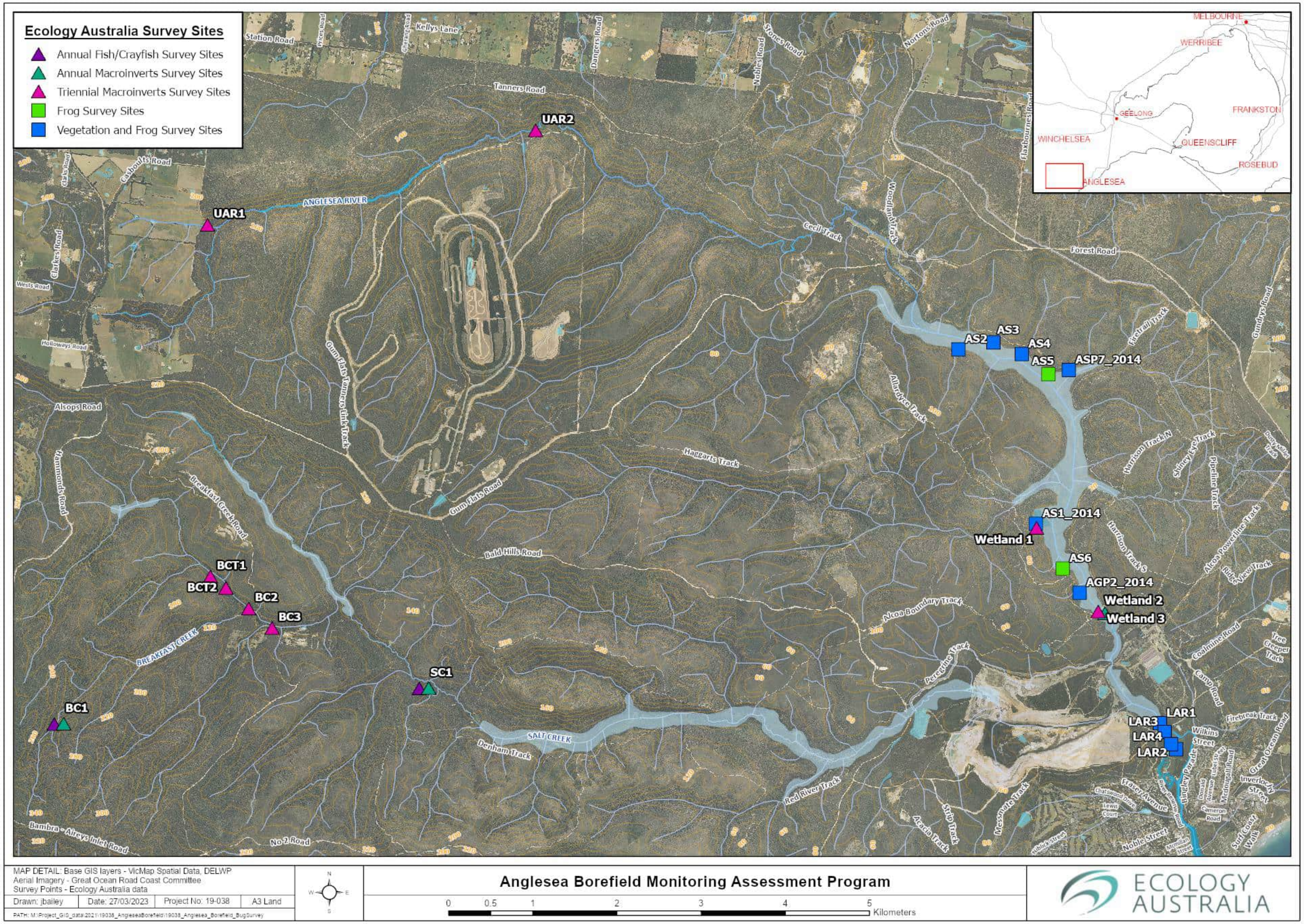


Figure 1 Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2022.

2 Methods

2.1 Vegetation

Vegetation monitoring was undertaken during the first and last week of November 2022 at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014; and at the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Data collection

One established 100 m transect was surveyed at each site. Along each transect, 1 m^2 quadrats were located every second metre along the left-hand side of the transect looking start to end, with the first quadrat placed at 1–2 m, the second placed at 3–4 m and so on. Therefore, 50 quadrats were established along each transect in the Anglesea swamp, 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along LAR1 in the estuary sites. Field staff walked on the right-hand side of the transect to avoid trampling vegetation within quadrats.

Survey methods collect the presence/absence of flora species within quadrats located along transects to produce a frequency score for each species. Each species that was alive and rooted in or overhanging each quadrat was recorded.

Additionally at each quadrat, EVCs following the Department of Environment, Land, Water and Planning (DELWP) benchmarks (DELWP 2022a) were recorded, as well as other attributes including water depth (in the swamp only) and percentage cover of bare ground (representing potential change at a site due to potential recruitment) rounded to the nearest 5% and presence of algal mats. Photo points were taken at each site and located at 0 m, 25 m, 50 m, and 75 m along each transect in the swamp and the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

Plant functional groups

Plant species recorded in surveys across the Anglesea Swamp and Anglesea Estuary were classified into functional groups (FGs) (Table 1). Functional groups were based on the ecology (known or likely water requirements) of plant species, modified from Cassanova (2011) and Doeg *et.al*. (2012), as detailed in Ecology Australia (2013b). Functional group T (instead of Tdr or Tda) and A (instead of Ate, Atl, Atw or Arp) were assigned where species were identified to genus or family level only.

2.1.2 Data analysis

Species composition

Species richness was presented in a table form displaying total number of native species and number of plants per broad functional group. Additionally, species richness was presented in a bar chart form for each site across each monitoring period.

Plant functional groups

Plant functional groups were used to assess the changes in ground water dependant vegetation across the swamp and estuary.

For both the Anglesea Swamp and Anglesea Estuary, charts were produced to display the proportion of functional group (Atw, Ate, Atl, Arp, Se, T, Tdr and Tda) abundance data across all sites for each monitoring period along with average rainfall.

At an individual site level, the average percentage frequency of broad functional groups was presented in a bar chart form for all monitoring years. The top 3 dominant species for each site were presented as a line chart as the percentage frequency across all monitoring years. For any given year, the dominant 3 species were displayed, therefore sites with fluctuating dominant species across the years may display more than 3 species.

Considerable ambiguity in the taxonomy exists when distinguishing between manuka *Leptospermum scorparium* and the prickly tea-tree *Leptospermum continentale* (Tdr). Therefore, records of prickly tea-tree and manuka were grouped together in this years' analysis as tea-tree *Leptospermum spp.* and assigned the summary functional group of T (Terrestrial). Similarly, within the water-ribbons *Cycnogeton* species, this group is taxonomically unresolved which has led to variation in the number of species recorded over the years (either *Cycnogeton procerum* or *Cycnogeton alcockiae* or both). Until the taxonomy of this species is finalised, all *Cycnogeton* records will be lumped under *Cycnogeton procerum* spp. aff for data analysis.

Algal mats

The presence of algal mats was presented in a bar chart form as the percentage frequency of algal mat at each site across all monitoring years.

Table 1 Anglesea Borefield, ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova 2011 and Doeg *et.al*. 2012).

FG	Definition	Example species
Dry		
Tdr	*Terrestrial dry.* This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia
Tda	*Terrestrial damp*. These species germinate and establish on saturated or damp ground but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka, Slender Bog-sedge
Amphibious		
Ati	*Amphibious fluctuation tolerator - low-growing.* This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for approximately 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed
Ate	*Amphibious fluctuation tolerator - emergent*. This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for 8–12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern
Atw	*Amphibious fluctuation tolerator- woody*. This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark
Arp	*Amphibious fluctuation responder - plastic.* This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup
Aquatic		
Se	*Perennial-emergent.* This category refers to monocotyledonous species that require permanent water in the root zone but remain emergent. They occur where water levels do not fluctuate or fluctuate with a relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons

2.2 Frogs

A survey team of 2 zoologists undertook 2 repeat surveys for frogs at 12 sites on 2–3/11/2022 and 28–29/11/2022 (Figure 1):

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary.

The survey sites comprise the 10 sites required by the MAP, as well as 2 additional sites (AS5 and AS6), which are surveyed if very low frog activity is observed at the Anglesea Swamp. Unlike the approach used for surveys conducted in 2021, where a local community group provided information on frog diversity from the greater Anglesea area, the surveys undertaken by Ecology Australia in the 2022 season were the only data on frog diversity included in the current study.

2.2.1 Habitat assessment and water quality

To supplement the habitat data collected as part of vegetation monitoring, the following frog habitat variables were recorded:

- Wetland permanence (i.e. ephemeral, semi-permanent or permanent)
- Water quality parameters:
  - Temperature (° C)
  - pH
  - Electrical Conductivity (EC) (mS/cm)
  - Dissolved Oxygen (DO) (mg/L)
  - Turbidity (NTU)
- A general habitat description, including cover of fringing, emergent, submergent and floating vegetation.

Photos were also taken showing representative frog habitats at each survey site.

2.2.2 Frog surveys

A pair of zoologists used both diurnal and nocturnal visual and auditory surveys to detect frogs at the survey sites. Nocturnal surveys also included call playback and spotlighting. Weather conditions at the time of the survey were recorded using a Kestrel weather meter. In 2022, all frog survey events were completed during suitable weather in spring.

Visual surveys

Visual and aural surveys were undertaken at each site during the diurnal habitat assessment and at the beginning of each nocturnal survey. Surveys comprised 2 zoologists listening for approximately 5 minutes for the distinctive calls of male frogs. The species heard, and an estimation of the number of frogs calling for each species was recorded. In addition, zoologists looked for frogs at each site, by traversing the sites and scanning vegetation and the water surface for the presence of frogs. Visual nocturnal surveys were aided by the use of head-torches and/or hand-held spotlights, to look for the distinctive eye-shine of frogs.

Nocturnal call playback

Call playback was used following the nocturnal aural survey to elicit calling behaviour by male frogs that were not calling independently onsite. This approach uses the broadcast of pre-recorded calls of each species through a speaker, followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- southern brown tree frog *Litoria ewingii*
- southern bullfrog *Limnodynastes dumerilii*
- spotted marsh frog *Limnodynastes tasmaniensis*
- striped marsh frog *Limnodynastes peronii*
- common spadefoot toad *Neobatrachus sudellae*
- Victorian smooth froglet *Geocrinia Victoriana*
- common froglet *Crinia signifera.*

Call response data were used to estimate frog species richness and abundance within each site across the Anglesea catchment and estuary.

2.3 Aquatic ecology

2.3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at 3 sites between 22–23 November 2022. As per the established methods for this program (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present, following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2021). A 250 µm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from sites with little to no flow. The sampling objective of the RBA method is to subsample all types of microhabitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample was collected from 10 m of habitat, which was not necessarily contiguous. The water column and microhabitats present were agitated to dislodge macroinvertebrates, suspend them within the water column and collect them within the net.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible
- If less than 200 animals are collected within 30 minutes, then picking continues for an additional 10 minutes
- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed
- Picking a maximum of approximately 30 of each taxa, except for groups that typically require microscopic examination to identify to the taxonomic resolution of family (e.g. Amphipoda) or taxa which are to be identified to a lower taxonomic resolution than family (e.g.

Chironomidae to sub-family, and Odonata, Ephemeroptera, Plectoptera and Trichoptera to genus).

At each site, RBA field sampling and habitat assessment sheets were completed, including *in situ* water quality measurements using a calibrated Horiba U-52 water quality meter.

Since the detection of Otway bush yabby *Geocherax tasmanicus* in 2017, this species has been monitored concurrently with fish and macroinvertebrates (Ecology Australia 2018–2022). During the 2022 macroinvertebrate surveys all Otway bush yabby (and southern pygmy perch) captured in the sweep nets were biometrically recorded per sweep sample as per section: 2.3.4 increasing the available data for these species.

2.3.2 Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level, with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family
- Oligochaeta and acarina are not identified below these taxonomic levels
- Adult and larval beetles are differentiated
- Terrestrial, semi-terrestrial and microcrustacean taxa were excluded
- Specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2016).

2.3.3 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both at individual sample and site scale (using the combined data from 3 samples). Where available, the results were compared against indices objectives outlined in the Environment Reference Standard (ERS) (Victorian Government Gazette, 2021) for rivers and streams in the 'Central Foothills and Coastal Plains' geographic region and for 'shallow inland with outflow' wetlands. Combined data is used for comparisons with previous years to indicate the overall trend of a site and when compared with ERS objectives is indicative only and the results at a sample level should be used when assessing an individual site.

The following indices were used to analyse macroinvertebrate data:

- Number of macroinvertebrate families — total number of taxa based on taxonomic resolution levels described above.
- SIGNAL2— average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003).
- VLAKES (new index used for ERS objectives for macroinvertebrates samples taken from wetlands) – average VLAKES score for taxa collected in each sample, based on methods of EPA (2010).

The following indices have been included in the analysis to show the number of more sensitive taxa and for ease of comparison with past reports, but were not compared to an objective as they are not included as objectives for edge samples within the ERS:

- EPT — number of genera from the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT). These taxa are typically considered more sensitive to pollution and disturbance and hence the index is an indicator of ecosystem health and
- EPTO — number of genera from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO). This modified version of the EPT index is used for waterways in 'Mediterranean climate' regions, and aid in interpreting the health of lentic (still water) systems, where the numbers of Plecoptera are diminished, while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004).

2.3.4 Fish surveys

Surveys targeting southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocharax tasmanicus* were undertaken at 2 sites: BCT1 and SC1 on 17 and 18 November 2021, respectively. For consistency with previous surveys, the BCT1 fish site was again relocated downstream at the V-notch gauging station.

Ten bait traps (stretched mesh size of 2 mm and funnel entrances of 40 mm diameter) with 100 mm long yellow glow sticks placed inside to serve as an attractant, were set in the afternoon and retrieved the following morning at both sites. This is consistent with the monitoring approach used in recent years (Ecology Australia 2018–2022).

All captures of southern pygmy perch and Otway bush yabby were recorded separately per gear type and replicate. The first 50 southern pygmy perch and Otway bush yabby captured at each site were measured (total length) to the nearest mm and weighed to the nearest 0.1 g (where their weight exceeded 1.0 g). All remaining southern pygmy perch and Otway bush yabby were counted. All southern pygmy perch and Otway bush yabby were returned to the point of capture.

2.4 Conservation status

Threatened species of state and/or national conservation significance were determined by reference to listings under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.5 Nomenclature and taxonomy

All scientific names, common names and systematic orders of flora and fauna species follow the Victorian Biodiversity Atlas (DELWP 2022b), with common names referring to fauna within the text of the report.

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plant species that are not indigenous to the region or local area.

3 Results

Vegetation and frog monitoring were undertaken at the same sites (with two additional sites for frogs). The findings for each of the sites is presented below followed by site summaries in Section 3.2.4.

The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Sections 4.3.

3.1 Vegetation

Site summaries displaying the results of vegetation monitoring are provided in Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 16, Figure 17, Figure 18 and Figure 19.

3.1.1 Floristic composition

A total of 30 vascular indigenous plant species were recorded across all sites in the Anglesea Swamp, while no exotic species were recorded (Appendix 1). In the Anglesea Estuary, 17 plant species were indigenous (81%), 2 were exotic (9.5%) and 2 were native Victorian species not indigenous to the study area (9.5%) (Appendix 2). Species richness in the Anglesea Swamp increased from 29 to 30 species between 2021 and 2022, while in the Anglesea Estuary sites, total species richness decreased by 6 species from 27 to 21 and native species remained stable at 17 species between 2021 and 2022.

Changes in species richness were variable across sites. Species richness decreased at 4 of the 6 Anglesea Swamp sites and increased at 2 sites compared to the 2021 monitoring season (Figure 2). Across the Anglesea Estuary, species richness remained stable at one site but decreased at 3 sites compared to 2021 (Figure 3). Furthermore, native species richness varied across sites, ranging from 7 to 15 in the swamp and 4 to 11 in the estuary (Table 2).

Table 2 Number of native plant species and associated functional groups recorded across Anglesea Borefield ecological Monitoring and Assessment Program sites.

Transect/Site	Total number of native plant species	Number of plant species in a dry FG	Number of Amphibious FG plants	Number of plant species in an Aquatic FG
Anglesea Swamp				
AS2	15	10	2	3
AS3	12	3	8	1
AS4	13	2	9	2
ASP7_2014	13	2	9	2
AS1_2014	10	2	6	2
AGP2_2014	7	1	4	2
Anglesea Estuary				
LAR1	9	3	3	3
LAR2	11	6	3	2
LAR3	10	5	3	2
LAR4	4	0	2	2

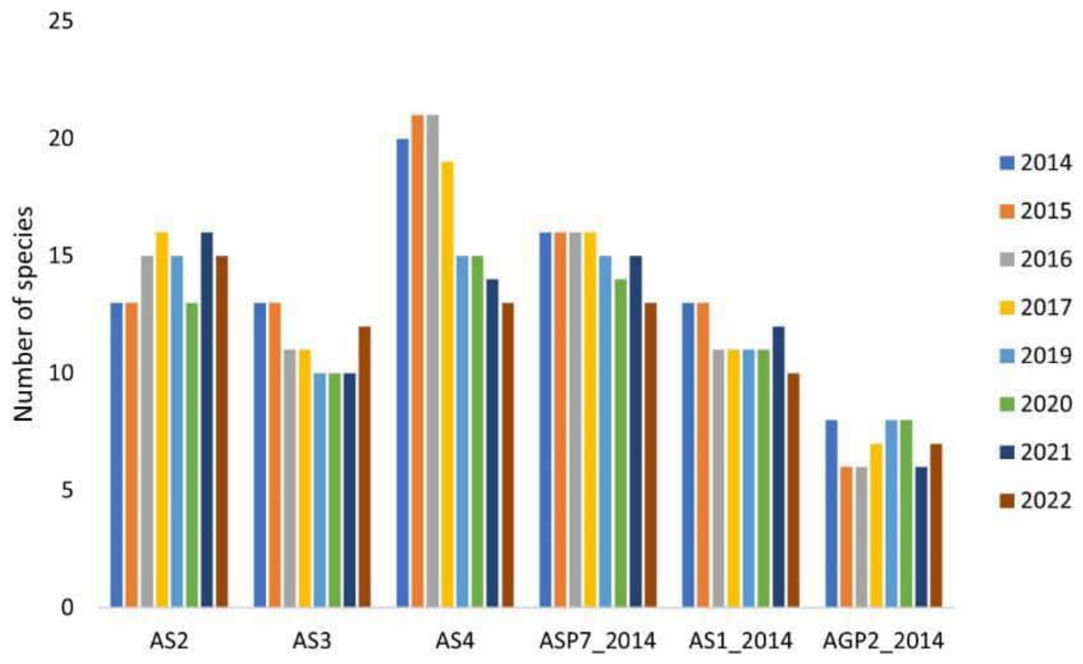


Figure 2 Native species richness at each survey site in the Anglesea Swamp (AS2, AS3, AS4, ASP7_2014, AS1_2014 and AGP2_2014) for each season which required monitoring.

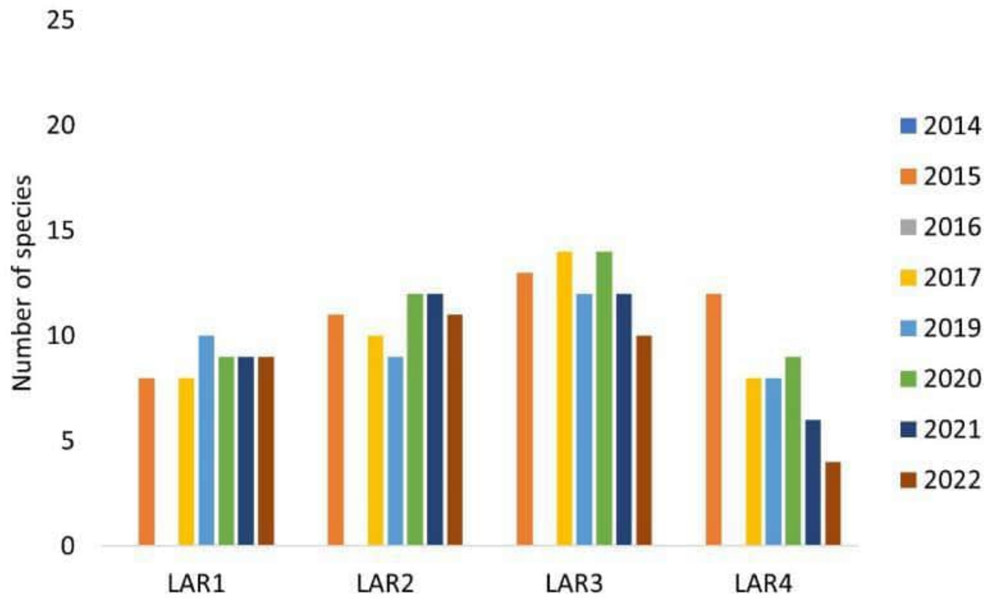


Figure 3 Native species richness at each survey site in the Anglesea Estuary (LAR1, LAR2, LAR3 and LAR4) for each season which required monitoring.

Anglesea Swamp

In the Anglesea Swamp, 7 FGs were represented (T, Tdr, Tda, Se, Atw, Atl and Ate), while no species from Arp functional group were recorded (Figure 4). Average proportions of functional groups remained relatively stable compared to 2021, however Atl species increased from .1% to .78% while Tda increased from .3% to 1.23%. Overall, Ate, Atl and Atw species have exhibited a longer-term trend of declining as a proportion of the plant community since 2019. However, the proportion of aquatic species (Se) has steadily increased over this time period. The 2021 rainfall data from Aireys Inlet shows an average annual rainfall of 631 mm from 1994 to 2021 (BOM 2022) and the 2021 rainfall was above average 726 mm. Aireys Inlet data was incomplete for 2022 and therefore data from the nearest weather station at Wendsleydale was used for those months (June, July and August).

Figure 4 **Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) and yearly and mean annual rainfall (right y-axis) across all sites in the Anglesea Swamp for each monitoring period. Swamp sites were not monitored in 2018 due to no water extraction to triggering monitoring.**

Anglesea Estuary

Plants from 7 FGs were recorded in the Anglesea Estuary (T, Tda, Tdr, Se, Ate, Atl, Arp), while no species from the Atw FGs were recorded (Figure 5). Average proportion of species in the functional group Arp declined slightly in 2022 (24.1%) from 2021 (22.4), continuing a longer-term trend dating back to 2019. Aquatic (Se) species increased slightly from 27.7% in 2021 to 31.3% in 2022, while other functional group proportions remained relatively stable.

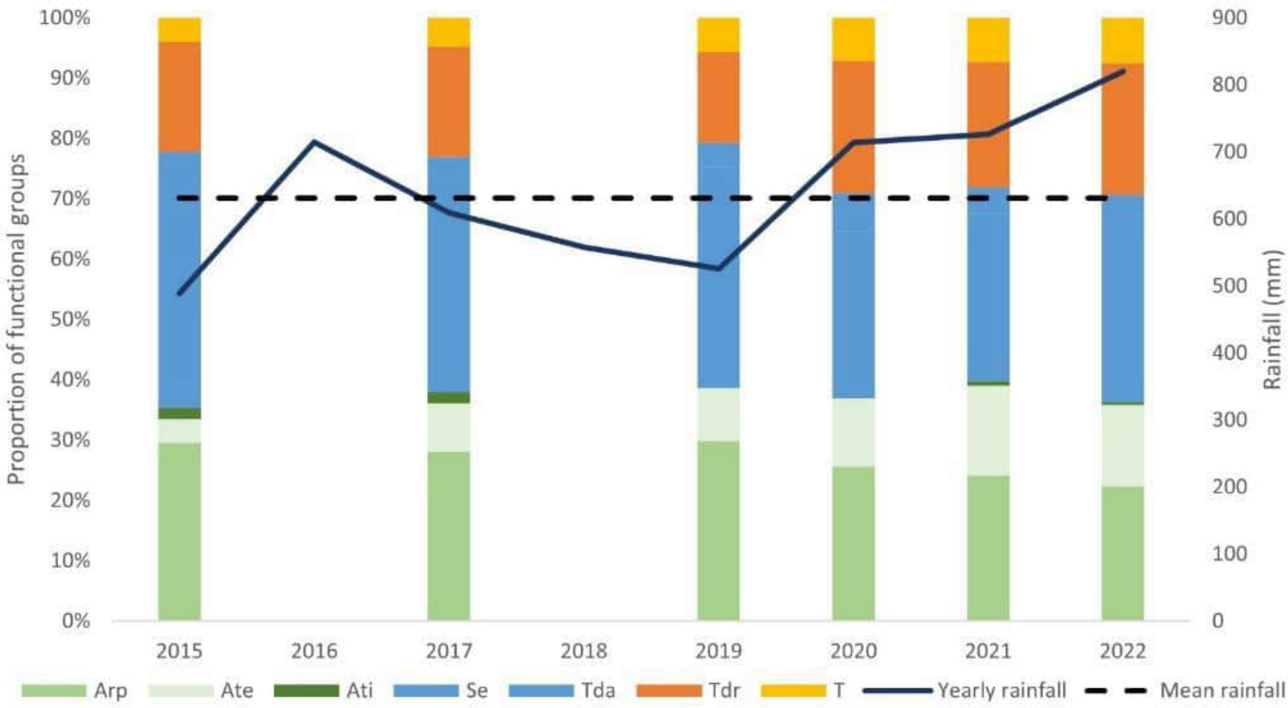


Figure 5 **Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) across all sites in the Anglesea Estuary for each monitoring period and yearly and mean annual rainfall (right y-axis). Estuary sites were not monitored in 2016 and 2018 due to no water extraction to triggering monitoring.**

Algal mats

Algal mats were present at all sites with the exception of AS3. Algal mat frequency increased greatly at ASP7_2014, where they hadn't previously been recorded since 2019 and even then remained at a very low frequency. Algal mat frequency was stable at AS1_2014, AGP2_2014 and AS4 compared with 2021, while algal mat presence was detected at AS2 for the first time in just one quadrat. Algal mats were not recorded in any of the Anglesea Estuary sites in 2022 (Figure 6).

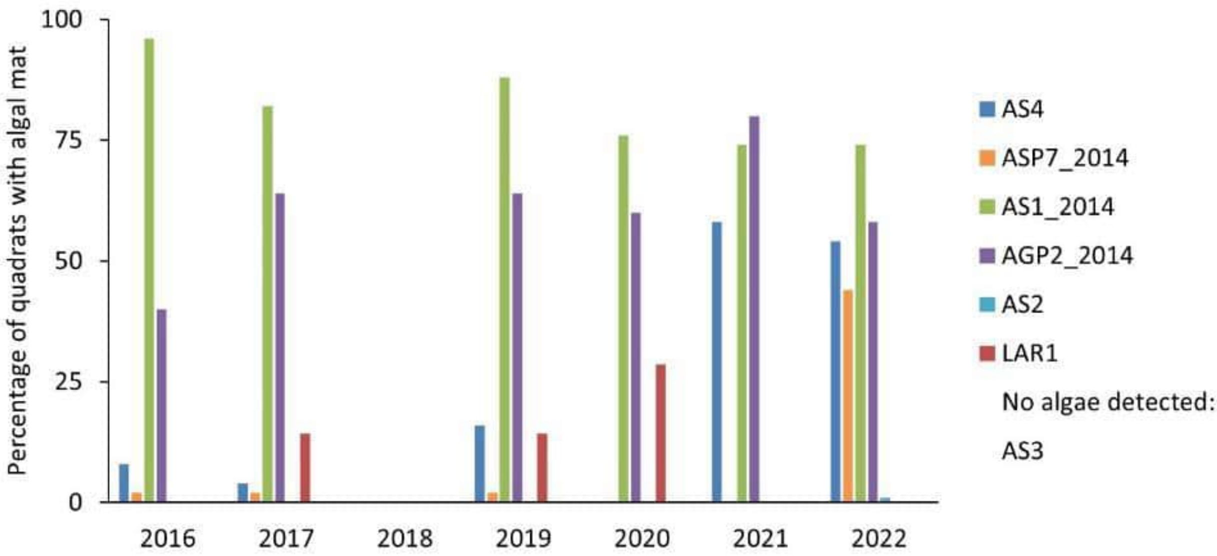


Figure 6 Algae mat records at all sites in the Anglesea Swamp and Anglesea Estuary from first detection in 2016. No monitoring was undertaken in the Anglesea Swamp 2018 or in the Anglesea Estuary in 2016 or 2018 due to no water extraction triggering monitoring.

3.2 Frogs

3.2.1 Survey conditions

The 8 sites at the Anglesea Swamp all contained water over the period that the 2 frog survey events were conducted. The average water depth among all Anglesea Swamp sites at the time of the first survey being approximately 0.35 m, with the average water depth among all study sites having increased to approximately 0.36 m by the time of the second survey. Similarly, the average depth of the estuary sites having increased from 1.63 m to 2.75 m by the time of the second survey event.

The weather conditions recorded during the two nocturnal frog surveys are summarised in Table 3.

Table 3 Weather conditions during nocturnal frog surveys, 2022.

Variable	Survey 1	Survey 2
Temperature (°C)	12.4	14.3
Humidity (%)	88.6	79.4
Cloud cover (0–8)	6.3	2.4
Moon light (0–4)	1.4	1.5
Wind speed (0–3)	0.5	0.5
Rainfall during survey (0–3)	0	0
Rain in past 24 hours (None–heavy)	Low	Low

3.2.2 Frog species richness and abundance

The number of frogs estimated to be calling within 100 m of each of the study sites is provided in Figure 7. Since 2014, the number of frogs detected calling has varied among years, with an obvious peak in frog abundance in 2016 for the swamp sites and in 2020 for the estuary sites. The common froglet was the most abundant frog species at the swamp sites in 2022 and had the highest number of individuals (50) detected since 2014. The number of southern tree frogs detected in 2022 was the highest (13) since the study began in 2014, with the number of southern bullfrogs also increasing to the highest (26) amount since 2016. All other frog species either decreased or did not change in abundance since the 2021 surveys. Total rainfall recorded over the winter and spring period for each year indicates 2 obvious peaks in 2016 and 2022, respectively. These rainfall peaks represent the two La Niña events that have occurred since the commencement of frog monitoring at the Anglesea swamp and estuary in 2014. Finally, the two peaks in frog abundance within the Anglesea swamp appears to be positively related to the two La Niña rainfall (2016, 2022) peaks.

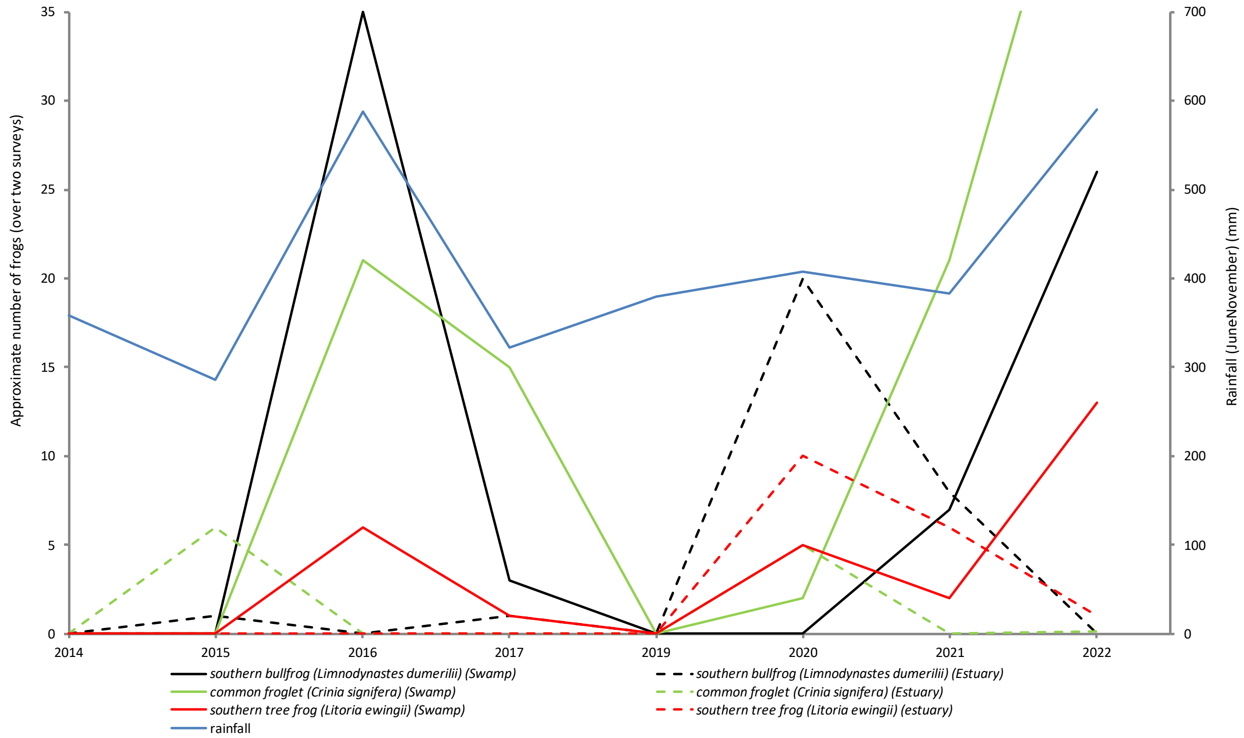


Figure 7 The number of frogs detected calling within 100 m of the survey sites at Anglesea swamp and Anglesea estuary from 2014 to 2022. Included is the total winter and spring rainfall recorded at Aireys Inlet (blue line).

Anglesea Swamp

Frogs were recorded from within 100 m of 7 of the 8 sites within the Anglesea swamp (Table 4), with frogs heard calling from more than 100 m at all Anglesea swamp sites. All the records were from calling individuals as there were no individuals sighted visually. The maximum number of frog species (species diversity) detected at any one site was 3 species: southern brown tree frog *Litoria ewingii*, common froglet *Crinia signifera* and southern bullfrog (pobblebonk) *Limnodynastes dumerilii*.

Sites AS1_2014, AS2, AS3, AS5 and AGP2_2014 all showed equal maximum species richness with all three frog species recorded being recorded across the 2 survey events. However, with the inclusion of frogs calling from greater than 100 m away were taken into account, both AS4 and ASP7_2014 also had all 3 species present.

Table 4 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Swamp sites. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species richness
	1	2	1	2	1	2	
AS1_2014	0 (0)	2 (0)	11-20 (0)	2 (0)	7 (0)	12 (0)	3
AS2	4 (0)	3 (0)	11-20 (0)	11-20 (0)	5 (0)	11-20 (0)	3
AS3	7 (0)	3 (0)	0 (0)	7 (0)	7 (0)	3 (5)	3
AS4	0 (5-10)	0 (2)	0 (5-10)	0 (3)	0 (3)	0 (11-20)	0
AS5	0 (5-10)	2 (0)	2 (0)	3 (0)	3 (0)	0 (3)	3
AS6	0 (0)	0 (0)	11-20 (0)	11-20 (0)	0 (0)	0 (4)	1
ASP7_2014	0 (2)	0 (5-10)	4 (0)	8 (1)	0 (3)	3 (4)	1
AGP2_2014	2 (0)	0 (0)	7 (0)	0 (0)	4 (0)	0 (3)	3

Anglesea Estuary

Frogs were recorded within 100 m at all Anglesea swamp sites with the exception of AS4 (Table 4). In contrast, relatively few frogs were detected at the Anglesea estuary site, with southern brown tree frog being the only species detected at any of the estuary sites (Table 5). However, while southern brown tree frog was detected at estuary site LAR1 during the first survey, it was detected at distances of greater than 100 m for all other Anglesea estuary (LA2, LA3, LA4) sites. Further, common froglet (LAR4) and southern brown tree frog (LA3 and LA4) was detected at a distance greater than 100 m on survey 2, with southern brown tree frog the most frequently detected frog during the second survey.

Table 5 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Estuary sites, 2022. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species Richness
	1	2	1	2	1	2	
LAR1	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
LAR2	0 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
LAR3	0 (3)	0 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0
LAR4	0 (3)	0 (3)	0 (0)	0 (1)	0 (0)	0 (0)	0

3.2.3 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites mostly support dense shrub cover of scented paperbark *Melaleuca squarrosa* and prickly teatree *Leptospermum continentale*, which open up into clearings of emergent aquatic vegetation, largely sedges such as zig-zag bog-sedge *Schoenus brevifolius*, square twig-sedge *Machaerina tetragona* and fine twig-sedge *M. arthrophylla.* Swards of dead and live sedges occasionally form thick mats across the site. Fringing vegetation sometimes includes shorter pink swamp-heath *Sprengelia incarnata* or pouched coral-fern *Gleichenia dicarpa*. Where monitoring sites support standing water, common water-ribbons *Cycnogeton procerum* sp. aff. and filamentous algae may be present as submergent and floating vegetation. Some sites also include small patches of bare ground and low cover of woody debris, especially at the interface between emergent and fringing vegetation.

All monitoring sites are considered intermittent except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). During the 2022 surveys, all sites had sufficient standing water to allow for all water quality parameters to be measured during both the first and second survey. In general, all sites were acidic (pH of 3.18–5.35) and electrical conductivity was low to moderate, ranging from 0.30 to 3.50 ms/cm. Water temperatures were relatively high, with all but 3 measurements above 13 °C (range: 11.13–20.50°C). Turbidity was more variable across sites, being generally low (range: 0–27 NTU) with the majority of values under 10 NTU. Similarly, dissolved oxygen levels were variable (range: 3.8–9.7 mg/L), with the dissolved oxygen levels slightly lower in the second survey.

Anglesea Estuary

The Anglesea Estuary is relatively deep, with slow-moving water. Apart from filamentous algae, the cover of aquatic vegetation was generally low, particularly the cover of floating and submergent vegetation. Common reed *Phragmites australis* is an emergent species that provides sparse emergent vegetation at most sites. Fringing vegetation occurs at higher levels of cover, dominated by grasses, sedges, rushes and herbs including cast tussock-grass, *Poa poiformis* var. *poiformis*, common blown-grass *Lachnagrosits filiformis*, sea rush *Juncus kraussii* ssp. *australiensis* and shiny swamp-mat *Goodenia radicans*. LAR1 also supports narrow-leaf cumbungi *Typha domingensis* and southern water-ribbons.

Scattered shrubs of hop goodenia *Goodenia ovata,* manuka *Leptospermum scoparium* and stands of swamp gum *Eucalyptus ovata* var. *ovata* were recorded near the water's edge.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 12 m wide, and up to 1–2 m deep. As such, water quality could be measured at all sites, and values were generally consistent between sites within surveys, compared to the measurements taken in the Anglesea swamp. All sites had very low pH (2.73–4.12), and water temperature above 13 °C during the first survey and 15–20 °C during the second survey. Electrical conductivity readings were relatively low during the first survey (3.5–4.0 ms/cm), with similar EC (0.5-6.5 ms/cm) among the 2 surveys. Conductivity remained relatively constant with a mean of 3.47 ms/cm in the first survey, to 3.82 ms/cm in the second survey. Turbidity was low (0–2 NTU) and dissolved oxygen concentrations varied from 6.2 to 9.3 mg/L.

3.2.4 Vegetation and frog site summaries

The following site summaries include:

- transect photos at 25 m intervals
- the proportion of each FG recorded at each site
- the top three dominant plant species and their FG
- other attributes including average water depth
- a habitat description
- frog species occurrence and abundance
- water quality data
- relevant comments.

A.

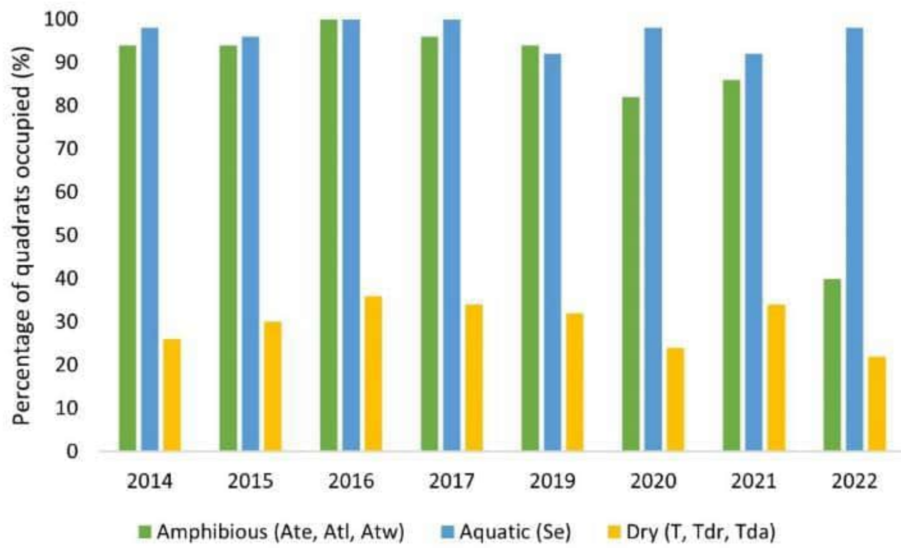
0 – 25 m

25 – 50 m

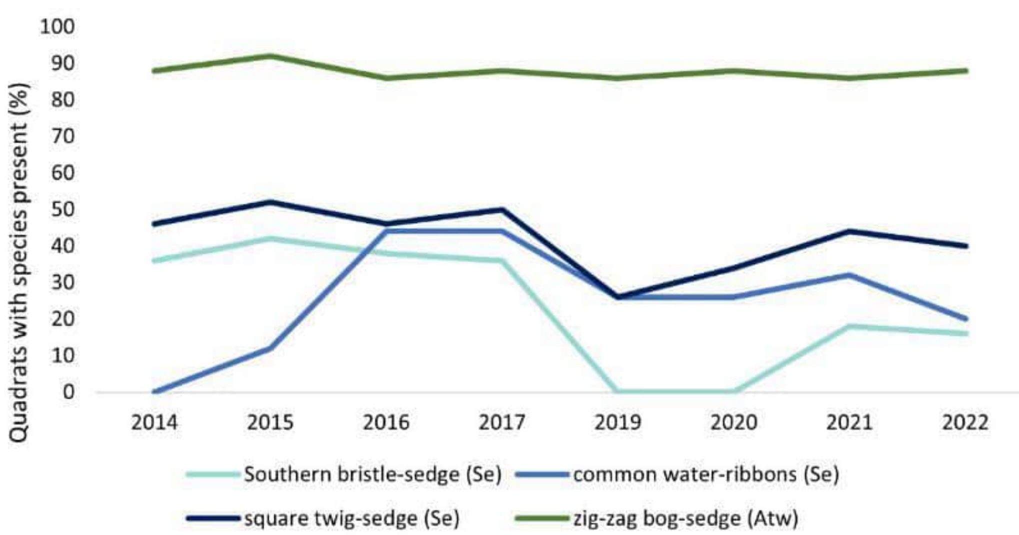
50 – 75 m

75 – 100 m

B.



C.



D.

AS2: General habitat description	
Ecological Vegetation Class (EVC)	Aquatic Sedgeland
Wetland permanence	Ephemeral
Swamp dominated by emergent dead and live sedges, with patches of clear open water at varying depth to c. 20 cm. Open water contains 5% floating, 5% submergent vegetation and 70-100% emergent vegetation. The swamp is fringed with 70–90% shrub and tree cover with 20 – 50% bare soil.	

AS2: Frog abundance and richness			
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**
3	11-20	11-15	3

AS2: Water quality parameters					
Survey 1					
pH	3.18	**Turbidity**	1.4 NTU	**Water temperature**	11 °C
EC	0.642 µs/cm	**Salinity**	0.3 %	**Dissolved Oxygen**	3.82 mg/L
Survey 2					
pH	4.29	**Turbidity**	1.0 NTU	**Water temperature**	13.4°C
EC	0.29 µs/cm	**Salinity**	0.1%	**Dissolved Oxygen**	7.46 mg/L

Comments
Pools of up to 40 cm depth were present during both surveys which provided relatively good conditions for frogs. Common froglet were heard calling prior to playback. Multiple southern bullfrog (>5) and southern brown tree frog (>3) called in response to call playback during both survey events. Water depth remained relatively constant over both survey events, providing and maintaining suitable habitat for frogs.

Figure 8 **Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS2, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.**

A.

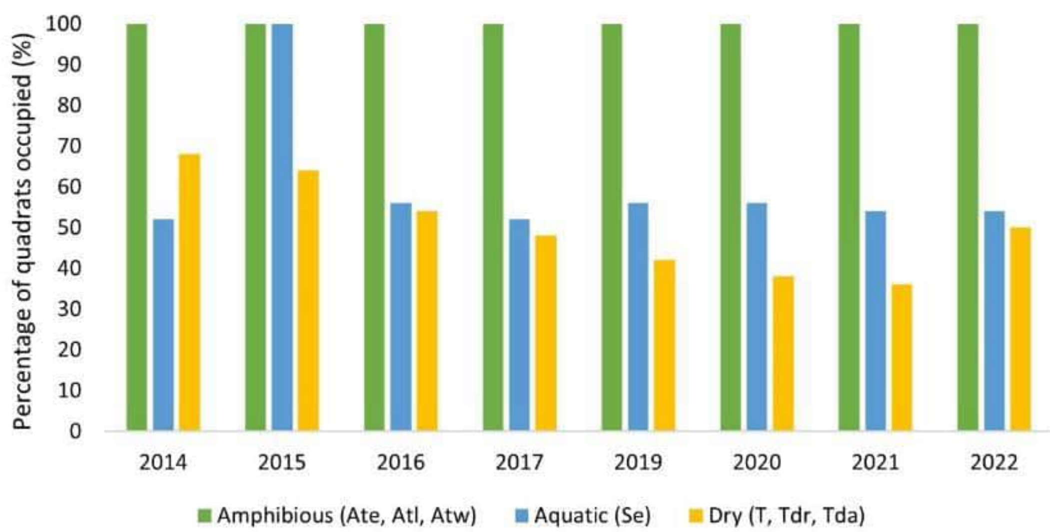
0 – 25 m

25 – 50 m

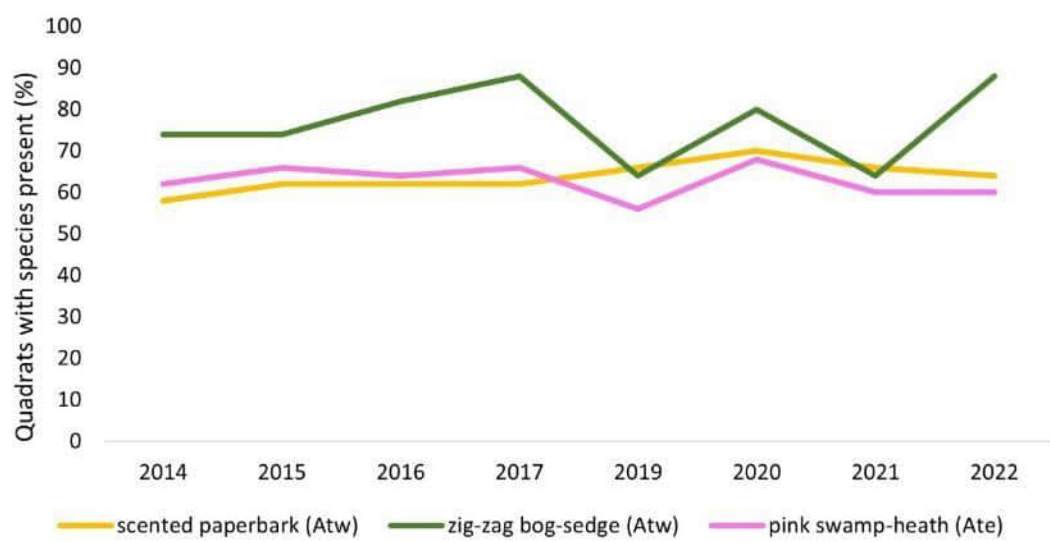
50 – 75 m

75 – 100 m

B.



C.



D.

AS3: General habitat description			
Ecological Vegetation Class (EVC)	Swamp Scrub		
Wetland permanence	Semi-permanent		
Site consists of a small (c. 0.25 ha) clearing in shrub vegetation. Emergent vegetation, mainly *Juncus sp.*, makes up 70–100% of the emerging cover. The shoreline is fringed with *Melaleuca* species (70-100%). Water was present to a depth of 30 cm during the first survey and dropped slightly to 25 cm by the second frog survey.			
AS3: Frog abundance and richness			
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**
6-10	6-10	11-20	3

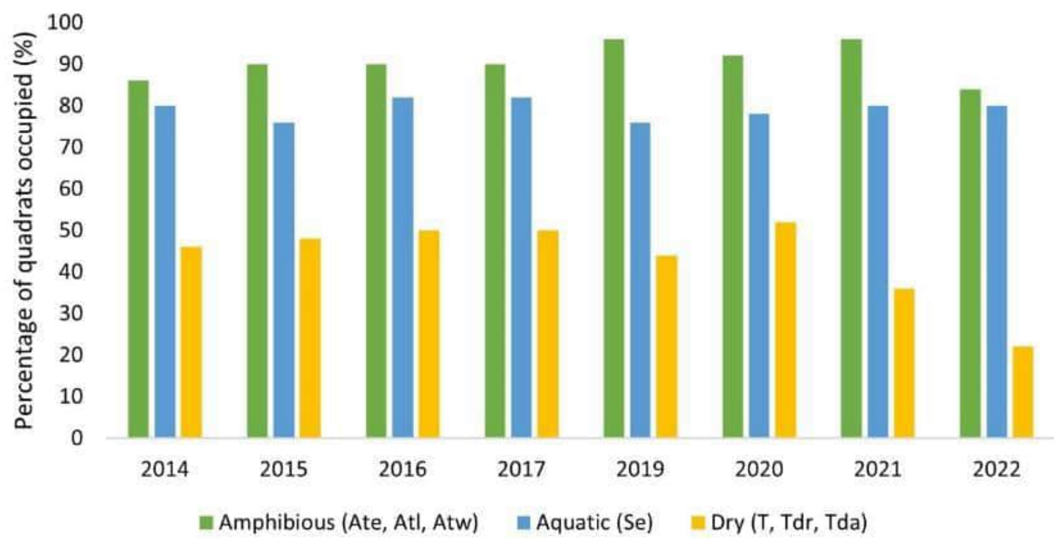
AS3: Water quality parameters					
Survey 1					
pH	4.6	**Turbidity**	8 NTU	**Water temperature**	13.5 °C
EC	1.03 µs/cm	**Salinity**	0.5 %	**Dissolved Oxygen**	9.7 mg/L
Survey 2					
pH	3.81	**Turbidity**	3 NTU	**Water temperature**	8.4 °C
EC	1 µs/cm	**Salinity**	0.5 %	**Dissolved Oxygen**	7.41 mg/L
Comments					
Water was adequate for measuring water quality during both surveys. Some frog species were heard during both surveys, with all species heard within 100-m during the second survey. There were additional southern bullfrog calling more than 150-m away on the second survey. The depth remained relatively constant over both survey events, providing suitable habitat for frogs.					

Figure 9 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS3, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

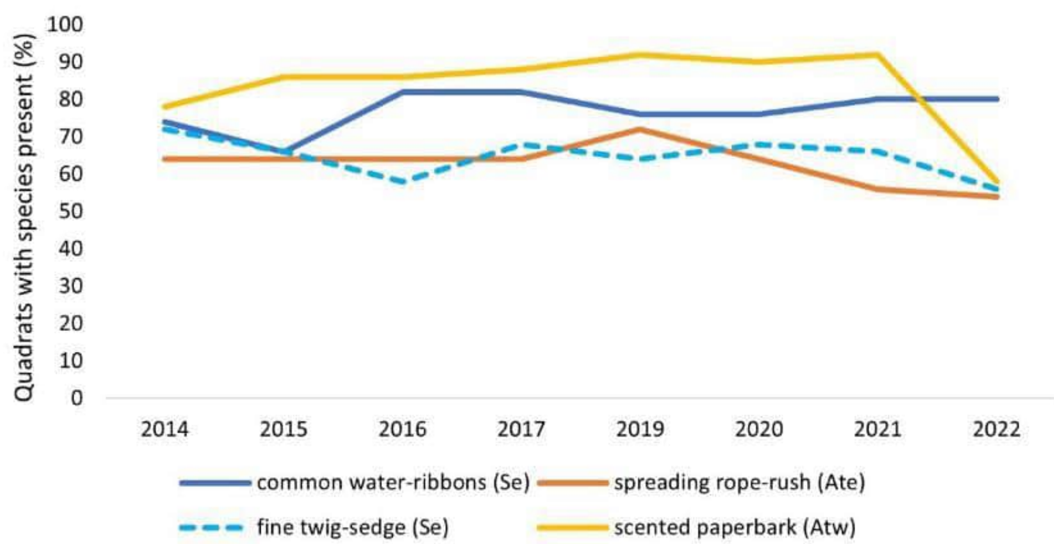
A.

0 – 25 m | 25 – 50 m | 50 – 75 m | 75 – 100 m

B.



C.



D.

AS4: General habitat description	
Ecological Vegetation Class (EVC)	Aquatic Sedgeland
Wetland permanence	Semi-permanent
Survey site located on the perimeter of the swamp in fringing vegetation. Depth was adequate (0.4-m) during both surveys. Emergent vegetation of Juncus sp. and scented paperbark (20-50%). Submergent vegetation was absent with fringing vegetation consisting of scented paperbark. There was evidence of off-road driving in the area.	

AS4: Frog abundance and richness			
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**
-	-	-	0

AS4: Water quality parameters							
Survey 1							
pH	3.85	**Turbidity**	7 NTU	**Water temperature**	12.4 °C		
EC	1.03 µs/cm	**Salinity**	0.5 %	**Dissolved Oxygen**	5.4 mg/L		
Survey 2							
pH	3.74	**Turbidity**	11 NTU	**Water temperature**	14.0 °C		
EC	0.93 µs/cm	**Salinity**	0.5 %	**Dissolved Oxygen**	7.5 mg/L		

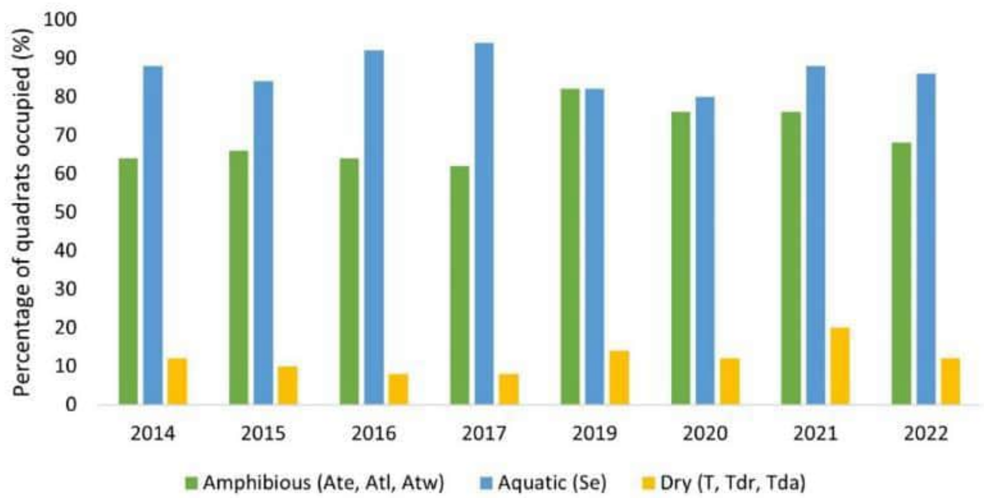
Comments
Frogs were heard calling during each survey but were estimated to be more than 100-m from the site; there were more frogs calling at the time of the second survey. Habitat in the greater area was suitable for frogs.

Figure 10 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS4, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

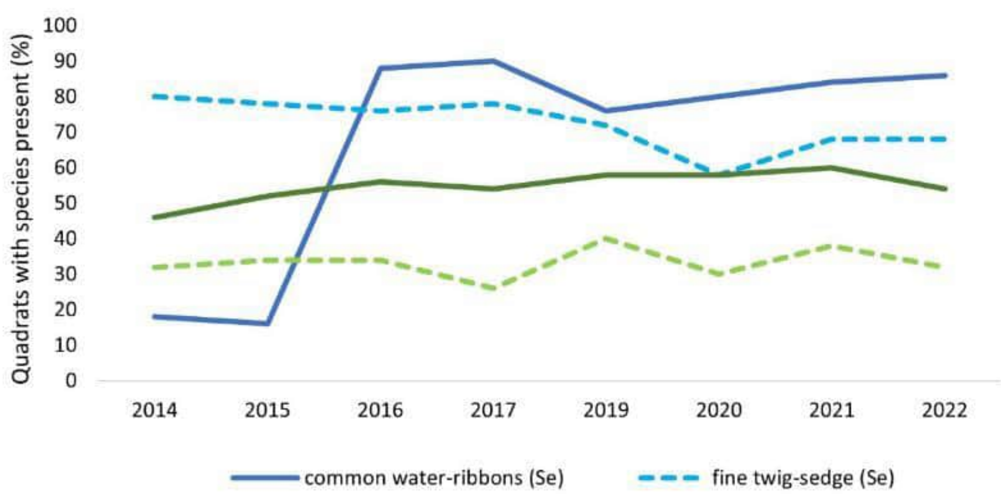
A.

0 – 25 m | 25 – 50 m | 50 – 75 m | 75 – 100 m

B.



C.



D.

ASP7_2014: General habitat description	
Ecological Vegetation Class (EVC)	Aquatic Sedgeland
Wetland permanence	Ephemeral
Site consists of a large (about 3 ha) clearing within the swamp, comprising 50- 70% emergent sedges, fringed with 70-100% cover of mostly scented paperbark. Some submergent (<5%) and floating plants (<5%) were present across both survey the swamp had an average depth of 0.4 m. The substrate consisted of dead and decomposing vegetation.	

ASP7_2014: Frog abundance and richness			
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**
-	6 –10	3	2

ASP7_2014: Water quality parameters					
Survey 1					
pH	3.34	**Turbidity**	2 NTU	**Water temperature**	16.7 °C
EC	1.18 µs/cm	**Salinity**	0.6 %	**Dissolved Oxygen**	8.63 mg/L
Survey 2					
pH	5.35	**Turbidity**	22 NTU	**Water temperature**	17.3 °C
EC	0.76 µs/cm	**Salinity**	0.4 %	**Dissolved Oxygen**	5.71 mg/L

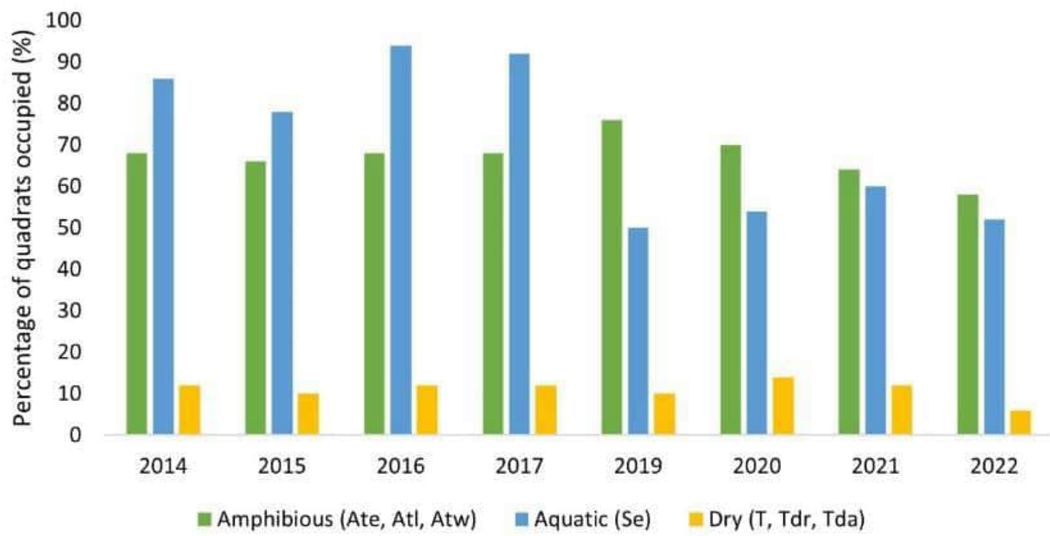
Comments
Despite the suitable water level (0.4-m) the site had high turbidity and elevated water temperature readings. Common froglet were recorded during first (4) and second (8) surveys and three southern bullfrog were detected during the second survey.

Figure 11 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site ASP7_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

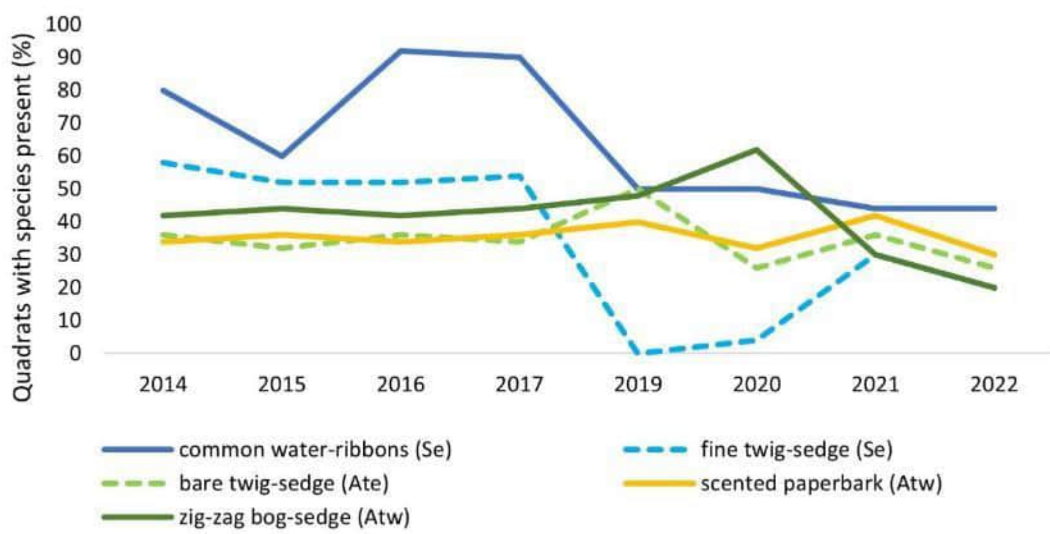
A.

0 – 25 m | 25 – 50 m | 50 – 75 m | 75 – 100 m

B.



C.

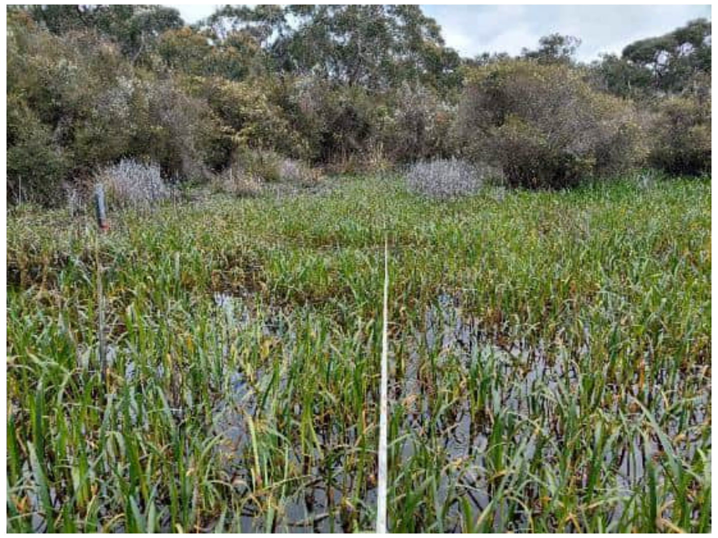


D.

AS1_2014: General habitat description							
Ecological Vegetation Class (EVC)			Aquatic Sedgeland				
Wetland permanence			Ephemeral				
This mostly open swamp area is almost extensively fringed with scented paperbark and prickly tea-tree consisting of 70–100%. Floating and submergent vegetation absent. Emergent rushes (20–50%) are located throughout the swamp. The water level was sufficient (>0.35-m) for water quality measurements during both surveys.							
AS1_2014: Frog abundance and richness							
Southern Brown Tree Frog			**Common Froglet**		**Southern Bullfrog**		**Species Richness**
2			11-20		12		3
AS1_2014: Water quality parameters							
Survey 1							
pH	5.27	**Turbidity**	5 NTU		**Water temperature**		16.0 °C
EC	1.01 µs/cm	**Salinity**	0.5 %		**Dissolved Oxygen**		7.04 mg/L
Survey 2							
pH	3.86	**Turbidity**	28 NTU		**Water temperature**		20.6 °C
EC	0.86 µs/cm	**Salinity**	0.4 %		**Dissolved Oxygen**		6.2 mg/L
Comments							
Common froglet and southern bullfrog heard calling at site during both surveys; southern tree frogs were only detected during the first survey. There were no frogs detected in either survey.							

Figure 12 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS1_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.



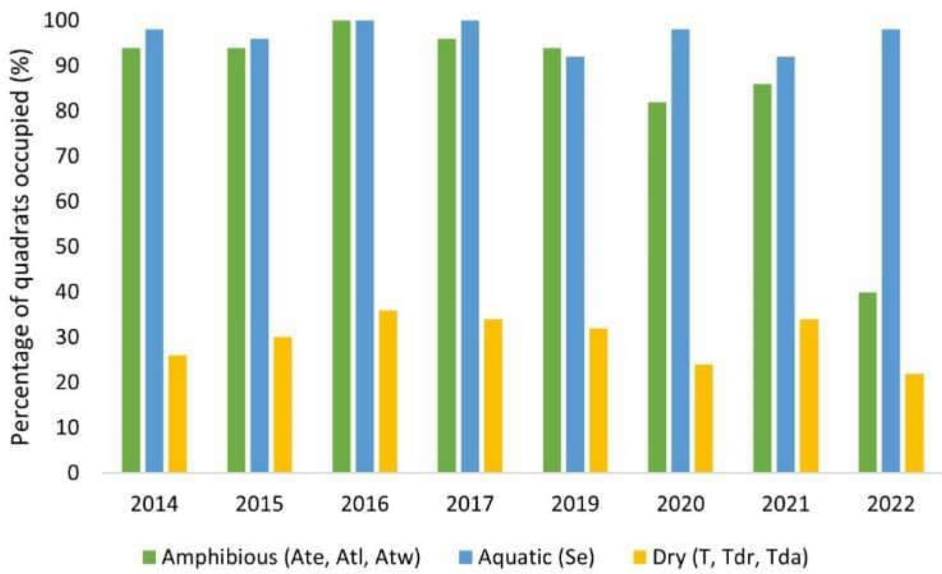
0 – 25 m

25 – 50 m

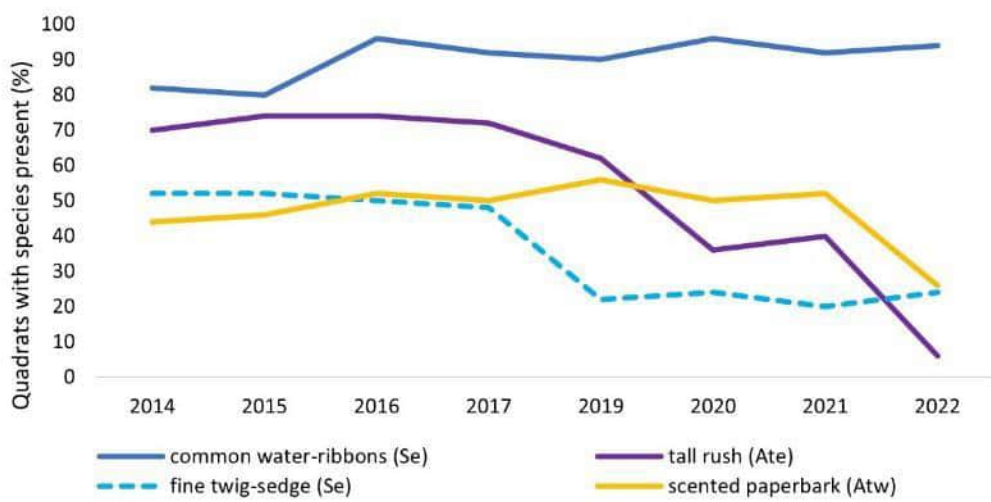
50 – 75 m

75 – 100 m

B.



C.



D.

AGP2_2014: General habitat description						
Ecological Vegetation Class (EVC)			Aquatic Sedgeland			
Wetland permanence			Ephemeral			
A small (c. 0.25 ha) clearing in tall (up to 4 m) fringing vegetation of scented paperbark and prickly tea-tree (70-100%). Approximately 40% open water with 10-20% cover of floating common water-ribbons, interspersed with emergent rushes (Juncus spp.) and patches of scented paperbark. Emergent vegetation consisted of Gahnia, common water-ribbon, and rushes (50-70%), with submergent common water-ribbon (5-10%).						
AGP2_2014: Frog abundance and richness						
Southern Brown Tree Frog			**Common Froglet**		**Southern Bullfrog**	**Species Richness**
2			6-10		4	3
AGP2_2014: Water quality parameters						
Survey 1						
pH	3.18	**Turbidity**	1 NTU	**Water temperature**		12.5 °C
EC	0.96 µs/cm	**Salinity**	0.5 %	**Dissolved Oxygen**		8.39 mg/L
Survey 2						
pH	3.36	**Turbidity**	0 NTU	**Water temperature**		15.4 °C
EC	0.66 µs/cm	**Salinity**	0.3 %	**Dissolved Oxygen**		6.4 mg/L
Comments						
Frogs were only detected at the site during the first survey. All frogs detected during second survey were more than 200-m from the site.						

Figure 13 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

AS5: General habitat description	
Ecological Vegetation Class (EVC)	Aquatic Sedgeland
Wetland permanence	Ephemeral
The small (0.25 ha) section of swamp was generally moist with occasional deeper depressions. The vegetation, consists of sedges surrounded by 70–100% cover of fringing prickly tea-tree and scented paperbark.	

AS5: Frog abundance and richness

Southern Brown Tree Frog	Common Froglet	Southern Bullfrog	Species Richness
2	3	3	3

AS5: Water quality parameters

Survey 1					
pH	3.72	**Turbidity**	1 NTU	**Water temperature**	12.1 °C
EC	0.79 µs/cm	**Salinity**	0.4 %	**Dissolved Oxygen**	3.87 mg/L
Survey 2					
pH	3.96	**Turbidity**	2.4	**Water temperature**	14.2
EC	0.57	**Salinity**	0.3 %	**Dissolved Oxygen**	7.2

Comments

Water levels (0.4 m) enabled water quality measurements during both surveys. Southern bullfrog and common froglet were detected calling at the site during the first survey, with 5–10 SBTF heard calling >200 m from the site. In survey 2, only SBTFs and common froglet were heard calling at the site; 3 southern bullfrogs were heard calling >200 m from the site.

Figure 14 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2022 frog summary data.

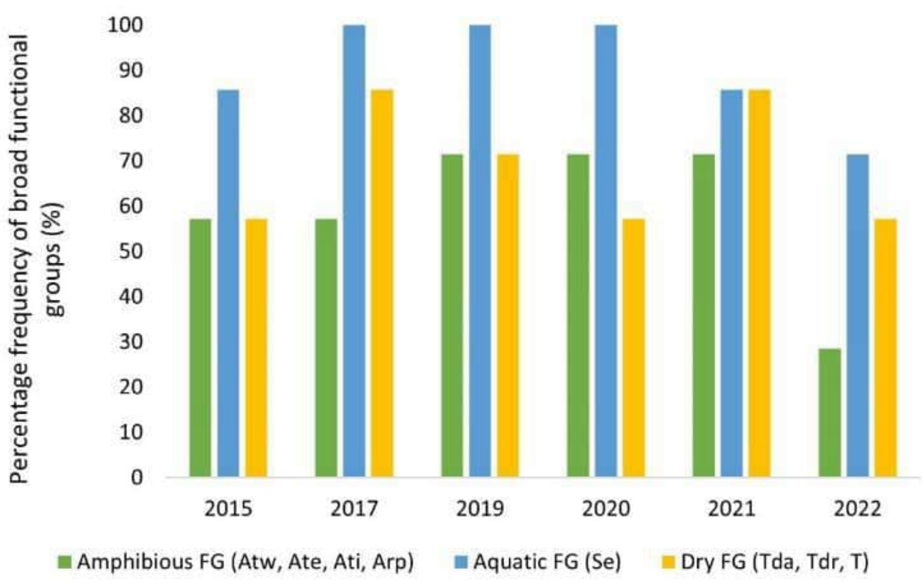
AS6: General habitat description					
Ecological Vegetation Class (EVC)	Aquatic Sedgeland				
Wetland permanence	Ephemeral				
Swamp relatively shallow (to 0.15 m) consisting of emergent (10–20%) vegetation consisting of decomposing sedges, small clumps of live sedges and scented paperbark. Submergent and floating vegetation was absent with the swamp fringed by 70–100% of scented paperbark. Water depth was sufficient across both surveys, being 0.2 m at the time of first survey; this had increases to 0.3 m by the time of the second survey.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**		
0	11-20	0	1		
AS6: Water quality parameters					
Survey 1					
pH	3.25	**Turbidity**	1 NTU	**Water temperature**	13.5 °C
EC	0.89 µs/cm	**Salinity**	0.4 %	**Dissolved Oxygen**	7.22 mg/L
Survey 2					
pH	3.49	**Turbidity**	0 NTU	**Water temperature**	16.9 °C
EC	0.62 µs/cm	**Salinity**	0.3 %	**Dissolved Oxygen**	6.3 mg/L
Comments					
Despite the sufficient water levels across at the site, frog diversity was relatively low with 11–20 common froglet calling when arriving at the site in survey one, with <5 SBTF calling from more than 200 m away. At the time of the second survey, 11–20 common froglet were heard calling at site, with 4 southern bullfrogs calling 200 m from site.					

Figure 15 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2022 frog summary data.

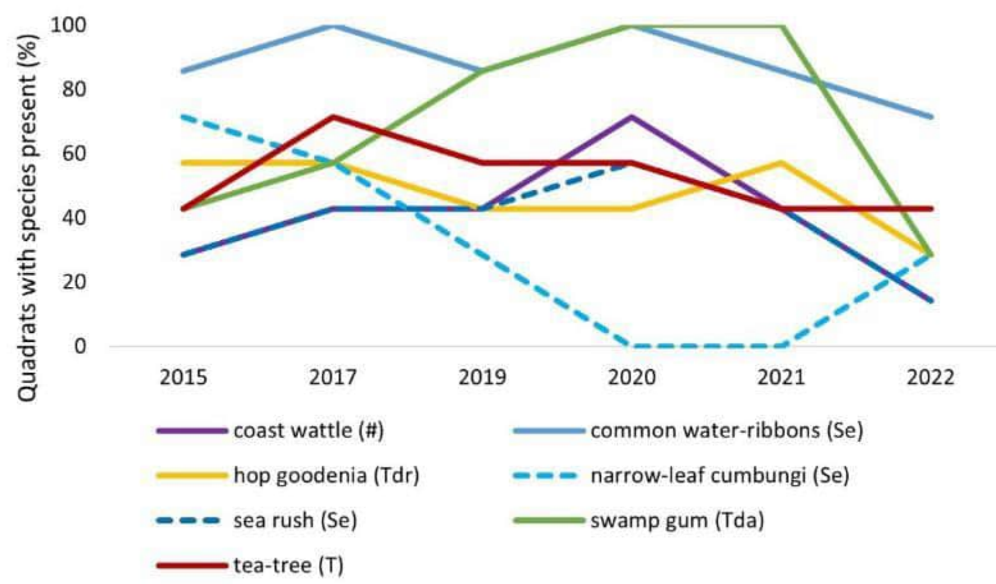
LAR1 vegetation and frog summary data

A.

B.



C.



D.

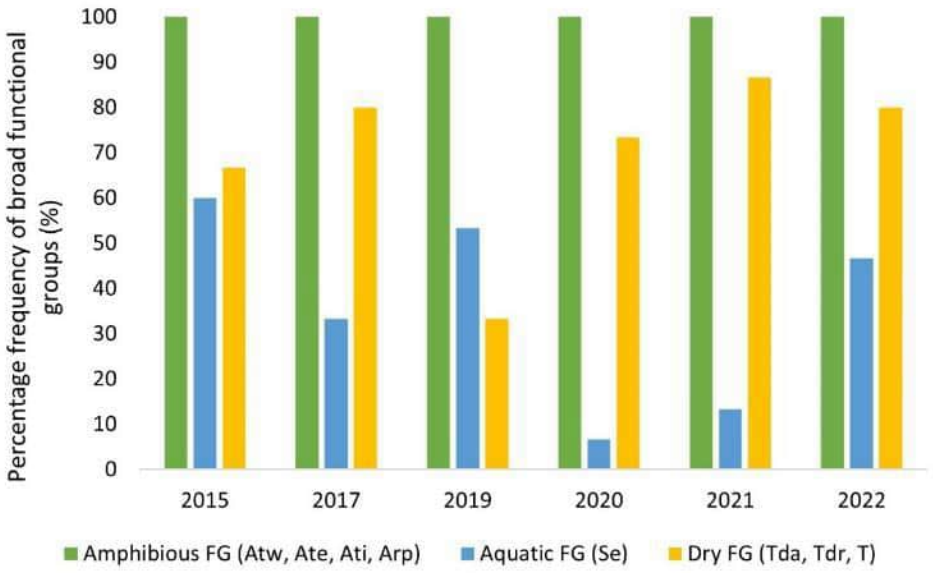
LAR1: General habitat description					
Ecological Vegetation Class (EVC)	Swampy Riparian Woodland				
Wetland permanence	Permanent				
This site is a section of slow-flowing creek up to 200 cm deep and 3–4 m wide. Submergent vegetation was absent, with 5–10% cover of floating water-ribbons. The creek is fringed with young common reeds, water-ribbons and revegetation in the form of prickly tea-tree, Eucalypts and Goodenia. Common reeds are an emergent vegetation along the banks.					
LAR1: Frog abundance and richness					
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**		
1	0	0	1		
LAR1: Water quality parameters					
Survey 1					
pH	2.73	**Turbidity**	2.2 NTU	**Water temperature**	13.3 °C
EC	0.78 µs/cm	**Salinity**	0.4 %	**Dissolved Oxygen**	9.3 mg/L
Survey 2					
pH	3.16	**Turbidity**	27.8 NTU	**Water temperature**	15.7 °C
EC	0.6 µs/cm	**Salinity**	0.3 %	**Dissolved Oxygen**	6.8 mg/L
Comments					
During the first frog survey a single southern brown tree frogs (1 individuals) was detected calling within 100 m of the site.					

Figure 16 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

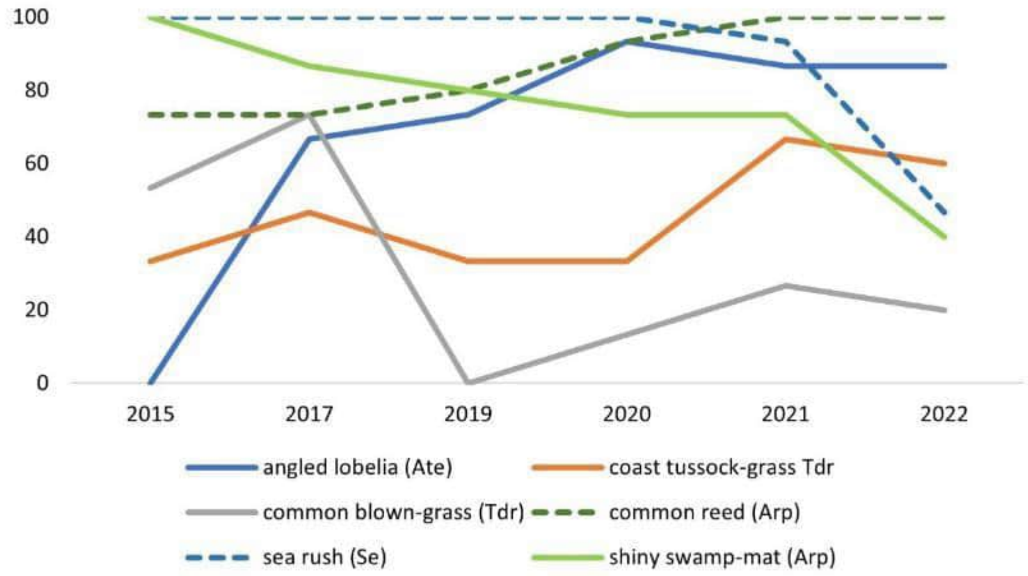
LAR2 vegetation and frog summary data

A.

B.



C.



D.

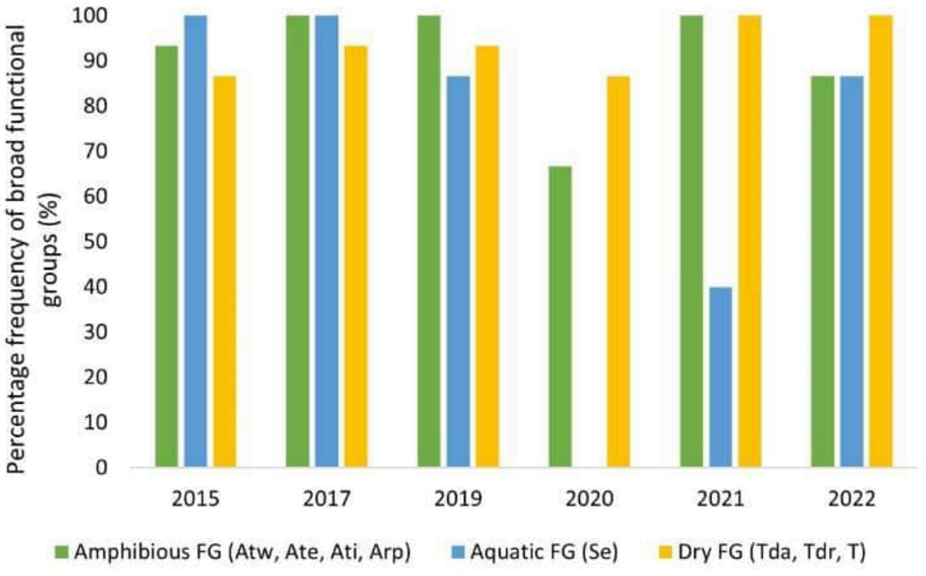
LAR2: General habitat description					
Ecological Vegetation Class (EVC)	Estuarine Woodland				
Wetland permanence	Permanent				
Slow-moving section of creek in estuary with depths of 1–2 m and 7–8 m wide. This section is fringed with 70–100% cover of angled lobelia, coastal tussock-grass, sea rush and common reed. There was no submergent or floating vegetation present. The site is mostly open, supporting less than 5% cover of emergent vegetation. A formed walking path runs along the edge of the waterway.					
LAR2: Frog abundance and richness					
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**		
-	-	-	0		
LAR2: Water quality parameters					
Survey 1					
pH	3.38	**Turbidity**	1.1 NTU	**Water temperature**	15.3 °C
EC	6.57 µs/cm	**Salinity**	3.6 %	**Dissolved Oxygen**	8.5 mg/L
Survey 2					
pH	4.12	**Turbidity**	0 NTU	**Water temperature**	15.5 °C
EC	6.5 µs/cm	**Salinity**	3.5 %	**Dissolved Oxygen**	6.15 mg/L
Comments					
During the first survey, 3 southern brown tree frogs were heard calling more than 300 m away from the site. There were no frogs detected calling during either survey from within 100 m of the site in either survey.					

Figure 17 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

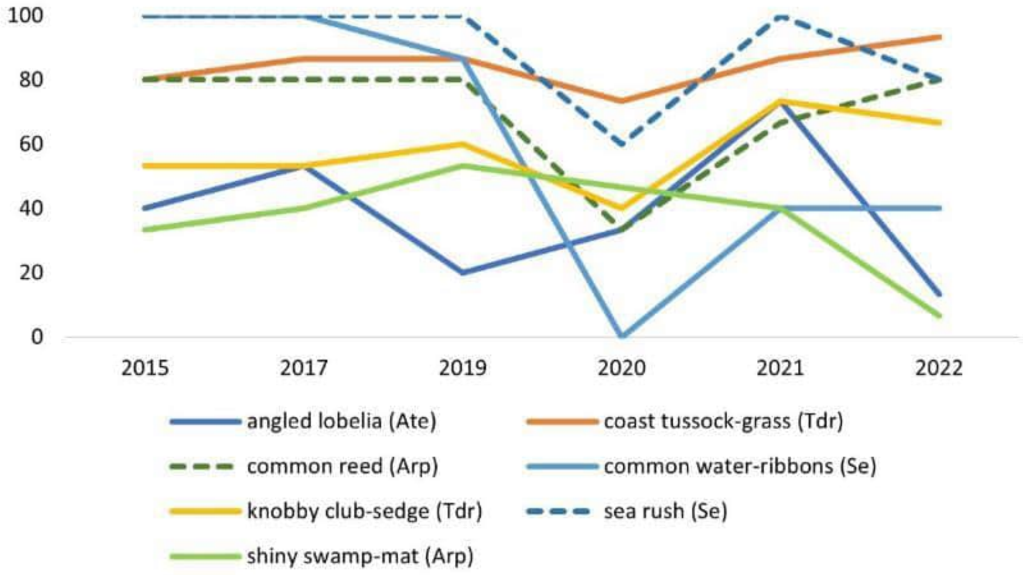
LAR3 vegetation and frog summary data

A.

B.



C.



D.

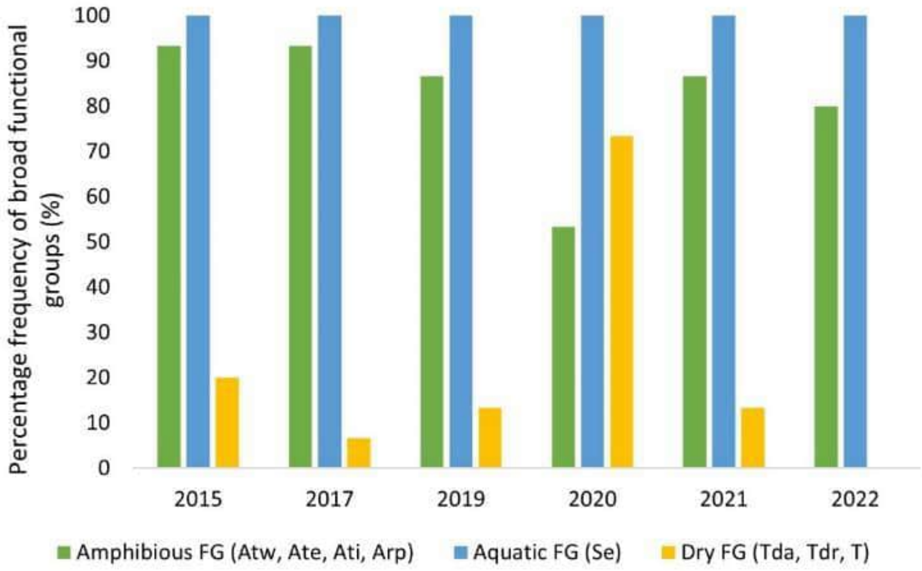
LAR3: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
This site is dominated by a slow-flowing creek 10–12 m wide, 1 – 1.5 m deep. There is an absence of emergent and floating vegetation. Emergent vegetation formed <5% of the area. The site is fringed by 70–100% cover of dominated by *Juncus*.					
LAR3: Frog abundance and richness					
Southern Brown Tree Frog		**Common Froglet**		**Southern Bullfrog**	**Species Richness**
0		0		0	0
LAR3: Water quality parameters					
Survey 1					
pH	3.8	**Turbidity**	1.4 NTU	**Water temperature**	15 °C
EC	2.6 µs/cm	**Salinity**	1.3 %	**Dissolved Oxygen**	8.74 mg/L
Survey 2					
pH	4.05	**Turbidity**	41.6 NTU	**Water temperature**	15.7 °C
EC	3.18 µs/cm	**Salinity**	1.6 %	**Dissolved Oxygen**	6.36 mg/L
Comments					
During both survey, 3 southern brown tree frogs were heard calling greater than 300 m away from the site. There were no frogs detected during calling from within 100 m of the site in either survey.					

Figure 18 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

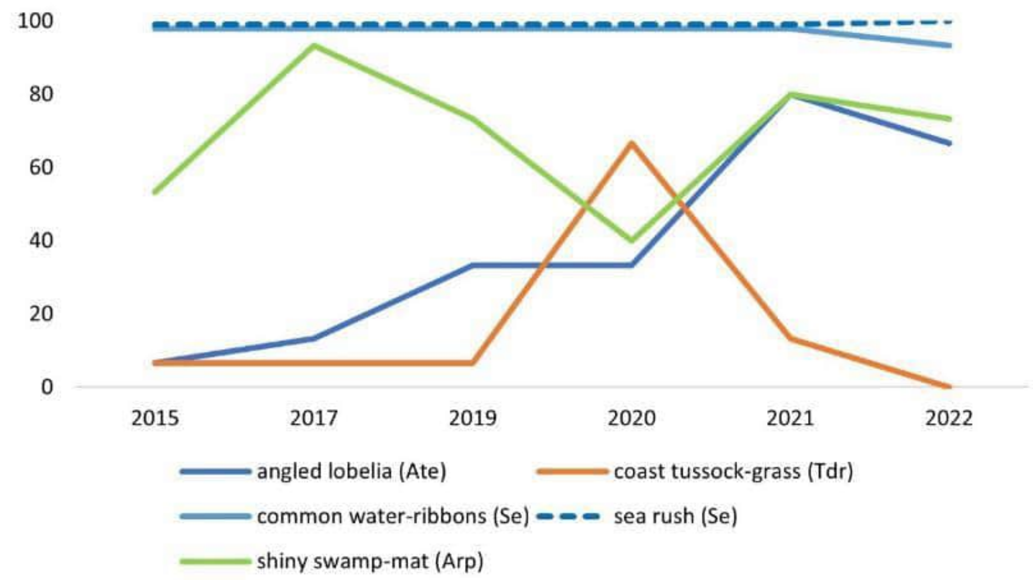
LAR4 vegetation and frog summary data

A.

B.



C.



D.

LAR4: General habitat description	
Ecological Vegetation Class (EVC)	Heathy Woodland
Wetland permanence	Permanent
This section of the creek site is 10–12 m wide and up to 2 m deep. The site is fringed by revegetation (70–100%) along the west bank consisting of: Goodenia and prickly tea-tree with some other species forming an understorey. The east bank is vegetated with sea rush, dead common reed and coastal tussock-grass. Submergent and floating plants were absent with less than 5% of the area covered with emergent vegetation.	

LAR4: Frog abundance and richness			
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**
0	0	0	0

LAR4: Water quality parameters					
Survey 1					
pH	3.28	**Turbidity**	0.7 NTU	**Water temperature**	15.6 °C
EC	3.92 µs/cm	**Salinity**	2.1 %	**Dissolved Oxygen**	7.9 mg/L
Survey 2					
pH	3.24	**Turbidity**	43 NTU	**Water temperature**	16.1 °C
EC	5.05 µs/cm	**Salinity**	2.7 %	**Dissolved Oxygen**	6.3 mg/L

Comments
During both surveys, 3 southern brown tree frogs were detected calling more than 300 m away from the site. A single common froglet was heard calling from more than 100 m from the site during the second survey. There were no other frog species detected during calling from within 100 m of the site in either survey.

Figure 19 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

3.3 Macroinvertebrates

The macroinvertebrate results based on combined sample data from each site are provided in Table 6. Due to the very wet winter/spring in 2022, all sites had sufficient wetted habitat to collect triplicate edge samples. No site met the objective for number of families either for the creek or wetland sites listed in the Environmental Reference Standard (ERS) (Vic. Gov. 2021) (Table 6). The Salt Creek site was more diverse (based on Number of Families) than the Breakfast Creek sites, which was more diverse than the wetland site. SIGNAL2 objectives were potentially met (refer to limitations section 2.3.1) for both the Breakfast Creek and Salt Creek sites. The VLAKES objective was not met for the wetland site. The EPT index objective was not met for any of the 3 sites. As no Odonata were detected at any sites in 2022, the EPT and EPTO results are the same. Individual sample results from each site are presented in section 3.7.

Table 6 Site macroinvertebrate indices result from all sites, combining the 3 edge samples taken (potential attainment of ERS objectives indicated by green and non-attainment by red). Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with BCT1 and SC1 and objectives for shallow inland wetlands with outflow (wetland) were compared with W2/3.

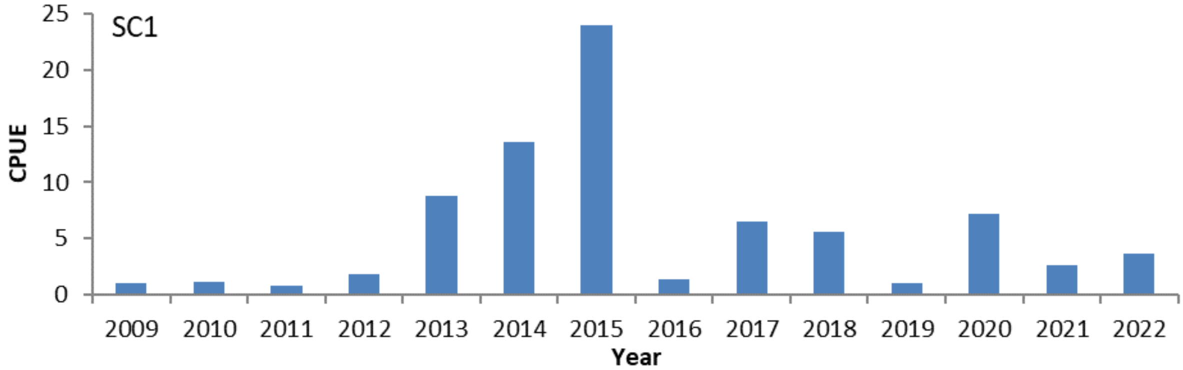
Index	BCT1	SC1	W2/3	ERS objective*
# families (creek)	11	15	-	20
SIGNAL2	5.5	5.0	-	3.4
# families (wetland)	-	-	6	15
VLAKES	-	-	4.0	4.3
EPT	3	4	1	-
EPTO	3	4	1	-

3.4 Southern Pygmy Perch

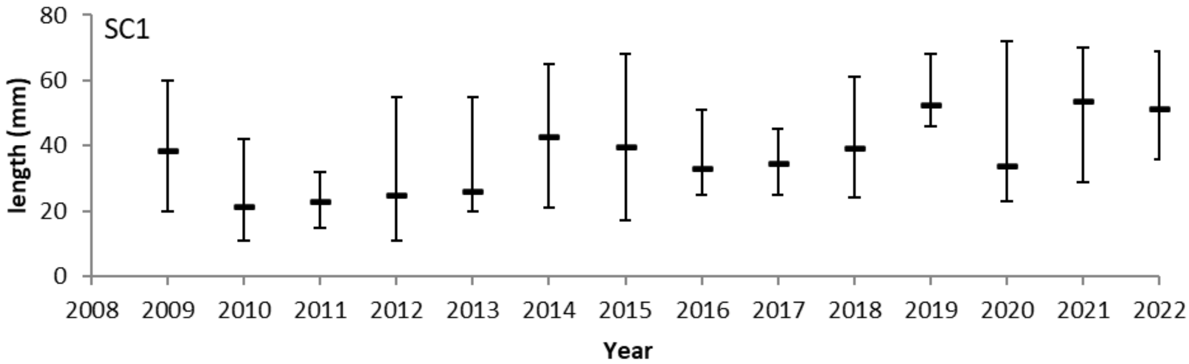
A total of 41 southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (Figure 20–Figure 21). Southern pygmy perch were captured both within the bait traps (37) and during the sweep netting (4). In 2022, southern pygmy perch Catch Per Unit Effort (CPUE) was higher than that recorded in the previous year (2021) but remains broadly comparable with the CPUE of the past 5 years (2018–2022) (Figure 21). No young-of-year fish (i.e. fish considered to be less than one year of age) were detected at SC1 in 2022, indicative of potential recent recruitment failure (i.e. failure to breed or for larval and juvenile fish to survive). Young-of-year fish were last recorded at SC1 in 2021. Observations of the fish colouration and condition (some were 'running ripe') at time of capture suggests that breeding was occurring or imminent in 2022. There was a possible bias towards capture of males at this site in 2022, with 12 females and 29 males captured.

2022 represents the fifth consecutive year that southern pygmy perch were not recorded at the Breakfast Creek tributary site, following indications of recruitment failure in 2017 (Ecology Australia 2017), strongly suggesting local extirpation.

Figure 20 Southern pygmy perch (male top & female bottom) from Salt Creek in 2022.



a) Fish Catch Per Unit Effort (CPUE; fish per trap) of southern pygmy perch at site SC1.



b) Mean (black bars), together with minimum and maximum lengths (TL) of southern pygmy perch.

Figure 21 Site SC1 southern pygmy perch spring CPUE (a) and length (b) summaries 2009–2022. Note: CPUE and length graphs for BCT1 have not been re-created for 2022 as no southern pygmy perch were detected for the fifth year in a row, for historical CPUE and length graphs please see Ecology Australia, (2022).

3.5 Otway Bush Yabby

Otway bush yabby *Geocharax tasmanicus* is a small freshwater crayfish listed as Endangered under the FFG Act 1988 and has been annually detected at Salt Creek and Breakfast Creek sites since 2017 (Ecology Australia 2018–2022). The species was again detected at Salt Creek and Breakfast Creek sites in 2022, by bait trapping and sweep netting in Breakfast Creek, but only by sweep netting in Salt Creek. A total of 48 Otway bush yabbies were captured in 2022, 46 from Breakfast Creek (bait traps = 16, sweep net = 30) and two from Salt Creek.

Figure 22 Multiple size classes of Otway bush yabby from Breakfast Creek during the 2022 fish surveys.

3.6 Water quality

Water quality results were consistent with results from previous years (GHD 2010–17, Ecology Australia 2018–2022; Table 7). It should be noted that water quality results are highly variable within short temporal periods, and that to assess against ERS indices, a minimum of 11 data points is required from a single year (i.e. to calculate annual percentiles). Thus, results are only compared with the ERS objectives to provide context. For both Breakfast Creek and Salt Creek, conductivity, dissolved oxygen and turbidity were at levels that would potentially meet ERS objectives, however, pH was considerably lower than the objectives, more so in Breakfast Creek than Salt Creek (Table 7). Wetland 2/3 would potentially meet the ERS objective for turbidity but would potentially fail to meet the objective for dissolved oxygen and pH.

Table 7 *In situ* water quality results and environmental reference standard (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) and for shallow inland wetlands with outflow (wetland). Potential attainment of ERS objectives indicated by green and potential non-attainment by red.

Objective/site	Temp (°C)	Conductivity (ms/cm@25oC)	Dissolved oxygen		pH	Turbidity (NTU)
			mg/L	%Sat		
ERS (creek)	N/a	≤2.0	N/a	≥70	6.8–8	≤25
BCT1	11.28	0.197	10.74	101.3	2.75	12
SC1	12.39	0.263	10.43	101	6.21	9.7
ERS (wetland)	N/a	N/a	N/a	80-120	6.5-8.5	15
W2/3	12.25	0.868	7.48	10.9	1.84	3.3

3.7 Aquatic monitoring sites

3.7.1 Breakfast Creek and tributaries

Breakfast Creek tributary site BCT1 consisted of a narrow, shallow stream, with a maximum width of 1.5 m (Figure 23). During the 2022 surveys BCT1 there was a moderate flow passing over the V-notch weir. The substrate was predominantly silt/clay, with some sand, pebble and gravel present. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), undercut banks, overhanging terrestrial vegetation, woody debris, filamentous algae and roots.

Figure 23 Breakfast creek in 2022, photo taken at BCT1 V-notch gauge.

The Breakfast Creek tributary site surveyed attained ERS objectives for SIGNAL2 scores for all 3 samples (Table 9). No other objectives were achieved. The SIGNAL2 score and number of different families are similar to the last several years of the project with both showing an increase in 2022 compared with 2021, however the overall trend since 2014 has been decline for both indices (Figure 24). The EPT taxa again make up a good proportion of the total number of families detected and continue to drive up SIGNAL2 scores for Breakfast Creek.

Table 8 Individual macroinvertebrate sample indices results for Breakfast Creek tributary site 1, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Breakfast Creek Tributary site 1			ERS objective
	Edge sample 1	Edge sample 2	Edge sample 3	
Abundance	26	16	39	-
# Families	9	4	8	20
SIGNAL2	5.8	5.5	6.1	3
EPT	3	2	3	-
EPTO	3	2	3	-

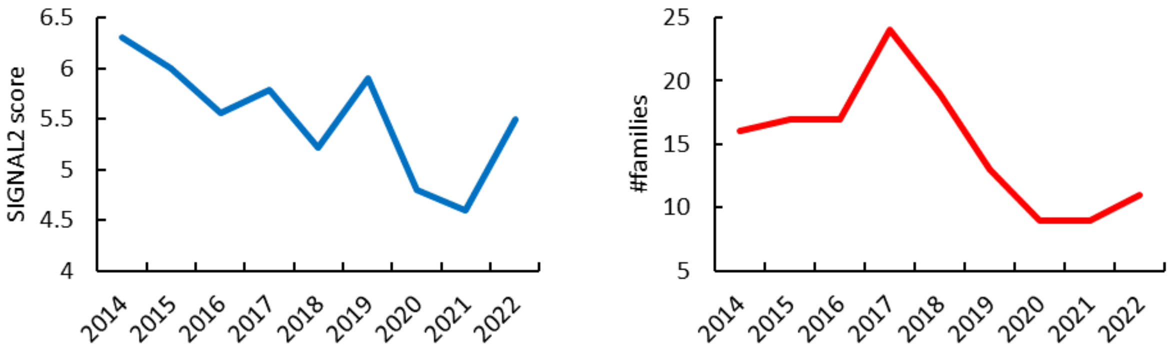


Figure 24 Yearly average SIGNAL2 scores and number of families at site BCT1 from 2014–2022 (no survey occurred in 2019).

No southern pygmy perch were detected at BCT1 during this round of monitoring. This is the fifth year in a row that this species has not been detected at BCT1. Recruitment failure was evident at this site in 2017 (Ecology Australia 2017), with consecutive years of non-detection now being indicative of local extirpation.

Otway bush yabby were captured in greater abundance in 2022 compared with 2021. A significant proportion were juvenile, and this suggests recent recruitment success. Individuals ranged in size from 4–21 mm Occipital Carapace Length (OCL) (Figure 25).

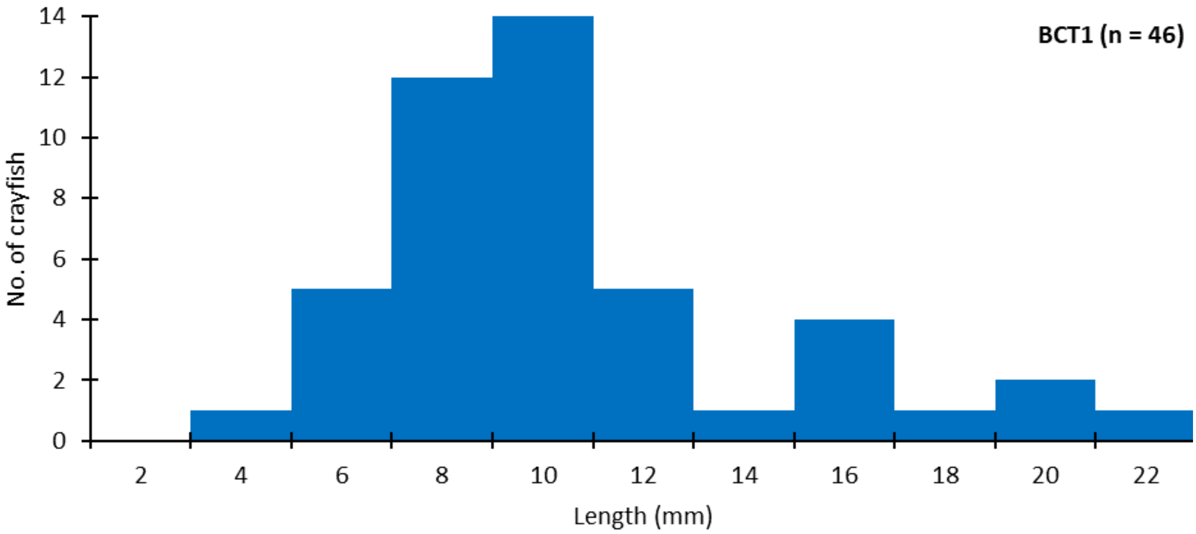


Figure 25 Length-frequency histogram for the 2022 Otway bush crayfish captured at Breakfast Creek site BCT1.

3.7.2 Salt Creek

The Salt Creek site consists primarily of a large and relatively deep permanent pool, located on an otherwise small and relatively shallow channel (Figure 26). Based on observations since 2017, this site should be considered a likely permanent refuge. The substrate was silt/clay and there was water flowing into and out of the large pool at a moderate velocity. Compared with previous years (especially 2017–2020) the areas of lentic habitat were reduced, and flow was visible from the pool entrance to exit. The amount of loose silt appeared similar to that of 2021, which was greatly reduced on previous years. Aquatic macrophytes remain absent from the pool.

Figure 26 Salt Creek in 2022 at site SC1.

The Salt Creek site attained ERS objectives for SIGNAL2 score for all 3 edge samples (Table 10). No other relevant objectives were achieved. The SIGNAL2 scores and number of families represent a slight improvement in the 2022 compared with the 2021 but the overall trend of the past few years has been decline compared with the 2014–2019 period (Figure 27).

Table 9 Individual macroinvertebrate sample results for Salt Creek, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Salt Creek site 1			ERS objective
	E1	E2	E3	
Abundance	12	39	31	-
# Families	5	11	9	20
SIGNAL2	4.0	4.7	4.9	3.4
EPT	0	3	1	-
EPTO	0	3	1	-

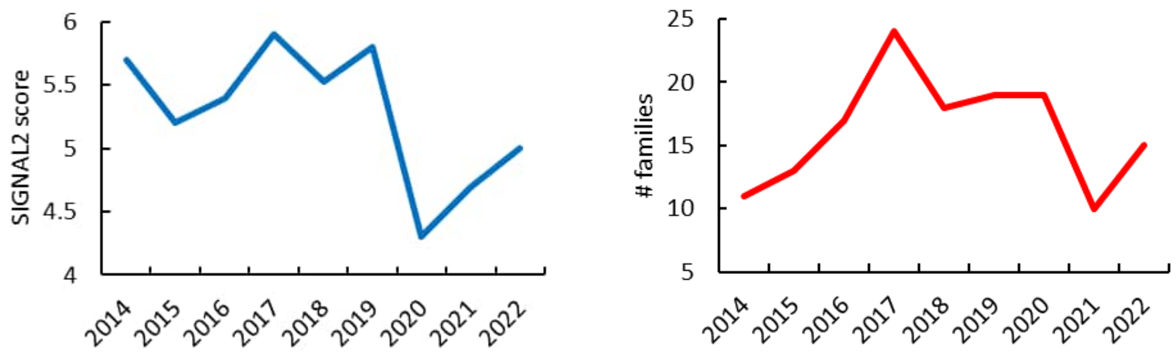


Figure 27 Yearly average SIGNAL2 scores and number of families at site SC1 from 2014–2022.

As outlined in section 3.4, southern pygmy perch were detected in comparable abundance to the previous five years. The length-weight frequency plot shows the population was between 35–70 mm, with more males (29) than females (12) (Figure 28).

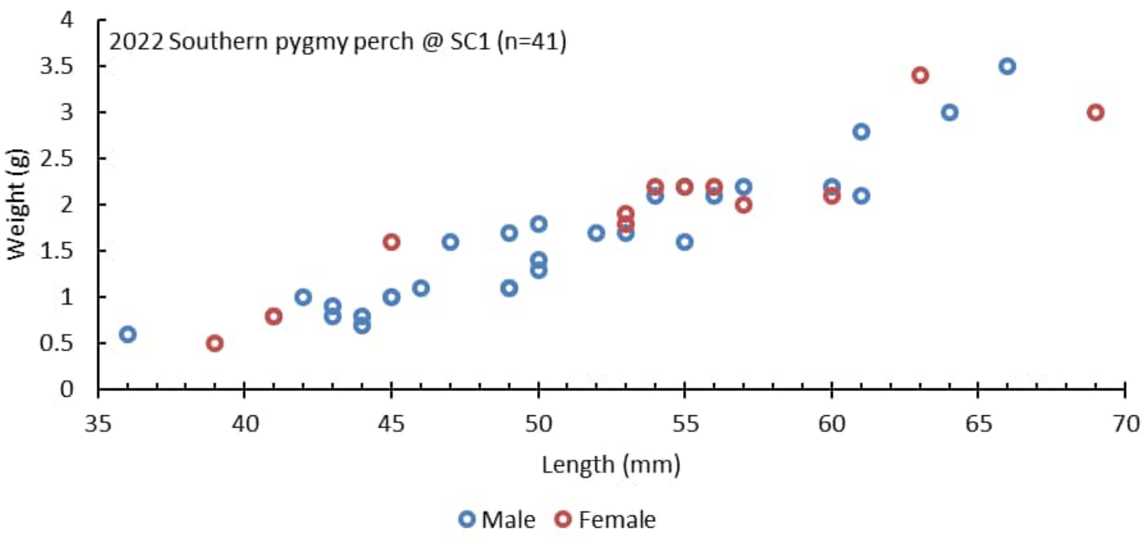


Figure 28 Length-weight plot for the 2022 southern pygmy perch, including sex, captured at Salt Creek site SC1.

Otway bush yabby were present at Salt Creek in 2022 in low abundance. The species was not detected with bait traps and only 2 individuals (16 mm OCL female and 7 mm OCL juvenile) were captured using sweep netting. There appears to have been a reduction in abundance of this species at this site since 2020.

3.7.3 Lower Anglesea River Wetlands

There were obvious visual differences in the water levels and filamentous algae cover at the Lower Anglesea River wetland 2/3 in 2022 compared the 2017–2022 period (Figure 29). The pool at wetland 2 was larger, slowly flowing (instead of still) and had an increased aquatic vegetation cover (*Triglochin* sp.). The cover of filamentous algae, which entirely dominated the pool (near 100% coverage) in previous years, was at about 40–50% coverage. Wetland 3 was also larger than during sampling events in previous years, with higher flows and overbank flows occurring (*Juncus* sp., paperbark and tea-tree were flooded throughout the site). The substrate was predominantly clay/silt. Some water was also flowing across the track at the time of survey at two locations. No southern pygmy perch or Otway bush yabby were detected at this time, consistent with the findings of previous years.

a) 2022

b) 2021

c) 2020

Figure 29 Lower Anglesea River wetland 2 site in 2022 (a) compared with 2021 (b) and 2020 (c).

The Wetland 2/3 site attained the VLAKES objective for 2 of the 3 samples (Table 11). No other relevant objectives were achieved. The macroinvertebrate assemblage at this site appeared to have marginally declined compared with 2021 and 2019 but was similar to that of 2020. No Otway bush yabbies were detected at any of the Lower Anglesea River wetland sites, consistent with the findings of previous years.

Table 10 Individual macroinvertebrate sample results for lower Anglesea River wetland 2/3, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Lower Anglesea River Wetland site 2/3			ERS objective
	E1	E2	E3	
Abundance	79	9	13	-
# Families	6	2	3	15
VLAKES	4.2	5.5	5.3	4.3
EPT	1	0	0	-
EPTO	1	0	0	-

4 Discussion

4.1 Vegetation

In the Anglesea Swamp sites, overall species richness within the wetland communities (Aquatic Sedgeland EVC and Swamp Scrub EVC) increased by one species from the previous year. Dominant species remained present at all sites, however some dominant species (tall rush and scented paperbark) decreased in frequency substantially at AGP2_2014 from 2021. Both these species require the presence of water for most of the year. The swamp at AGP2_2014 is an ephemeral wetland, however based on water depth at the site (average 18.9 cm) and above average mean rainfall, it is unlikely this site dried out substantially between the 2021 and 2022 surveys. Since the revised MAP commenced, the total number of species has decreased across 5 of the 6 sites in the Anglesea Swamp. Partly, this reduction in species can be explained by a decrease in several species which are associated with drier vegetation of the Heathy Woodland and Swamp Scrub EVC interface. Site AS4 has displayed a reduction of several species which contribute very little cover to the overall transect and are not predictive of changes to either the Swamp Scrub EVC or the Aquatic Sedgeland EVC.

In the Anglesea Estuary sites, native species richness remained relatively stable at LAR1, 2 and 3 and the variation displayed is within expected ranges of annual variation. However, site LAR4 has decreased in total number of species since the revised MAP commenced. In particular, this site has exhibited a significant trend of decreased species richness since 2020. The species which have no longer been recorded in LAR4 all contributed to only 1 or 2 quadrats in total and their disappearance from the transect is unlikely due to hydrological changes. Weed species were only recorded the LAR2 Estuary site (Appendix 2). Native plant species continue to be recorded in higher numbers and higher frequencies than weeds since monitoring in the estuary began (see Ecology Australia 2015, 2017, 2019, 2020 and 2021).

Overall, the proportion of aquatic functional groups has remained relatively stable across all sites between 2014 and 2022. However, the proportion of aquatic functional groups decreased substantially between 2017 and 2019, before steadily increasing between 2019 and 2022. Aquatic species are highly sensitive to changes in hydrology as they require permanent water in their root zone to survive (Cassanova 2011 and Doeg et.al. 2012). The 2022 rainfall data from Aireys Inlet recorded average annual rainfall as 631 mm from 1994 to 2021 (BOM 2022). Both 2014 (498 mm) and 2015 (488 mm) were relatively dry years and little to no standing water was present across all sites (Ecology Australia 2014, Ecology Australia 2015). Following this was 2 years of above or near average rain fall in 2016 (714 mm) and 2017 (609 mm), during which time the Aquatic functional groups showed little change in abundance. By contrast, yearly rainfall decreased in 2019 to 525 mm and as a result, the Aquatic functional groups dropped approximately 20% across all sites. Yearly rainfall across 2020 (713 mm) and 2021 (726 mm) was higher than average, which is likely resulting in the increased proportion of aquatic species recorded during this time.

Across most Anglesea Swamp sites, aquatic functional group species, including southern bristle-sedge *Chorizandra australis*, fine twig-sedge *Machaerina arthrophylla* and the square twig-sedge *Machaerina tetragona* dropped in frequency after 2017 and have not yet returned to pre-2017 levels. The exception to this appears to be the common water-ribbons *Cycnogeton procerum sp. aff.* which increased in frequency in 3 sites and appears to respond quickly to changes in available water and tends to increase in frequency after yearly rainfall increases.

As with the 2021 surveys, it appears that several dominant species have died back in recent years. This has occurred for the square twig-sedge at site AS2 and the fine twig-sedge, the tall rush and the spreading rope-rush at site AGP2_2014. The timing and cause of this die-back remains unclear. It is understood that these sites were dry in 2014 and were either dry or had only 3 cm of standing water recorded in only 2 quadrats in 2015 (Ecology Australia 2014, Ecology Australia 2015). Using the photo point data from 2014, neither site had the same extent of clearly dead vegetation in 2014 or 2015 with AGP2_2014 showing many healthy flowering stems of tall rush. In the dominant species frequency data for AGP2_2014, the frequency of tall rush and the fine-twig sedge remain relatively stable until 2017 after which their frequency drops significantly. Similarly at AS2, the dominant square twig-sedge shows a drop in frequency after 2017. Both twig-sedges fit within the Aquatic functional group, which are most susceptible to changes in hydrology and not tolerant of long periods without water. The tall rush fits within the Amphibious fluctuation tolerator–emergent functional group which have more tolerance to changing water levels but require 8–12 months of the year to have water present. It is likely that the dry conditions of 2014 and 2015 initiated the die-back of these species, however there are other variables that can affect plant health such as soil and water salinity and acidity. Both the tall rush and the square twig-sedge appeared to show signs of recovery in 2021 with both species increasing in frequency at their respective sites, however this was not obvious in the field. Dead thickets had one or two resprouting live stems which allowed them to be scored as present despite the majority of the individual or stand being dead. This means while each species is still present and increasing in frequency, it clearly hasn't yet recovered to pre-die-off levels.

Algal mats have increased in 2 sites in the Anglesea Swamp (first recorded in 2016) from 2021. While algae are a normal part of wetland ecosystems, the growth of algae can also be associated with low flows (Mitrovic and Bowling 2013, Davie and Mitrovic 2014) and might suggest reduction of overbank flows in the swamp. At this stage, there are no obvious impacts on the vegetation.

4.1.1 Botanical recommendations

Recommendations regarding the vegetation monitoring component include:

- Addition of cover estimates of species in each quadrat along a transect following the Braun Blanquet cover abundance scale. Cover estimates allow trends to be detected at a finer scale compared to presence and absence scores alone. This will allow the MAP to detect changes in vegetation before species decline significantly and be able to track the trajectory of species which appear to have significantly declined in sites AS1 and AGP2_2014.
- Consider as part of the Bulk Entitlement review process using GIS to analyse and detect large scale changes in vegetation across the Anglesea swamp and estuary. This could be approached by analysing the percentage cover and change over time of the dominant Swamp Scrub EVC and Aquatic Sedgeland EVC (or representative dominant species). Dominant components of each EVC or key species could be differentiated using colour (ariel, satellite or drone), reflectance properties of vegetation (satellite) or heights using LIDAR. This may allow changes in extent of dominant species such as the scented paperbark *Melaleuca squarrosa* to be detected at the scale of the whole swamp. This was attempted this year across selected Anglesea Monitoring sites however, the differences in resolution and colour of available imagery provided

unmeaningful results. Despite this, the method used was successful enough at identifying vegetation types and it is believed that with appropriate imagery, this could be a valuable tool to detect largescale changes in vegetation.

4.2 Frogs

The 2022 frog surveys completed as part of the Anglesea MAP were broadly consistent with those of previous years. However, there was an increase in abundance of the three frog species occurring within the Anglesea Swamp over the two survey events (Table 4, Figure 7). This increase in abundance appeared to have corresponded with the increase in rainfall recorded for the year. Conversely, there was a reduction in the numbers and diversity of frog species recorded at the Anglesea Estuary (Table 5, Figure 7).

Frogs were typically heard within 100 m of Anglesea swamp sites during at least one of the surveys, with the exception of AS4 where no frog species were heard calling within 100 m. Similarly, southern brown tree frog where not detected within 100 m of AS6 and ASP7, while pobblebonk were not detected within 100 m of AS6. Conversely, across the 4 estuary sites, frogs were typically heard calling from distances of greater than 100 m away (Table 5), with southern brown tree frogs the only frog species detected calling within 100 m of site LAR1, suggesting that frogs tended to be present within the wider estuary area. The increased diversity and abundance relative to previous years, with the exception of 2016 at the Anglesea swamp appears related to the increase in habitat and quality across these sites.

The persistence of frog populations at a site depends on the ability for individual species to produce viable offspring that, in turn, have the ability to reproduce and contribute to the subsequent generation of individuals. As such, there is an obvious need for adequate aquatic habitat at each site for breeding purposes, with adequate water depth being a primary determinant of successful breeding in frogs. Although the timing of water availability may differ between species, adequate water must be present for an adequate period for larvae to undergo development and achieve metamorphosis; whereby they are less dependent on free-standing water. Moreover, while all 3 frog species (common froglet, southern bullfrog and southern brown tree-frog) have extensive breeding seasons, the period required for metamorphosis is more variable. Southern bullfrog tadpoles metamorphose from December to April and require 3–6 months to metamorphose. Conversely, common froglet tadpoles may metamorphose in as little 4–6 weeks and are tolerant of small, highly intermittent waterbodies with unstable conditions, making this species less susceptible to water level changes and the drying-out of water bodies (Lane and Mahony 2002, Hazell et al. 2003, Anstis 2013). As such, for southern bullfrog to achieve successful metamorphosis at a site, and hence maintain all three species at a site likely requires free-standing water for over 6 months (Anstis 2013).

During the 2022 surveys, water levels and associated water quality parameters remained relatively constant and suitable for frogs across all Anglesea Swamp sites and frog diversity and abundance (as indicated by frog call behaviour) remained consistent among surveys and sites at the Anglesea Swamp. Conversely, among the Anglesea estuary sites, water levels and water quality parameters remained relatively ideal, with the exception of salinity among both surveys. In past years, a combination of water availability and associated water quality, resulting from changes in water level were suggested for the observed differences in frog abundance and diversity. In the 2022 survey there appears to be no such clear biophysical descriptor relating to frog abundance and diversity, particularly among estuary sites.

Most importantly, the number of frogs heard calling at the estuary site was the lowest since 2019, suggesting that frog diversity at the estuary sites may be more variable, despite having relatively constant water quality conditions, than the Anglesea swamp sites. A likely explanation for the absence of frogs (frogs were calling nearby >100 m away) at the Anglesea Estuary being that the increase in availability of suitable free-standing water surrounding the Anglesea Estuary. As such, it is possible that frogs located around the estuary had access to an increased range of suitable free-standing water, which may have caused them to move away from the survey sites located along the estuary. The ability to disperse and move being a key adaptive strategy among many south-east Australian frog species in response to climate variability and change (Wassens et al. 2013).

In summary, the presence and detection of frogs is closely linked to the weather conditions preceding the survey events. Climatic variability and annual variation in rainfall can cause frogs to move within the landscape. As such, frogs may move considerable distances in response to changes in water availability. In the case of frogs located at the Anglesea Estuary this may have resulted in frogs being located away from the sites examined as part of this study, as such the estuary sites may be more variable than those of the Anglesea Swamp.

4.3 Aquatic ecology

The macroinvertebrate monitoring results were relatively consistent with the previous 3 years (Ecology Australia 2020–22), with a slight improvement evident in the present year compared with the previous three. The overall trend for the macroinvertebrate assemblage for the study area as shown at the Breakfast Creek tributary and Salt Creek sites has been decline since at least 2014, in particular for the Breakfast Creek tributary site. Due to the new index (VLAKES) used for the wetland site this year in addition to the inconsistency with which wetland site(s) have been surveyed (wetland 2/3 combined during annual, wetland 2 and wetland 3 during triennial and wetland 1 annually prior to 2017), we did not plot the macroinvertebrate assemblage trajectory through time. The inconsistency of sites surveyed should be resolved during the next MAP review and trajectory at wetland sites tracked through time. Attainment of ERS objectives remains low with SIGNAL2 (creek sites) and VLAKES (wetland site) being the only categories meeting relevant objectives. The extreme low pH conditions within the sites are the most obvious explanation for the depauperate macroinvertebrate assemblage with low pH having been shown to have a negative effect on macroinvertebrate diversity (e.g. Courtney and Clements 1998, Tripole et al. 2008).

Southern pygmy perch CPUE at site SC1 was broadly comparable with the last 5 years. Salt Creek CPUE was expected to be relatively low during the 2022 survey due to higher flows and the corresponding dilution effect this has on fish densities and capture rates, although even higher flows were encountered in 2021. There were no young-of-year fish detected during 2022 (with the majority of the fish >40 mm TL), which is the first failure to detect young-of-year individuals since 2019 and is indicative of recruitment failure (either failure to spawn or mortality of eggs/larvae or early juveniles). The reasons for this are unknown but could include the sustained increased flow conditions in 2021 with southern pygmy perch benefiting from stable spring/summer conditions. Fish colouration (in breeding colours) and the presence of ripe fish is a good sign that the southern pygmy perch within Salt Creek were in good condition and that spawning activity was occurring or was imminent at the time of survey.

No southern pygmy perch have been detected at BCT1 since 2017. This result potentially provides a strong indication of local extirpation of the southern pygmy perch population formerly located in the vicinity of site BCT1. This population has previously 'reappeared' after several years of no detection or recruitment (GHD 2013–2015), suggesting that more favourable and permanent habitat (i.e. a 'source population') may be located somewhere nearby. However, 5 years of non-detection including multiple wetter years with periods of connectivity for dispersal and recolonisation is a bad sign for population recovery. We recommend additional effort occur to determine the ongoing existence of the southern pygmy perch in the Breakfast Creek catchment and the proximity of any new sites to the existing monitoring site. Given the population of southern pygmy perch in the Anglesea catchment is genetically distinct (Cesar 2012), it is likely to be important to maintain populations within both Salt Creek and Breakfast Creek. Identification and monitoring of source population sites should, therefore, form an important component of the monitoring program for future years.

Otway bush yabby abundances appeared to be considerably higher in 2022 compared with 2021 (although not quite at the high abundances of 2020). During the present project year, an attempt was made to track the trajectory of this species over time, however due to the inconsistent collection of data (i.e. considered a non-target by-catch species previously) and the misidentification of this species prior to 2017, this was not possible. However, this analysis did show that bait traps alone are not a sufficient method to monitor for this species. For example, in 2022 at Salt Creek no Otway bush yabby were captured in the bait traps but this species was present at the site as shown by the sweep netting. This was likely due to the habitat targeted by these methods with sweep netting targeting more suitable habitat (i.e. littoral habitat) for this species during the wet year in Salt Creek than the bait trapping (i.e. deeper habitat). We therefore suggest that all Otway bush yabbies captured be recorded (measured, weighed, counted as appropriate) regardless of the method used, i.e. by both bait trap and sweep net per replicate. All sites where Otway bush yabby were detected in 2022 were again flowing and suitable habitat was abundant in the littoral areas. During 2022, young-of-year and juvenile individuals were detected in 2022 in good abundance at Breakfast Creek, indicating this species is continuing to recruit well within Breakfast Creek. This species can complete its life cycle in both permanent and more intermittent habitats and the 2021–2022 wetter conditions are providing this species with dispersal opportunities, which may lead to larger and more widespread populations in future years. Low pH levels (< 3.5), particularly within the lower Anglesea River wetlands, may inhibit the spread of Otway bush yabby within the Anglesea catchment, however the species has been detected in areas of lower pH in 2022 (2.8 in Breakfast Creek) and previously (4.85 in 2021 and 4.2 in 2020) (Ecology Australia 2020–2021), hinting that the Anglesea catchment population may tolerant of or adapting to lower pH conditions.

4.3.1 Aquatic ecology recommendations

Recommendations regarding the aquatic monitoring component were proposed after the 2018 monitoring event (Ecology Australia 2019). These recommendations remain current and are reproduced and expanded upon below:

- The monitoring design should be reviewed and refined as part of the review of the MAP. For example, it is unusual to collect 3 RBA samples per site for a compliance monitoring program, when objective attainment can be assessed using a single edge sample (in the absence of a riffle sample). Additionally, one site (Wetland 2/3) typically has too small an area of available habitat to collect 3 edge samples without potentially reducing the quality of all 3 samples collected (e.g. overlapping areas of habitat sampled). This is shown in the present year with the first edge sample collected at wetland 2/3 (i.e. targeting the 'best' habitat with no overlap) being the most diverse and abundant and subsequent samples producing a lesser result. Although collection of additional samples in monitoring programs is typically recommended for data analyses benefits (e.g. higher statistical power), RBA samples are not qualitative samples, and much more than three samples per site would be required to account for the large amount of variability. The cost savings associated with this change would be better directed towards enhancing the monitoring of southern pygmy perch and Otway bush yabby populations.

    - We also suggest that the review better define wetland 2/3 as this site is surveyed inconsistently between the annual and triennial survey years, i.e. combined in the annual survey and separated during the triennial survey since the annual surveys were relocated to wetland 2/3 from wetland 1. Given the very close proximity and lack of independence (wetlands 2 and 3 are only separated by a road with a connecting culvert crossing underneath), our suggestion is to permanently combine this site and re-define collectively as 'wetland 2'.

- Given that it has been 5 years since southern pygmy perch have been detected at BCT1, it would be beneficial to survey additional/alternative locations on Breakfast Creek to establish if a population persists in the area. At a minimum, we suggest including bait trapping at all Breakfast Creek sites during future triennial macroinvertebrate surveys (i.e. when additional sites on Breakfast Creek are surveyed for macroinvertebrates). Ideally, a one-off broader survey of the catchment would be undertaken including known refuge pools in the Breakfast Creek, Salt Creek and Anglesea River catchments (as identified in GHD 2010), supplemented by eDNA at other locations. As a genetically distinct population in an isolated catchment (Cesar 2012), it is of concern that local extirpation of the Breakfast Creek population may have occurred, that the current status of the species in the catchment is unknown, and that only one site is being monitored as part of this monitoring program. The broader survey would ideally be undertaken in late summer/autumn in terms of maximising capture rates (traditional methods) and minimising dilution rates (eDNA).
- Otway bush yabby has been an informal target species of the monitoring program since 2019. Although monitoring of this species has yielded more promising results than for southern pygmy perch in recent years, knowledge of the distribution and demographics of the broader population is still limited. It is recommended that Otway bush yabby be formally recognised as a target species in the next MAP. As the survey methods for southern pygmy perch is also suitable for Otway bush yabby (i.e. bait traps), we recommend that this be cost effectively piggy-backed on the expanded ongoing and one-off southern pygmy perch monitoring that is detailed above.
    - Collection of data from 2022 onwards should be consistent with the approach used in 2022, i.e. all Otway bush yabby should be recorded (measured, weighed, counted as appropriate) for both bait trapping and sweep netting.
    - Tracking population change over time for Otway bush yabby should occur when sufficient comparable data for this species is available.

5 References

Anstis M (2013) 'Tadpoles and Frogs of Australia.' (New Holland Publishing Pty Ltd: Sydney)

Barth BJ, Wilson RS (2010) Life in acid: interactive effects of pH and natural organic acids on growth, development and locomotor performance of larval Striped Marsh Frogs (*Limnodynastes peronii*). *The Journal of Experimental Biology* **213:** 1293–1300.

Barwon Water (2021) Anglesea borefield, Barwon Water, available at: https://www.yoursay.barwonwater.vic.gov.au/anglesea-borefield (accessed February 2021)

BOM (2022) Climate data online, Bureau of Meterology, available at: http://www.bom.gov.au/climate/data/ (accessed February 2022)

Cassanova M T (2011) Using water plant functional groups to investigate environmental water requirements. Freshwater Biology 56; 2637-2652.

Chessman (1995) Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* **20**, 122–129.

Chessman (2003) New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research*, 2003, **54**, 95–103.

Chinathamby K, Reina RD, Bailey PCE, Lees BK (2006) Effects of salinity on the survival, growth and development of tadpoles of the southern brown tree frog, *Litoria ewingii*. *Australian Journal of Zoology* **54:** 97–105.

Courtney L.A. & Clements W.H. (1998) Effects of acidic pH on benthic macroinvertebrate communities in stream microcosms. *Hydrobiologia* **379**, 135–145.

Davie A W, Mitrovic S M, (2014) Benthic algal biomass and assemblages changes following environmental flow releases and unregulated tributary flows downstream of a major storage. *Marine & Freshwater Research* **65** (12) 1059-1071

DELWP (2021c) Flora and Fauna Guarantee Act Threatened List. Available at https://www.environment.vic.gov.au/conserving-threatened-species/threatened-list (accessed: February 2022).)

DELWP (2022a) Ecological Vegetation Class (EVC) Benchmarks for each Bioregion. Available at: https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks (accessed: February 2022)

DELWP (2022b) Victorian Biodiversity Atlas Version 3.2.8 database. Available at https://vba.dse.vic.gov.au/vba/index.jsp (accessed: February 2022).]

DEPI (2014) Advisory list of rare or threatened plants in Victoria – 2014. (Department of Sustainability and Environment: East Melbourne)

Doeg T, Muller K, Nicol J and VanLarrhoven J (2012) Environmental Water Requirements of Groundwater Dependant Ecosystems in the Musgrave and Southern Basins Prescribed Wells Areas on the Eyre Peninsula. DFW Technical Report 2012/16, (Government of South Australia, Department of Water: Adelaide).

DSE (2009) Advisory list of threatened invertebrate fauna in Victoria – 2009. (Department of Sustainability and Environment: East Melbourne)

DSE (2013) Advisory list of threatened vertebrate fauna in Victoria - 2013. (Department of Sustainability and Environment: East Melbourne)

Ecology Australia (2009) Anglesea Borefield Flora and Fauna monitoring. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2011) Anglesea Borefield Flora and Fauna monitoring: Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2012) Anglesea Borefield Flora and Fauna monitoring: 2011-12. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2013a) Anglesea Borefield Flora and Fauna monitoring: 2012-13. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2013b) Anglesea Borefield Bulk Entitlement Review: Terrestrial Ecology Assessment. Report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2014) Anglesea Borefield 2014 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2015) Anglesea Borefield 2015 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2016) Anglesea Borefield 2016 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2017) Anglesea Borefield Ecological Monitoring and Assessment Program 2017. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2018) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2018. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2020) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2019. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2021) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2020. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

Ecology Australia (2022) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2021. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)

EPA (2010) Environmental quality guidelines for Victorian lakes. Publication 1302, February 2010 (Environment Protection Authority Victoria: Southbank).

EPA (2021) Guideline for Environmental Management (GEM) – Rapid bioassessment methodology for Rivers and Streams. Publication 604.2, April 2021. (Environment Protection Authority Victoria: Southbank)

Foti R, del Jesus M, Rinaldo A and Rodriguez-Iturbe I (2012) Hydroperiod regime controls the organization of plant species in wetlands. Proceedings of the National Academy of Sciences of the United States of America. 109: 48, 19596–19600

GHD (2010) Anglesea Borefield Project BE Aquatic Monitoring. Unpublished report prepared for Barwon Water. August 2010

GHD (2011) Report for Anglesea Borefield Project Bulk Entitlement Aquatic Monitoring. Unpublished report prepared for Barwon Water. November 2011

GHD (2012) Anglesea Borefield MAP Aquatic Monitoring. Unpublished report prepared for Barwon Water. February 2013

GHD (2013) Anglesea Borefield Bulk Entitlement Review: Bulk Entitlement Review Report. Unpublished report prepared for Barwon Water. July 2013

GHD (2013b) Anglesea Borefield MAP 2012-2013 Aquatic Monitoring Program. Unpublished report prepared for Barwon Water

GHD (2014) Anglesea Borefield MAP Aquatic Ecology Report spring 2013 autumn 2014. Unpublished report prepared for Barwon Water. December 2014.

GHD (2015) Anglesea Borefield MAP Aquatic Ecology Report Spring 2014. Unpublished report prepared for Barwon Water. August 2015.

GHD (2016) Anglesea Borefield MAP Aquatic Ecology Report Spring 2015. Unpublished report prepared for Barwon Water. September 2016

GHD (2017) Anglesea Aquatic Monitoring Spring 2016. Unpublished report prepared for Barwon Water. June 2017

Hamer AJ, Smith PJ, McDonnell MJ (2012) The importance of habitat design and aquatic connectivity in amphibian use of urban stormwater retention ponds. *Urban Ecosystems* **15:** 451–471.

Hawking JH (2000) A preliminary guide to keys and zoological information to identify invertebrates from Australian freshwaters. Cooperative Research Centre For Freshwater Ecology, Ellis Street, Thurgoona, P.O. Box 921, Albury, NSW 2640

Hazell D, Osborne W, Lindenmayer D (2003) Impact of post-European stream change on frog habitat: southeastern Australia. *Biodiversity and Conservation* **12:** 301–320.

Lane SJ, Mahony MJ (2002) Larval anurans with synchronous and asynchronous development periods: contrasting responses to water reduction and predator presence. *Journal of Animal Ecology* **71:** 780–792.

MDFRC (2013) Draft index of keys. Murray-Darling Freshwater Research Centre: Wodonga

Mitrovic S, Bowling L (2013) Chapter 2.4 Identification and management of freshwater algae in Paul, S (Ed), 'Workbook for Managing Urban Wetlands in Australia'. 1st edn. (Sydney Olympic Park Authority), eBook available through www.sopa.nsw.gov.au/education/WETeBook/, ISBN 978-0-9/874020-0-4.

Tripole S., Vallania A. & Corigliano M. (2008) Benthic macroinvertebrate tolerance to water acidity in the Grande river sub-basin (San Luis, Argentina). *Limnetica*, **27**, 29-38

Victorian Government (2009) Bulk Entitlement (Anglesea Groundwater) Order 2009, Victorian Government Gazette, No S 224 Tuesday 30 June 2009. Victorian Government Gazette

Victorian Government (2014) Bulk Entitlement (Anglesea Groundwater) Order 2009, Victorian, 6 revised, September 2014. Victorian Government

Victorian Government Gazette (2021) Environment reference standard. S245 26 May 2021

Wassens S, Wacott A, Wilson A, Freire R (2013) Frog breeding in rain-fed wetlands after a period of severe drought: implications for predicting the impacts of climate change. Hydrobiologia 708: 69-80.

Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Swamp, native plant species and Functional Groups (native plant species only) spring 2022.

Status	Scientific name	Common name	FG	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	Banksia marginata	silver banksia	Tdr			x			
	Cassytha glabella	slender dodder-laurel	Tdr				X	X	X
	Cassytha pubescens	downy dodder-laurel	Tdr			X			
	Chorizandra australis	southern bristle-sedge	Se			X			
	Cycnogeton procerum sp. aff.	common water-ribbons	Se	X	X	X		X	X
	Drosera binata	forked sundew	Tda				X		
	Empodisma minus	spreading rope-rush	Ate		X		X	X	X
P	*Epacris obtusifolia*	blunt-leaf heath	Atw				X	X	X
vu	*Eucalyptus falciformis*	western peppermint	Tdr			X			
	Gahnia radula	thatch saw-sedge	Tdr			X			
	Gahnia sieberiana	red-fruit saw-sedge	Ate	X				X	X
P	*Gleichenia dicarpa*	pouched coral-fern	Ate		X		X	X	X
P	*Gleichenia microphylla*	scrambling coral-fern	Ate				X	X	
	Isolepis inundata	swamp club-sedge	Ati	X	X				
	Juncus procerus	tall rush	Ate	X					
	Lepidosperma longitudinale	pithy sword-sedge	Ate					X	X
	Leptospermum lanigerum	woolly tea-tree	Atw						X
	Leptospermum spp.	tea-tree	T	X	X	X	X	X	X
	Machaerina arthrophylla	fine twig-sedge	Se	X	X			X	X
	Machaerina juncea	bare twig-sedge	Ate		X				X
	Machaerina tetragona	square twig-sedge	Se			X	X		
P	*Melaleuca squarrosa*	scented paperbark	Atw	X	X	X	X	X	X
	Opercularia varia	variable stinkweed	Tdr			X			
	Platylobium obtusangulum	common flat-pea	Tdr			X			

Status	Scientific name	Common name	FG	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	Pteridium esculentum subsp. *esculentum*	austral bracken	Tdr		X	X			
	Rhytidosporum procumbens	white marianth	Tdr			X			
	Schoenus brevifolius	zig-zag bog-sedge	Atw		X	X	X	X	X
P	*Sprengelia incarnata*	pink swamp-heath	Ate				X	X	
	Thelymitra sp.	sun-orchid	Tdr			X			
	Xyris operculata	tall yellow-eye	Ate				X		
Number of species per site				**7**	**10**	**15**	**12**	**13**	**13**
Total number of species						**30**			

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Estuary, plant species and Functional Groups spring 2022.

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
# P	*Acacia longifolia* subsp. *longifolia*	sallow wattle	NA			X	
# P	*Acacia longifolia* subsp. *sophorae*	coast wattle	NA	X			
	Cycnogeton procerum sp. aff.	common water-ribbons	Se	X	X	X	X
	Eucalyptus ovata subsp. *ovata*	swamp gum	Tda	X		X	
	Ficinia nodosa	knobby club-sedge	Tdr			X	
	Gahnia sieberiana	red-fruit saw-sedge	Ate	X			
*	*Gladiolus spp.*	gladiolus	NA		X		
	Goodenia ovata	hop goodenia	Tdr	X	X	X	
	Goodenia radicans	shiny swamp-mat	Arp		X	X	X
	Isolepis inundata	swamp club-sedge	Ati	X			
	Juncus kraussii subsp. *australiensis*	sea rush	Se	X	X	X	X
	Lachnagrostis filiformis	common blown-grass	Tdr		X		
	Leptospermum spp.	tea-tree	T	X	X	X	
	Lobelia anceps	angled lobelia	Ate	X	X	X	X
	Myoporum insulare	common boobialla	Tda		X		
	Phragmites australis	common reed	Arp		X	X	
	Poa poiformis var. *poiformis*	coast tussock-grass	Tdr		X	X	
P	*Senecio glomeratus*	annual fireweed	Tdr		X		
*	*Symphotrichum subulatum*	aster-weed	NA		X		
	Typha domingensis	narrow-leaf cumbungi	Se	X			
	Rytidosperma sp.	wallaby-grass	NA		X		
Number of species per site				**10**	**14**	**11**	**4**
Total number of species				**21**			

Appendix 3 Results by sample, including genus identifications where identified, for all macroinvertebrate sites sampled in 2022 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Species		W2/3				BCT1				SC1			
Family	**Genus**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**
Acarina	sp.							1	**1**				
Chironominae	sp.		7		**7**								
Corixidae	sp.	1			**1**								
Culicidae	sp.	6		2	**8**								
Dytiscidae	sp.	3		1	**4**		1		**1**	1	1	3	**5**
Gripopterygidae	*Illiesoperla*					13	13	23	**49**			1	**1**
Hydrobiosidae	*Taschorema* complex					1		1	**2**				
Janiridae	sp.	3			**3**						1		**1**
Leptoceridae	sp.*	2			**2**								
Leptoceridae	*Triplectides*					3	1	1	**5**		4		**4**
Leptophlebiidae	*Nousia*										1		**1**
Nannochoristidae	sp.					1		1	**2**		4	1	**5**
Oligochaeta	sp.										1		**1**
Orthocladiinae	sp.										1	2	**3**
Paramelitidae	sp.									3	4	8	**15**
Polycentropodidae	*Plectrocnemia*										1		**1**
Scirtidae	sp.	64	2	10	**76**	3	1		**4**	3			**3**
Simuliidae	sp.					2		9	**11**			4	**4**
Talitridae	sp.					1			**1**				
Tanypodinae	sp.					1		2	**3**		18	6	**24**
Tipulidae	sp.									1		1	**2**
Veliidae	sp.					1		1	**2**	4	3	5	**12**

*Specimens damaged and could not be identified to genus