ECOLOGY
AUSTRALIA

Anglesea Borefield Ecological Monitoring and Assessment Program 2021

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, Greenfield A, Goodman B, and Bloink C.	
File	REPORT Anglesea MAP 2021_Ecology Australia 19-038_FIN02 30May22	
Bioregion	Otway Plain	
Distribution	Tom Scarborough	Barwon Water

Document History

Status	Changes	Author	Reviewer	Date
Draft 1	First Draft	Halliday B.T, Kerr N, Greenfield A, Goodman B, and Bloink C.	Bloink C. and Palmer G.	28/02/2022
Draft 2	Updates addressing client comments	Halliday B. T, Kerr N, Greenfield A and Bloink C.		19/04/2022
Final	Minor update	Halliday B. T. and Goodman B.		01/08/2022

Citation: Halliday B.T, Kerr N, Greenfield A, Goodman B, and Bloink C. (2022). Anglesea Borefield Ecological Monitoring and Assessment Program 2021. Report to Barwon Water, Ecology Australia Pty. Ltd., Fairfield, Victoria.

Cover photo: Otway bush yabby released into Breakfast Creek during the 2021 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
- Ashlen Campbell	Ecology Australia
- Matthew Linn	Ecology Australia
- Iris Hickman	Ecology Australia
- Matilda Alvarez	Ecology Australia
- Josie Bailey	Ecology Australia
- Gary Palmer	Ecology Australia

All works were completed under the following permits:

- Animal ethics: WSIAEC #7.19
- Fisheries general research permit 1142
- DELWP research permit 10009126
- 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 2021. The 2021 aquatic ecological monitoring in 2021 included the triennial macroinvertebrate survey of 11 sites. The terrestrial monitoring, which is typically biennial and last conducted in 2020, was required again in 2021 as the borefield was operated in 2021, albeit in standby mode, 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 six permanent transects in the Anglesea Swamp and four 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 eight sites in the Anglesea Swamp and four 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 two sites. Fish and macroinvertebrate monitoring included:

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

Findings

Vegetation

Ecological Vegetation Classes and 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. 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 have displayed a slightly decreasing trend across all monitoring years. However, in the Anglesea Estuary, the dry functional group is displaying a slight increasing trend across all monitoring years.

The number of sites containing algal mats has decreased from a maximum of five (2017 and 2019) to three sites (2020 and 2021). Despite this, two of the three sites display an increasing trend in the frequency of algal mats recorded across each site.

Frogs

Frogs were recorded from 3 of 8 sites at Anglesea Swamp within 100 m of the site and frogs were heard calling from more than 100 m away at 6 of the 8 sites in 2021. Southern brown tree frog, common froglet and southern bullfrog were all recorded within the Anglesea swamp. Frogs were recorded at all 4 of the Anglesea Estuary sites in 2021. Only southern brown tree frog and southern bullfrog were recorded within the Anglesea Estuary. All records in 2021 were from calling male frogs with none visually sighted. Results of the 2021 frog surveys show in general that the number of frogs heard calling at the estuarine sites are higher than all years except 2020. On the other hand, the swamp sites show an increase in frog numbers compared to 2019 and 2020. However, both sites show that there are different responses by different species each year.

Southern pygmy perch & Otway bush yabby

Southern pygmy perch were again only detected from one of the two monitoring sites, the Salt Creek site, which has been a consistent result for the past four years. Recruitment was again detected at the Salt Creek site and is the second year in a row where young-of-year and juvenile fish were detected. This year's sampling (2021) was the fourth 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 six of the 11 sites surveyed during the triennial macroinvertebrate survey including the Salt Creek and Breakfast Creek tributary sites where they have been detected annually since 2017 (Ecology Australia 2018–2021). Otway bush yabby abundance abundances were considerably lower in 2021 compared with 2020, although this may be due to the increased habitat available in 2021 due to the wet winter/spring. Small, young-of-year/juvenile, individuals were detected in 2021, indicating this species is continuing to recruit.

Macroinvertebrates

The macroinvertebrate monitoring results were relatively consistent with previous years and indices comparison against State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018) was overall fairly poor. The Breakfast Creek and tributary sites appear to have marginally improved and the upper Anglesea River sites appear to have marginally declined (C.f. Ecology Australia 2019, 2021). Due to the very wet winter/spring in 2021 all 11 triennial macroinvertebrate survey sites had sufficient water to collect triplicate edge samples (only nine we sufficiently wet during the most recent triennial macroinvertebrate survey).

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 2009–2021).

The current MAP requires aquatic ecological monitoring to be undertaken annually (with an increased number of sites every three 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 stand-by maintenance mode during the 2020/21 financial year only extracting a very small volume of 13.5 ML (Barwon Water 2022). As borefield extraction occurred during 2021 (i.e. during this present reporting period) the MAP requirement for terrestrial ecological monitoring was triggered (this would not have been required in 2021 if the borefield was not operated).

The 2021 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic Ecology

The Aquatic Ecological monitoring component included the one in three year spring monitoring of macroinvertebrates at 11 sites:

- Breakfast Creek (BC 1–3) tributary (BCT 1–2)
- Salt Creek (SC1)
- Lower Anglesea River wetland (Wetland 1–3)
- Upper Anglesea River (UAR1–2)

Additionally, this component included spring sampling of southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocherax tasmanicus* at two 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 six sites and frog monitoring at eight 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 four 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 2020 data with annual data collected since the MAP review and update in 2014.

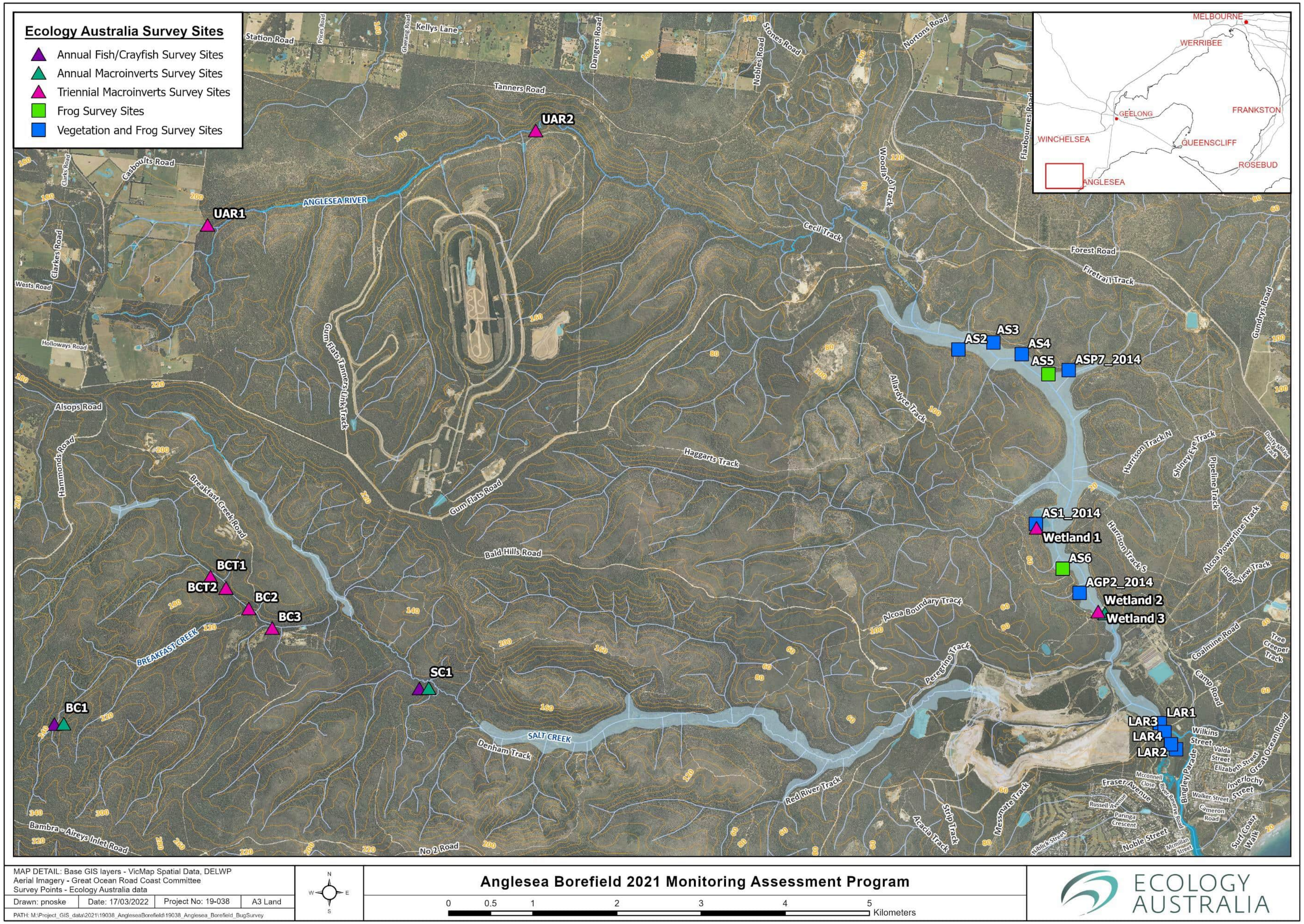


Figure 1. Anglesea Borefield Ecological Monitoring and Assessment Program survey sites, 2021

2 Methods

2.1 Vegetation

In the last week of October 2021, vegetation monitoring was conducted at the following sites in the Anglesea Swamp.: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014; and the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Data collection

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

Survey methods collect the presence/ absence of vegetation species within quadrats located along transects to produce a frequency score for each species. Species abundance in each quadrat is determined by recording the presence of each species that have live plants rooted in or overhanging each cell.

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, rounded to the nearest 5% and presence of algal mat. Photo points are taken at each site and are 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.

Water depth is a snapshot in time (one day of the year) and will vary considerably over time depending on rainfall. Hydroperiod is a fundamental driver of wetland condition (e.g. Foti et al. 2012).

Bare ground provides space for plant recruitment. This can indicate potential change at a site, for example — are the extant Functional Groups (FGs) recruiting, or are conditions favouring the recruitment of drier or wetter groups?

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 are 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.

To analyse species composition across monitoring seasons, the average percentage frequency of each species across all sites was calculated for each monitoring season for both the Anglesea Swamp and Anglesea Estuary. Species composition (species richness and abundance) was then analysed through an ordination using non-metric multidimensional scaling (NMDS). Vectors were fitted for species that significantly contributed to the community composition differentiation between years.

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, the average percentage frequency of broad functional groups: Amphibious (Atw, Ate, Atl, Arp), Aquatic (Se) and Dry (T, Tdr, Tda) across all sites for each monitoring period was presented in a bar chart form 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 three 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 three species were displayed, therefore sites with fluctuating dominant species across the years may display more than three species.

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		
Atl	*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 ATl 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 ATl 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

Zoologists undertook two repeat surveys for frogs at 12 sites, on 17–18/11/2021 and 21–22/12/2021(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.

Survey sites comprise the ten sites required by the MAP, as well as two additional sites (AS5 and AS6), which are surveyed if very low frog activity is observed in the Anglesea Swamp. In addition to the surveys undertaken by Ecology Australia, the local community provided information of frog calling from the greater Anglesea area.

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

Zoologists used both diurnal and nocturnal visual 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 2021, all frog sampling 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 two zoologists listening for approximately five 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 11 sites between 28 October and 30 November 2021. As per the established methods (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 2003). 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 water bodies with little to no flow. The sampling objective was to subsample all types of habitats 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 habitats 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, Odonata, Ephemeroptera, Plectoptera and Trichoptera).

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 in 2017, this species has been monitored concurrently with fish and macroinvertebrates (Ecology Australia 2018–2021).

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 listed separately
- 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 three samples). Where available, the results were compared against indices objectives outlined in State Environment Protection Policy – Waters (SEPP(W); Victorian Government Gazette 2018) for surface waters in the Central Foothills and Coastal Plains geographic region. Where there is no relevant index available in the SEPP (W), the results were compared against the indices objectives used in previous reports.

The following indices were used to analyse macroinvertebrate data:

- Number of taxa — total number of taxa based on taxonomic resolution levels described above
- SIGNAL2 score — average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003). Table 2 provides the corresponding water quality categories.
- Number of EPT taxa — number of taxa 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
- Number of EPTO taxa — number of taxa 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).

Table 2 SIGNAL score classifications (Chessman 1995)

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

2.3.4 Fish surveys

Surveys targeting southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocharax tasmanicus* were undertaken at two sites: BCT1 and SC1 on 9and 16 November 2021, respectively. For consistency with previous surveys, the BCT1 fish site was again relocated downstream.

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 2018–2021).

The first 30 southern pygmy perch captured at each site were measured (total length) to the nearest millimetre and weighed to the nearest 0.1 gram. All remaining southern pygmy perch were counted.

All captures of Otway bush yabby were recorded per gear replicate (with individuals captured both within the bait traps and within sweep samples). All Otway bush yabbies captured using sweep samples were returned to the point of capture before macroinvertebrate samples were live-picked as described above (see: Section 2.3.1).

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and in situ water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).
- The flow status estimate as per the USEPA field sheets that are incorporated into later iterations of the Victorian EPA Rapid Bioassessment field sheets (e.g. Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on the identification of several disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads, bridges/culverts/fords, rubbish, drain input, water extraction points, stock access, sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and

hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (°C), conductivity (mS/cm) and turbidity (NTU)) were made with a calibrated Horiba U-52 water quality meter.

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).

Up until late 2021, Victoria maintained two threatened species lists including taxa listed under the FFG Act and the non-statutory list called the Victorian Threatened Species Advisory Lists (DEPI 2014). These two lists have recently been consolidated into one comprehensive list under the FFG Act referable to as the FFG Threatened List (DELWP 2022c) and the Advisory list has now been revoked.

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). Findings for each site are 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 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 14, Figure 17, Figure 18, Figure 19 and Figure 20.

3.1.1 Floristic composition

A total of 29 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 (62.9%), eight plant species were exotic (29.6%) and two plant species were native Victorian species not indigenous to the study area (7.4%) (Appendix 2). Species richness in the Anglesea Swamp increased from 26 to 29 species between 2020 and 2021, while in the Anglesea Estuary sites, total species richness decreased by one species from 27 to 26 and native species richness decreased from 17 to 16 between 2020 and 2021.

Changes in species richness were variable across sites. At 3 of the 6 Anglesea Swamp sites, species richness increased, while one site remained stable, and two sites decreased in the total number of species recorded compared to the 2020 monitoring season (Figure 2). Across the Anglesea Estuary, species richness remained stable at two sites and decreased at two sites compared to the 2020 monitoring period (Figure 2). Furthermore, native species richness varies across sites, ranging from 6–16 in the swamp and 6-12 in the estuary (Table 3).

Table 3 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	16	9	3	4
AS3	10	2	7	1
AS4	14	3	8	3
ASP7_2014	15	2	10	3
AS1_2014	12	3	6	3
AGP2_2014	6	1	3	2
Anglesea Estuary				
LAR1	9	3	4	2
LAR2	12	6	4	2
LAR3	12	6	4	2
LAR4	6	1	3	2

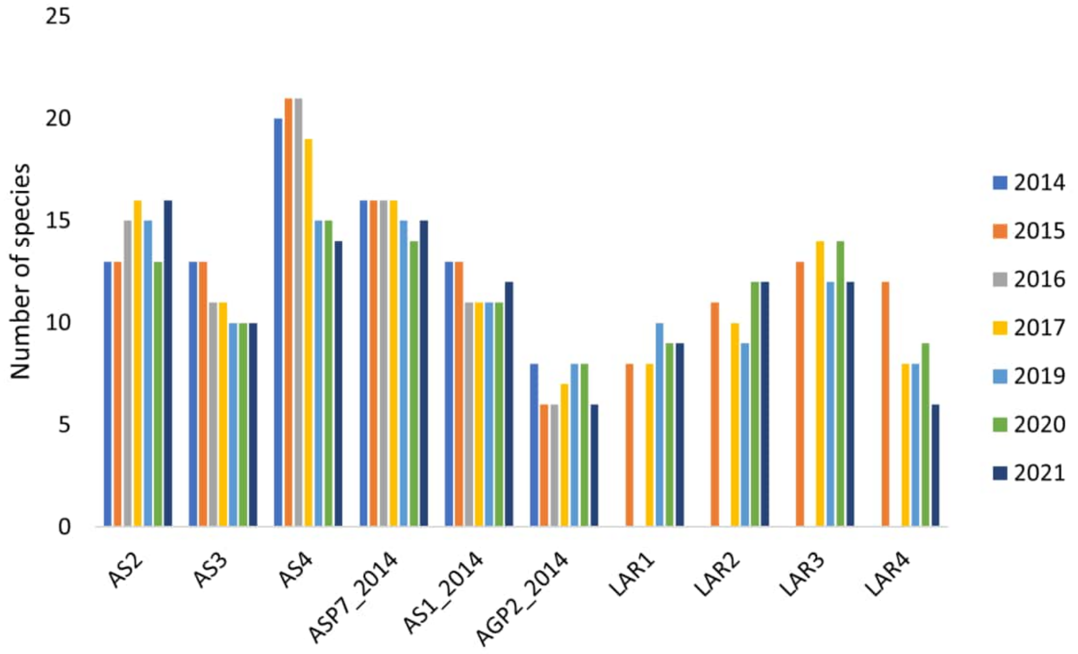


Figure 2 Native species richness at each survey site in the Anglesea Swamp (AS2, AS3, AS4, ASP7_2014, AS1_2014 and AGP2_2014) and the Anglesea Estuary (LAR1, LAR2, LAR3 and LAR4) for each season which required monitoring.

3.1.2 Species composition across years

The Anglesea Swamp NMDS ordination showed a large and distinct difference in species community composition between the 2019, 2020, and 2021 surveys and the 2014, 2015, 2016 and 2017 surveys (Figure 3). In addition, community composition in 2015 differed from 2014, 2016 and 2017. The difference between these groups of years was greatly driven by the reduction in frequency of common water-ribbons *Cycnogeton procerum sp. aff.* from near 80% in 2016 and 2017 to approximately 65% in 2019-2021. The other species driving differentiation between years were primarily dry land species associated with the Heathy Woodland EVC. This EVC fringes the wetland ecosystems and makes up a very small proportion of the monitored quadrats. Changes within dryland species composition such as this are not indicative of meaningful changes in the swamp vegetation between years.

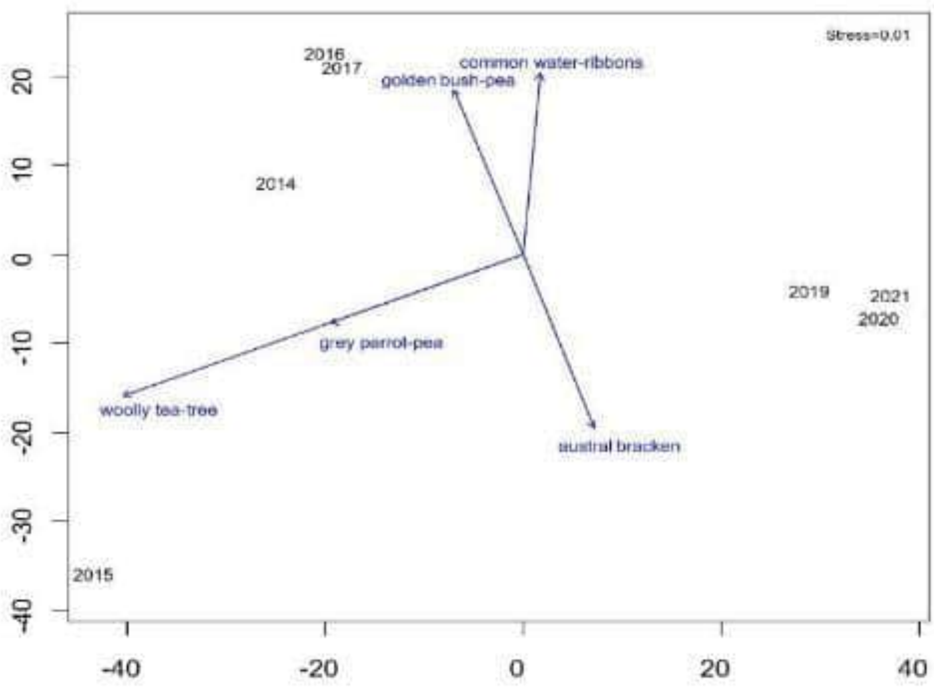


Figure 3 NMDS ordination of among-year variation in plant species composition across all Anglesea Swamp sites for all monitoring years. Lines show statistically significant (p = 0.01) vectors indicating strength of each species' association with each year.

The Anglesea Estuary NMDS ordination showed that weak similarity in species composition between all years. This result could not be easily explained and there appears to be large variability between species, sites and years (Figure 4).

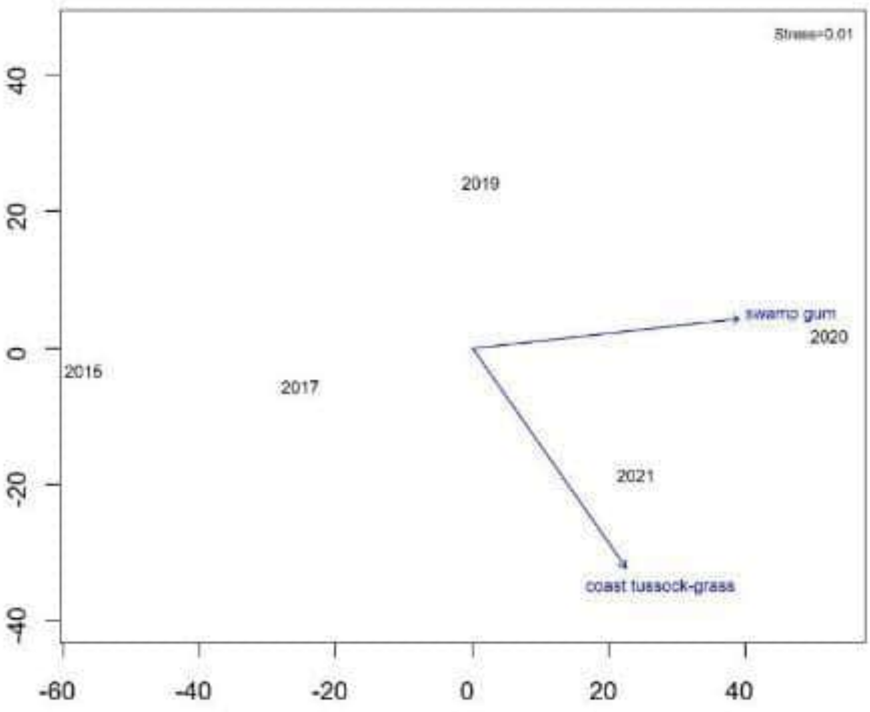


Figure 4 NMDS ordination of species composition across all Anglesea Estuary sites for all monitoring seasons. Lines show statistically significant (p = 0.05) vectors indicating strength association with each year.

3.1.3 Plant functional groups

Anglesea Swamp

In the Anglesea Swamp, six FGs were represented (T, Tdr, Se, Atw, Atl and Ate), while no species from Arp functional group were recorded (Table 3). The manuka *Leptospermum scorparium* (Tda) was recorded in previous years however, this species was not recorded present in the 2021 monitoring period. This is not due to a local extinction of the species but due to taxonomic difficulty. The prickly tea-tree *Leptospermum continentale* (Tdr) and the manuka (Tda) have proven to be difficult to distinguish between in the field. Therefore, for this year's analysis, all records of prickly tea-tree and manuka were grouped together as tea-tree *Leptospermum spp.* and assigned the summary functional group of T (Terrestrial).

The average frequency of Aquatic FGs (Se) across all Anglesea Swamp sites showed a slight increase from 67% in 2019 to 72% in 2021, however the average frequency still remained lower than the first four monitoring years (Figure 5). Overall, average frequency of Dry FGs (T, Tda, Tdr) continued to decrease slightly each monitoring season from 29% in 2014 to 24% in 2021. The average frequency of Amphibious FG's (Atw, Ate, Atl, Arp) has remained relatively consistent ranging from 83 – 86 %, apart from 2019 which showed an increase to 90% average frequency across all sites (Figure 5). 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.

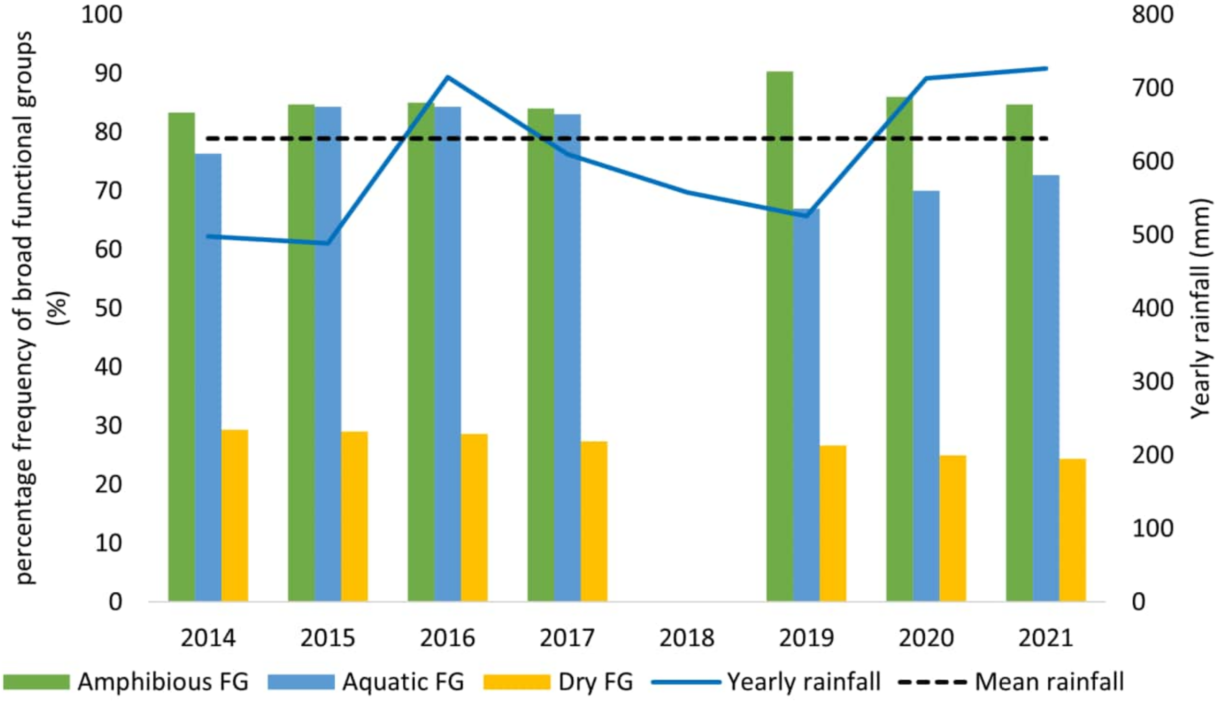


Figure 5 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) and yearly and mean annual rainfall (right y-axis) across all sites in the Anglesea Swamp for each monitoring period. Swamp sites were not monitored in 2018 due to no water extraction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

Anglesea Estuary

Plants from seven FG's were recorded in the Anglesea Estuary (T, Tda, Tdr, Se, Ate, Atl, Arp), while no species from the Atw FGs were recorded (Table 3). Prickly tea-tree and manuka were treated the same as in the swamp and combined with tea-tree *Leptospermum spp.*(T).

The average frequency of Aquatic FGs (Se) across all Anglesea Estuary sites exhibited a slight increase from 51% in 2020 to 59 % in 2021, however, this remains lower than all other monitoring years which ranged from 84 – 86 % (Figure 6). The average frequency of Amphibious FGs in 2021 was 89.5% which remained relatively consistent with 2015 – 2019 results despite the decrease in 2020 to 72%. The average frequency of Dry FGs has fluctuated, however 2021 represented an increase from 53% in 2019 to 71% in 2021 (Figure 6).

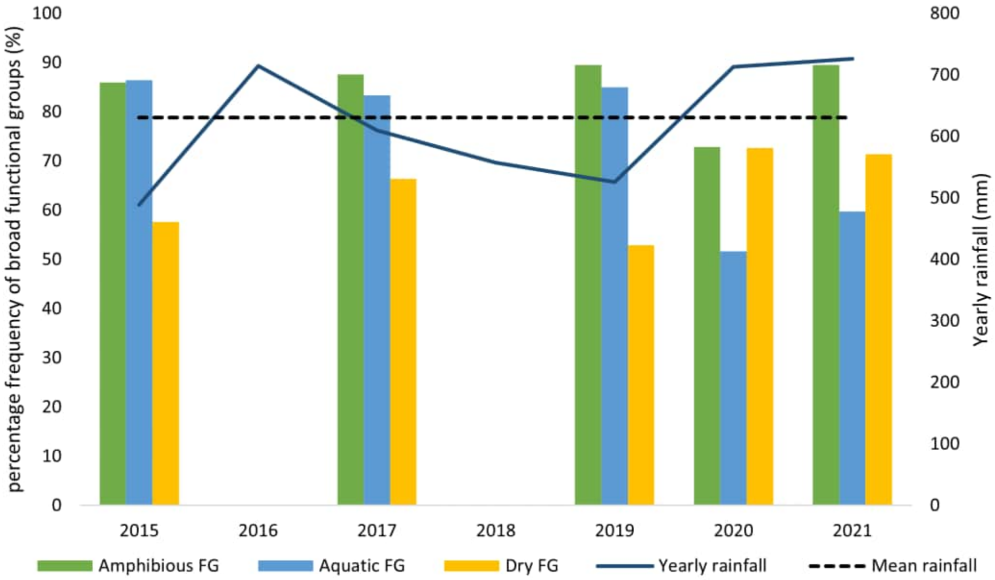


Figure 6 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) across all sites in the Anglesea Estuary for each monitoring period and yearly and mean annual rainfall (right y-axis). Estuary sites were not monitored in 2016 and 2018 due to no water extraction to triggering monitoring.

Algal mats

Algal mats remained absent from sites AS2 and AS3 and have not been recorded in ASP7_2014 since 2019. Algal mats continue to be present in AS1_2014, AG2_2014 and AS4 with a large increase in the percentage of quadrats containing algae at AS4 from zero in 2020 to 58% of quadrats in 2021 (Figure 7). Algal mats were not recorded in any of the Anglesea Estuary sites in 2021 (Figure 7).

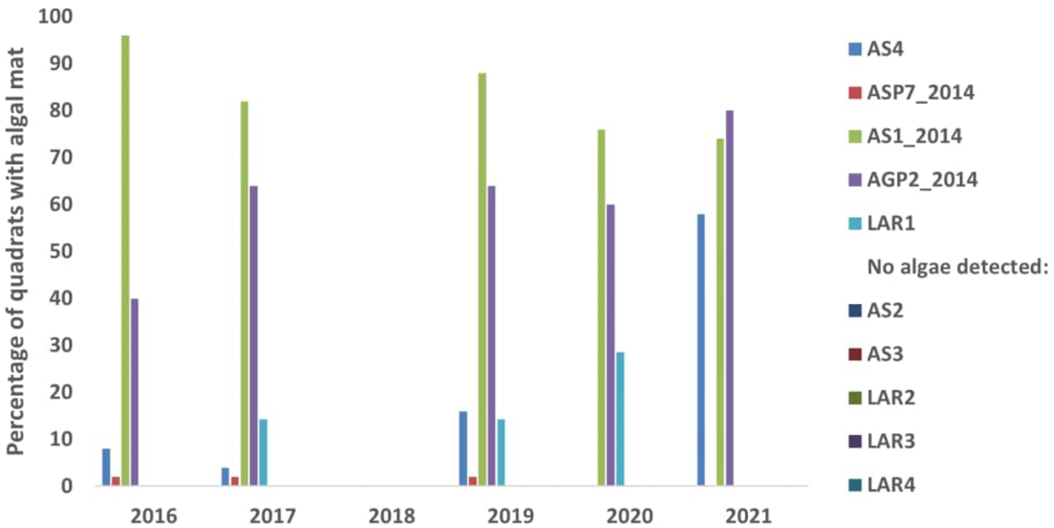


Figure 7 Algae mat records at all sites in the Anglesea Swamp and Anglesea Estuary from first detection in 2016. No monitoring was undertaken in the Anglesea Swamp 2018 or in the Anglesea Estuary in 2016 or 2018 due to no water extraction triggering monitoring.

3.2 Frogs

3.2.1 Survey conditions

The 8 sites at Anglesea Swamp all held water during the first survey period, with an average water depth at the site approximately 31 cm. Water depth at the study sites decreased by the second survey period to an average depth of approximately 8 cm. One site (AS5) had dried completely. At the estuary sites, the water depth remained relatively constant.

Weather conditions recorded during the two survey periods are summarised in Table 4.

Table 4 Weather conditions during frog surveys, 2021

Variable	Survey 1	Survey 2
Temperature (°C)	16.5	16.3
Humidity (%)		73
Cloud cover (0–8)	4	0
Moon light (0–4)	3	4
Wind speed (0–3)	0	0
Rainfall during survey (0–3)	0	0
Rain in past 24 hours (None–heavy)	Moderate	None

3.2.2 Frog species richness and abundance

The number of frogs estimated to be calling within 100 m of the study sites is provided in Figure 8. Since 2014 the number of frogs has varied every year, peaking 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 2021 and had the highest number of individuals detected since 2014. The number of southern bullfrogs also increased this year, with all other species at the other sites decreasing in abundance from last year.

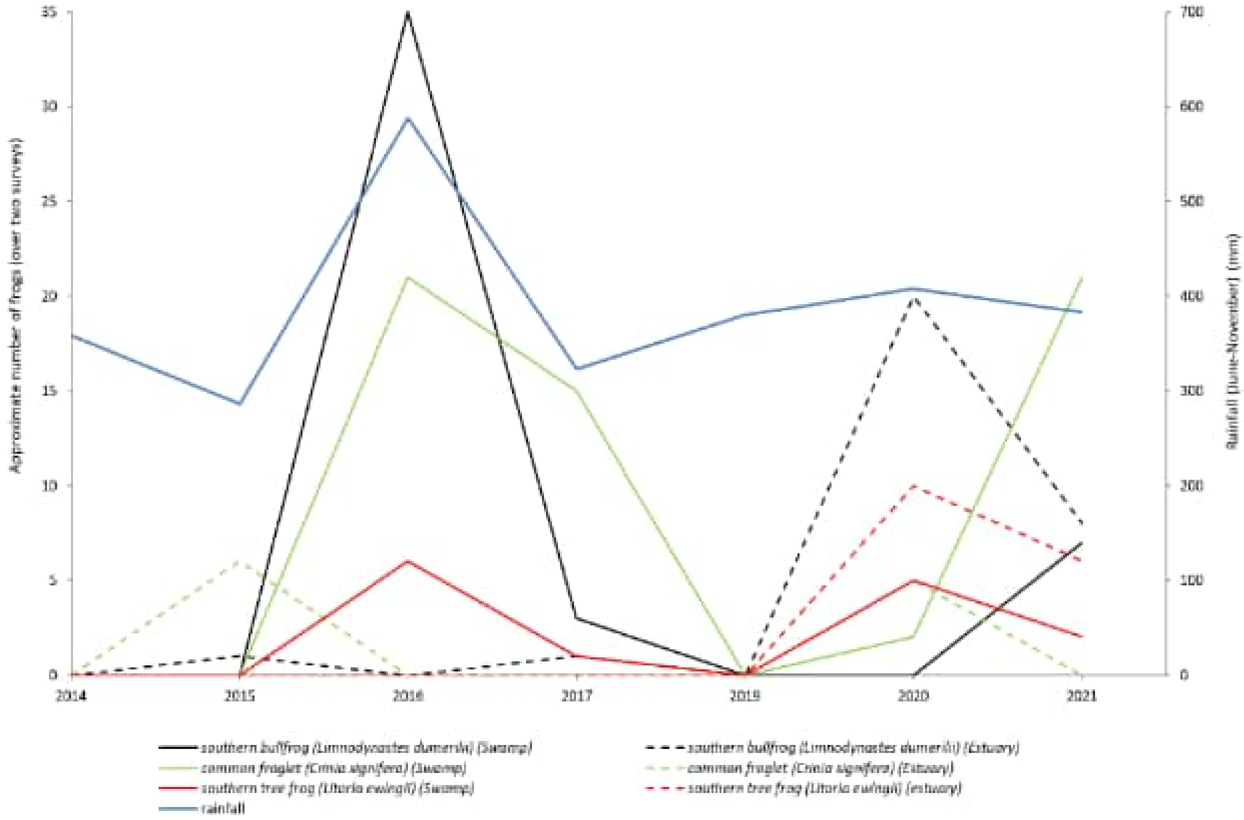


Figure 8 **The number of frogs heard calling within 100 m of the survey sites at Anglesea Swamp and Anglesea Estuary from 2014 to 2021. Included in the mean winter to spring rainfall at Aireys Inlet (blue line).**

Anglesea Swamp

Frogs were recorded from 3 of the 8 sites at Anglesea Swamp within 100m of the site (Table 5). Frogs were heard calling from more than 100m away at 6 of the 8 sites. All the records were from calling male frogs, and none were visually sighted. Only 3 species were recorded at the site: southern brown tree frog *Litoria ewingii*, common froglet *Crinia signifera* and southern bullfrog (pobblebonk) *Limnodynastes dumerilii*.

Site AS2 showed the highest species richness with all three species recorded from that site during the first survey. If frogs calling from more than 100 m were taken into account, then AS4 and AS3 also had all 3 species present.

Table 5 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)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
AS2	2 (0)	0 (0)	11-20 (0)	0 (0)	6-10 (0)	1 (0)	3
AS3	0 (1-5)	0 (0)	1-5 (0)	0 (0)	0 (6-10)	0 (0)	1
AS4	0 (1-5)	0 (0)	0 (1-5)	0 (0)	0 (3)	0 (0)	0
AS5	0 (1-5)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0
AS6	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
ASP7_2014	0 (2)	0 (0)	1-5 (0)	0 (0)	0 (0)	0 (0)	1
AGP2_2014	0 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0

Anglesea Estuary

Frogs were recorded at all 4 of the Anglesea Estuary sites (Table 6). In contrast to the Anglesea Swamp sites, the common froglet was not detected from any of the estuary sites. Site LAR1 was the only site where both the southern brown tree frog and southern bullfrog (pobblebonk) were heard. The southern brown tree frog was the most often heard frog during the second survey, with only 1 site (LAR2) recording any frogs within 100 m of the site.

Table 6 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Estuary sites, 2021. 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	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)	5–10 (0)	2
LAR2	0 (2)	1–5 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
LAR3	0 (1)	0 (0)	0 (0)	0 (0)	5–10 (0)	0 (0)	1
LAR4	0 (1)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1

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 2021 surveys, all sites had sufficient standing water to allow for all water quality parameters to be measured during the first survey. This had declined by the second survey such that three sites (AS2, AS3, AS6 and ASP7) had insufficient standing water for reliable water quality measurement. Sites were acidic (pH of 2.65–3.97) and electric conductivity was low to moderate, ranging from 0.67 to 1.86 ms/cm. Water temperatures were relatively high, with all but three measurements above 15 °C (range: 16.5–19.7 °C). Turbidity was more variable across sites, being generally low (range: 0–52 NTU) with most values being under 15 NTU. Similarly, dissolved oxygen levels were variable (range: 7.9–18.8 mg/L), with only 3 sites able to be measured during 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 measurements taken in the Anglesea Swamp. All sites had very low pH (3.51–4.01), and water temperature below 10 °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 significantly higher EC (12.5-14 ms/cm) during the second survey. Conductivity remained relatively constant, with a mean of 7.82 ms/cm in the first survey, to 7.85 ms/cm in the second survey, a change in mean from 1.67 ms/cm to 12.93 ms/cm. Turbidity was low (0–2 NTU) and dissolved oxygen concentrations varied from 8.3 to 15.5 mg/L.

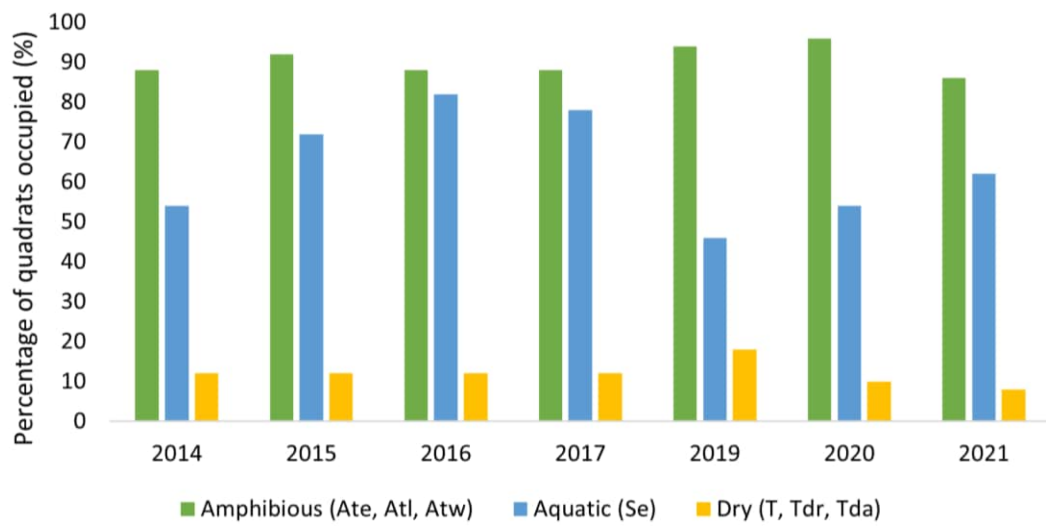
3.2.4 Vegetation and frog site summaries

The following site summaries include:

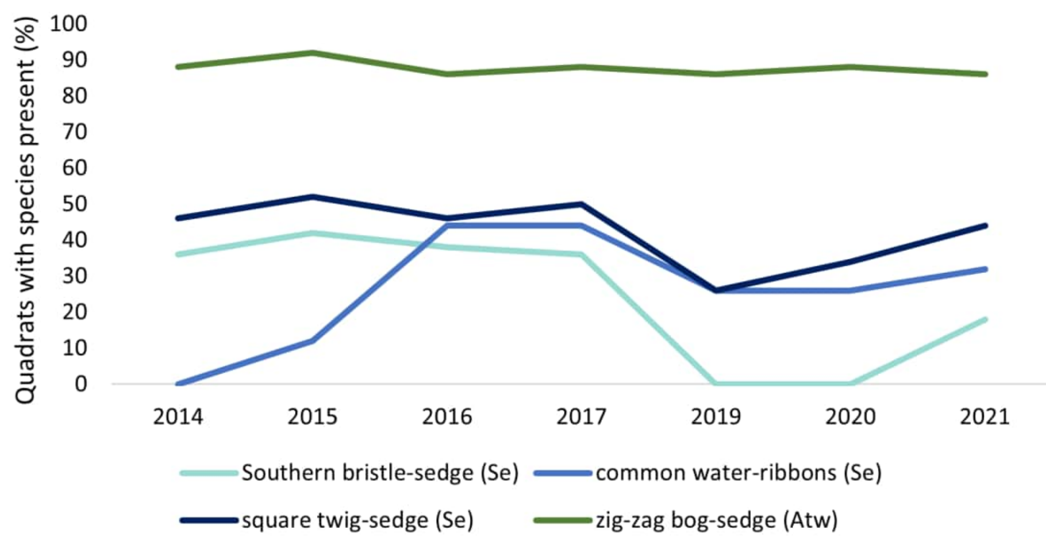
- transect photos at 25 m intervals
- the proportion of each FG recorded at each site
- the top three dominant plant species and their FG
- other attributes including average water depth
- a habitat description
- frog species occurrence and abundance
- water quality data
- relevant comments.

A

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**
2	11-20	6-10	3

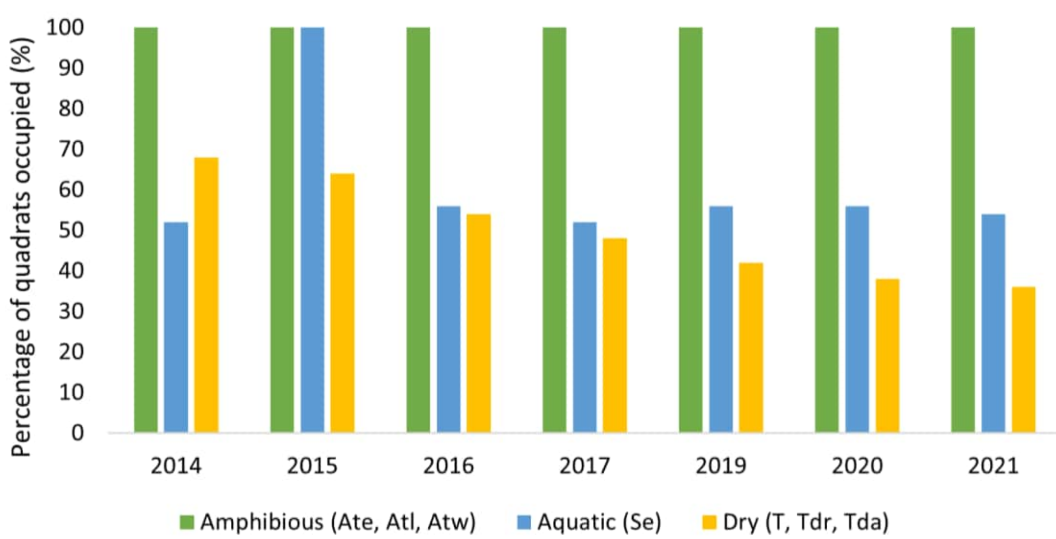
AS2: Water quality parameters					
Survey 1					
pH	3.97	**Turbidity**	3.0 NTU	**Water temperature**	12°C
EC	0.674 µs/cm	**Salinity**	0.02%	**Dissolved Oxygen**	9.88 mg/L
Survey 2					
pH	5.34	**Turbidity**	0.966 NTU	**Water temperature**	20.3°C
EC	19 µs/cm	**Salinity**	0.04%	**Dissolved Oxygen**	- mg/L

Comments
Pools of up to 50 cm depth were present during the first survey, making conditions relatively good for frogs. All three species were heard during the first survey and responded to call playback. The common froglet was already calling prior to playback. A single pobblebonk was heard calling during the second survey, but no other frogs. By the second survey, water depth had decreased to less than 5 cm, providing very little good habitat for frogs.

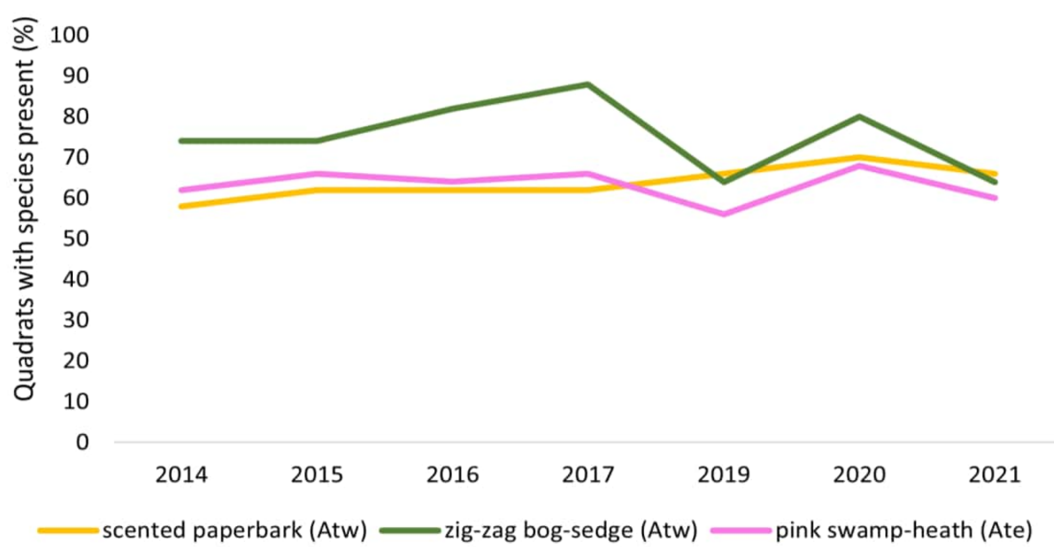
Figure 9 Anglesea Borefield Monitoring and Assessment Program: Anglesea Swamp Site AS2, 2021 including: A. photopoints, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.

B.



C.



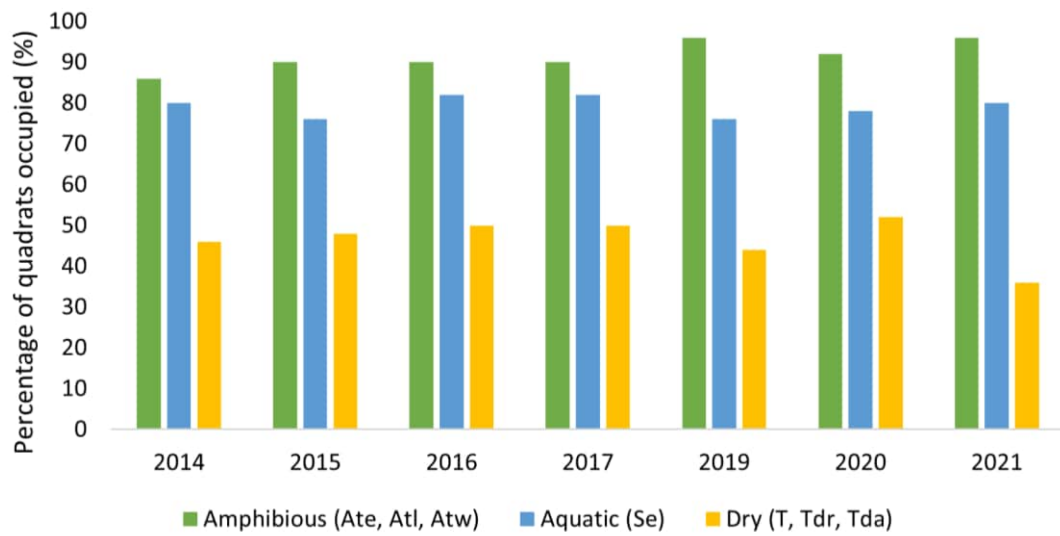
D.

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 emergent cover. The shoreline is fringed with *Melaleuca* species (70-100%). Water was present to a depth of 20 cm during the first survey and dropped to less than 10 cm by the second frog survey.					
AS3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
1-5		1-5		6-10	3
AS3: Water quality parameters					
Survey 1					
pH	3.67	Turbidity	1.3 NTU	Water temperature	11.9°C
EC	0.904 µs/cm	Salinity	0.04%	Dissolved Oxygen	1.56 mg/L
Survey 2					
pH	3.72	Turbidity	2.5 NTU	Water temperature	18.2°C
EC	1.9 µs/cm	Salinity	0.09%	Dissolved Oxygen	NA
Comments					
Water was adequate for measuring water quality during the first survey, but the level had dropped significantly by the second survey making some parameters difficult to measure. Frogs were only heard during the first survey, with all species heard. Calling positions was estimated to be greater than 300 m away.					

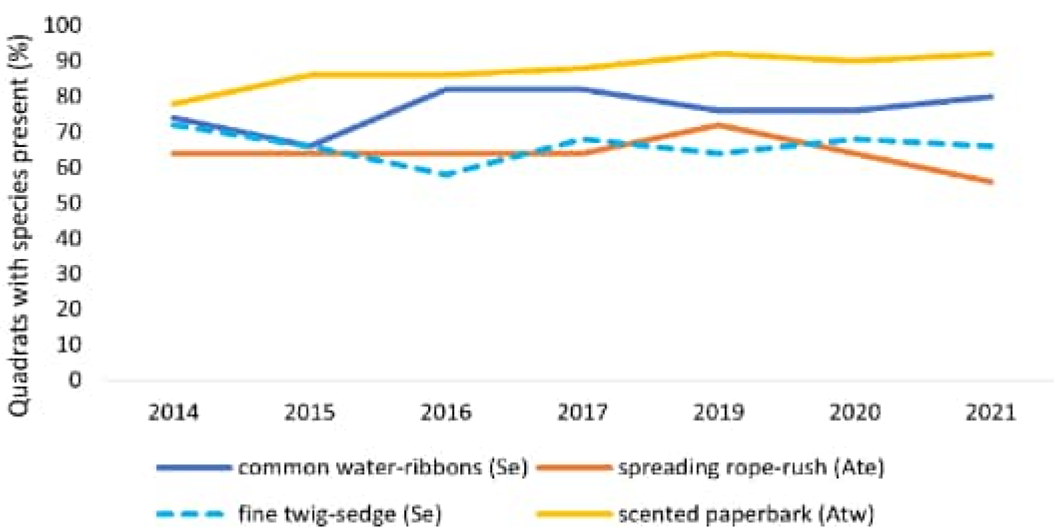
Figure 10 Anglesea Borefield Monitoring and Assessment Program Anglesea Swamp Site AS3, 2021 including A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.

B.



C.



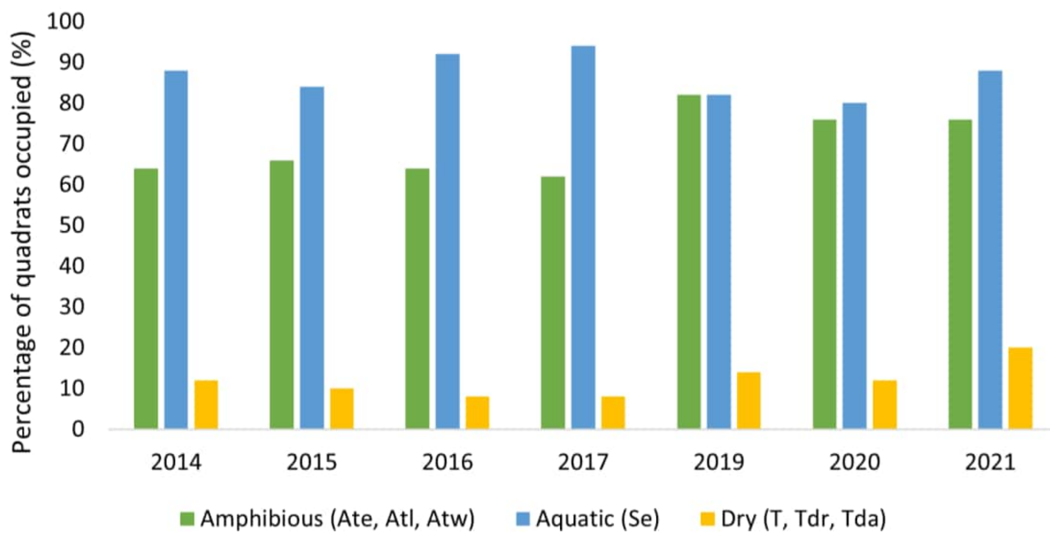
D.

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. 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		
1-5	1-5	3	3		
AS4: Water quality parameters					
Survey 1					
pH	3.76	**Turbidity**	0 NTU	**Water temperature**	11.8°C
EC	1.12 µs/cm	**Salinity**	0.04%	**Dissolved Oxygen**	7.49 mg/L
Survey 2					
pH	3.26	**Turbidity**	3.0 NTU	**Water temperature**	21.4°C
EC	1.53 µs/cm	**Salinity**	0.07%	**Dissolved Oxygen**	7.9 mg/L
Comments					
Frogs were only heard during the first survey. All three species were heard but calling was estimated to be more than 300 m away.					

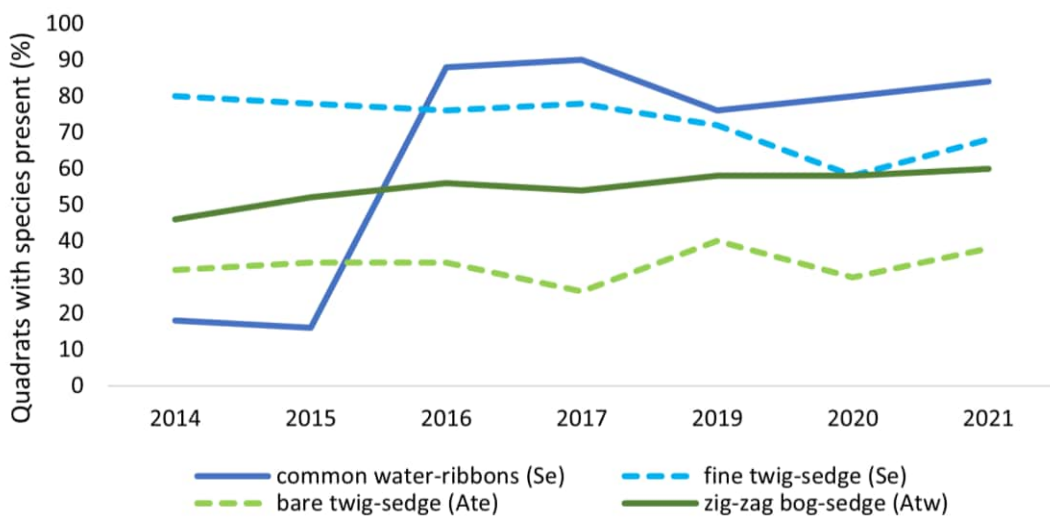
Figure 11. Anglesea Borefield Monitoring and Assessment Program Anglesea Swamp Site AS4, 2021 including A. photopoints, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.

B.



C.



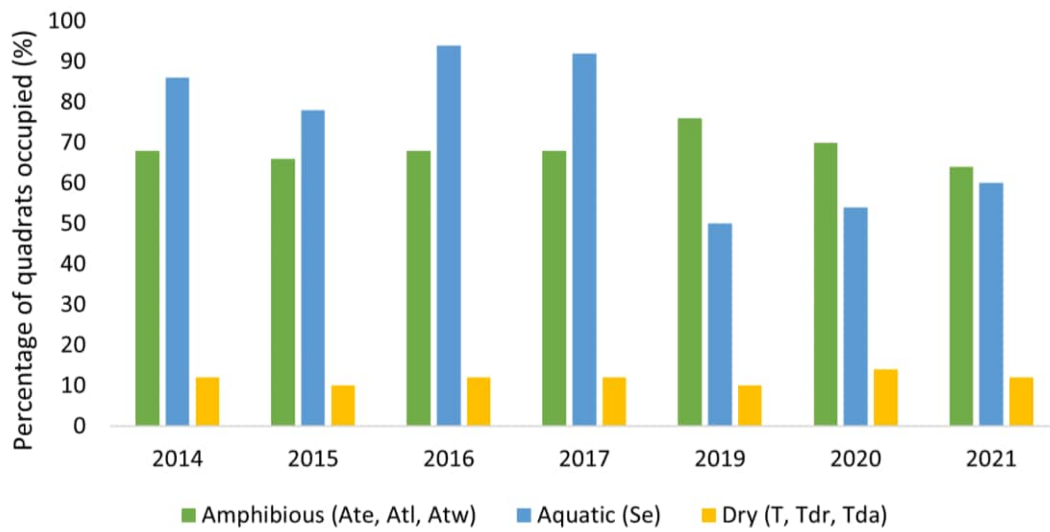
D.

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. During the first survey the swamp had an average depth of 0.2 m. The reduced depth observed during the second survey revealed a substrate of dead and decomposing vegetation.					
ASP7_2014: Frog abundance and richness					
Southern Brown Tree Frog	Common Froglet	Southern Bullfrog	Species Richness		
2	15	0	2		
ASP7_2014: Water quality parameters					
Survey 1					
pH	3.2	Turbidity	1 NTU	Water temperature	15.2°C
EC	123 µs/cm	Salinity	0.05%	Dissolved Oxygen	12.5 mg/L
Survey 2					
pH	3.22	Turbidity	52 NTU	Water temperature	31.2°C
EC	174 µs/cm	Salinity	0.08%	Dissolved Oxygen	N/A
Comments					
By the second survey, the water level was very shallow, too shallow to measure dissolved oxygen. The low water level is likely responsible for the high turbidity reading and high water temperature. Frogs were recorded during the first survey only with 2 southern brown tree frogs heard during the first survey and 15 heard during the second survey.					

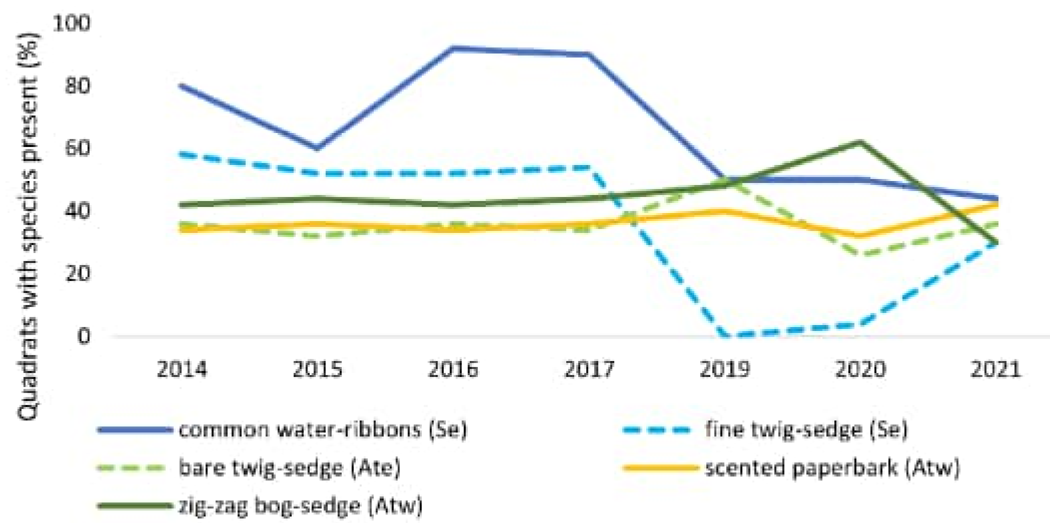
Figure 12. Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp Site ASP7_2014, 2021 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.

B.



C.



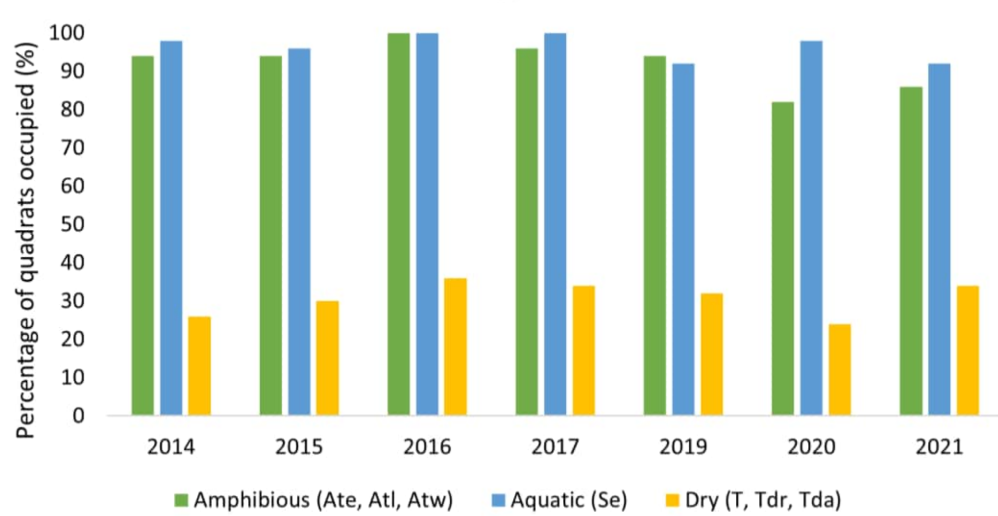
D.

ASL_2014: General habitat description					
Ecological Vegetation Class (EVC)		Aquatic Sedgeland			
Wetland permanence		Ephemeral			
Mostly open swamp almost completely 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. Some evidence of macropod tracks present.					
ASL_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
ASL_2014: Water quality parameters					
Survey 1					
pH	2.76	Turbidity	0 NTU	Water temperature	20.9°C
EC	163 µs/cm	Salinity	6.07%	Dissolved Oxygen	16.87 mg/L
Survey 2					
pH	2.82	Turbidity	6 NTU	Water temperature	31.1°C
EC	234 µs/cm	Salinity	0.11%	Dissolved Oxygen	14.67 mg/L
Comments					
The depth of the swamp by the second frog survey was still suitable for water quality measurements. There were no frogs detected in either survey.					

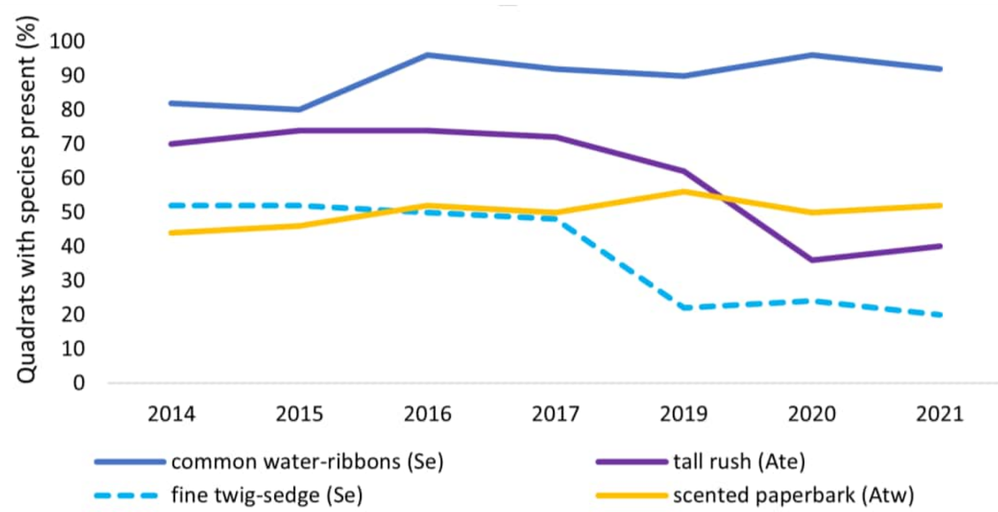
Figure 13 Anglesea Borefield Monitoring and Assessment Program Anglesea Swamp Site ASL 2014, 2021 including A. photopoints, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data

A.

B.



C.



D.

AGP2_2014: General habitat description	
Ecological Vegetation Class (EVC)	Aquatic Sedgeland
Wetland permanence	Ephemeral
This is 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
1	0	1	2

AGP2_2014: Water quality parameters					
Survey 1					
pH	2.65	Turbidity	0 NTU	Water temperature	15.6 °C
EC	185 µS/cm	Salinity	0.08%	Dissolved Oxygen	1.88 mg/L
Survey 2					
pH	2.94	Turbidity	2.6 NTU	Water temperature	23.5 °C
EC	182 µS/cm	Salinity	0.09%	Dissolved Oxygen	1.582 mg/L

Comments
The only frogs detected were estimated to be more than 300 m away from the site.

Figure 14. Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp Site AGP2_2014, 2021 including: A. photo points, B. percentage of quadrats occupied by broad PFGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frogs 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**		
1-5	0	1	2		
AS5: Water quality parameters					
Survey 1					
pH	3.44	**Turbidity**	1 NTU	**Water temperature**	12.3 °C
EC	1.14 µs/cm	**Salinity**	0.07 %	**Dissolved Oxygen**	8.5 mg/L
Survey 2					
pH	Dry	**Turbidity**	Dry	**Water temperature**	Dry
EC	Dry	**Salinity**	Dry	**Dissolved Oxygen**	Dry
Comments					
Water levels were adequate for measuring water quality parameters during the first survey. By the second survey the site was dry. Frogs were only heard calling during the first survey, both species estimated to be more than 300m away from the site.					

Figure 15 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2021 frog summary data.

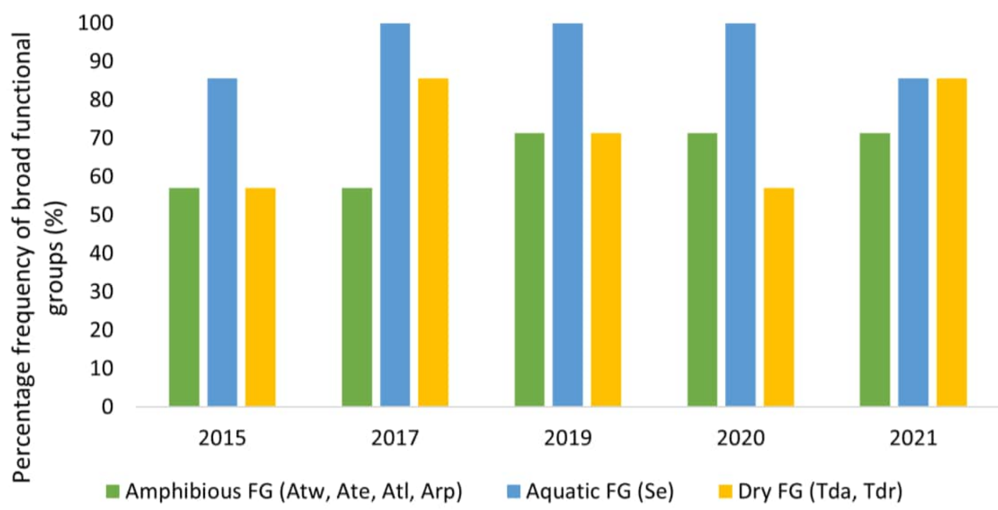
AS6: General habitat description					
Ecological Vegetation Class (EVC)	Aquatic Sedgeland				
Wetland permanence	Ephemeral				
Swamp relatively shallow (to 0.15 m) consisting of emergent (10-20%) vegetation consisting of decomposing sedges, small clumps of live sedges and scented paperbark. Submergent and floating vegetation was absent with the swamp fringed by70-100% of scented paperbark.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog	**Common Froglet**	**Southern Bullfrog**	**Species Richness**		
0	0	0	0		
AS6: Water quality parameters					
Survey 1					
pH	5.4	**Turbidity**	2 NTU	**Water temperature**	20.8 °C
EC	1.79 µs/cm	**Salinity**	0.08 %	**Dissolved Oxygen**	16.08 mg/L
Survey 2					
pH	2.81	**Turbidity**	32 NTU	**Water temperature**	25.3 °C
EC	2.04 µs/cm	**Salinity**	0.09 %	**Dissolved Oxygen**	NA
Comments					
Water levels were too low to measure dissolved oxygen during the second survey. The low water level is reflected by the water parameters. No frogs were heard calling during either survey.					

Figure 16 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2021 frog summary data.

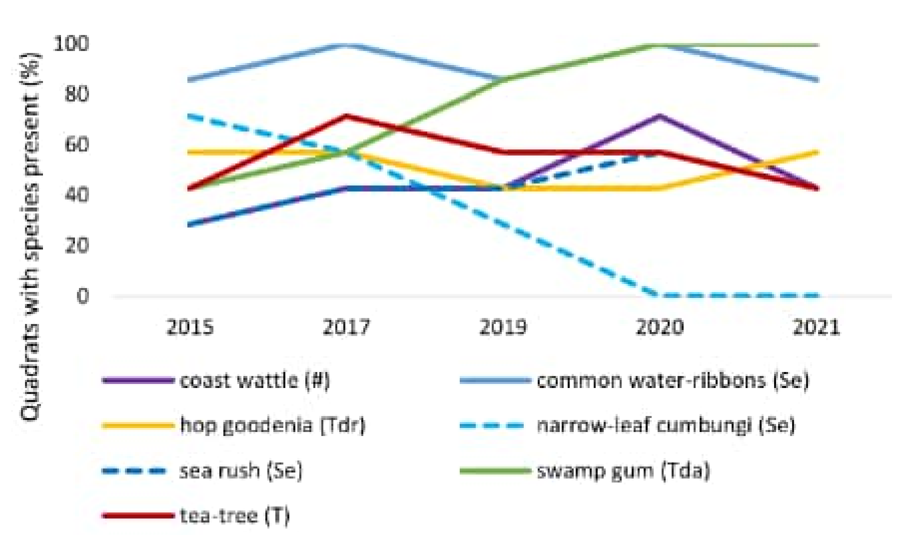
LAR1 vegetation and frog summary data

A.

B.



C.



D.

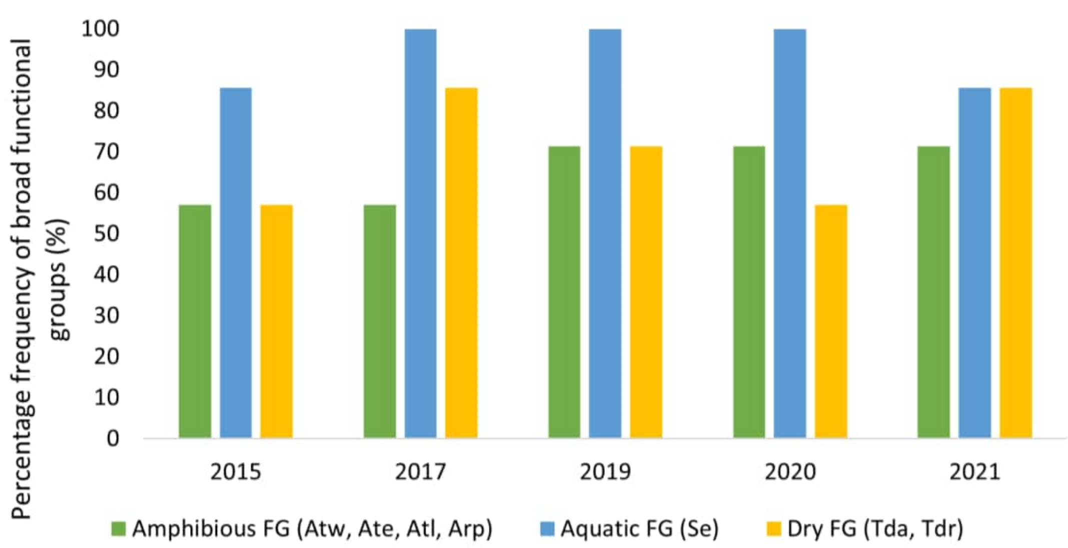
LAR1: General habitat description					
Ecological Vegetation Class (EVC)			Swampy Riparian Woodland		
Wetland permanence			Permanent		
This site is a section of slow-flowing creek up to 150 cm deep and 3-4 m wide. Submergent vegetation was absent, with 5–10% cover of floating water-ribbons. The creek 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
2		0		5-10	2
LAR1: Water quality parameters					
Survey 1					
pH	3.51	Turbidity	0 NTU	Water temperature	14.5 ℃
EC	1.33 µs/cm	Salinity	0.06%	Dissolved Oxygen	11.8 mg/L
Survey 2					
pH	3.56	Turbidity	0 NTU	Water temperature	17 ℃
EC	14 µs/cm	Salinity	0.06%	Dissolved Oxygen	8.31 mg/L
Comments					
During the second frog survey pobblebonk (5-10 individuals), and southern brown tree Frogs (2 individuals) were detected calling within 100 m of the site.					

Figure 17 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, 2021 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

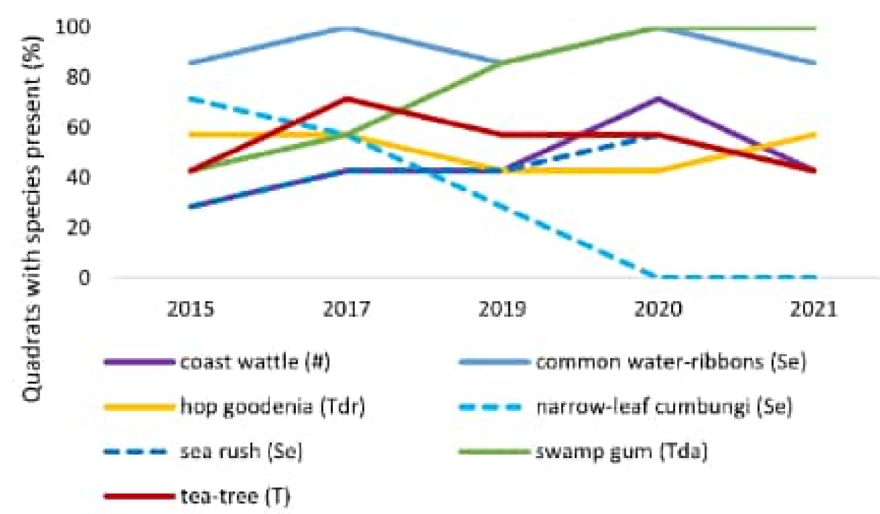
LAR2 vegetation and frog summary data

A.

B.



C.



D.

LAR2: General habitat description	
Ecological Vegetation Class (EVC)	Estuarine Woodland
Wetland permanence	Permanent
Slow-moving creek in estuary 1-2 m deep and 7 - 8 m wide, fringed with 70-100% cover of angled lobelia, coastal tussock-grass, sea rush and common reed. Submergent and floating vegetation was absent. 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**
1-5			1

LAR2: Water quality parameters					
Survey 1					
pH	3.68	**Turbidity**	0 NTU	**Water temperature**	15 ℃
EC	1.99 μs/cm	**Salinity**	0.09 %	**Dissolved Oxygen**	15.51 mg/L
Survey 2					
pH	4.05	**Turbidity**	2 NTU	**Water temperature**	23.8 ℃
EC	12.5 μs/cm	**Salinity**	0.74 %	**Dissolved Oxygen**	15.5 mg/L

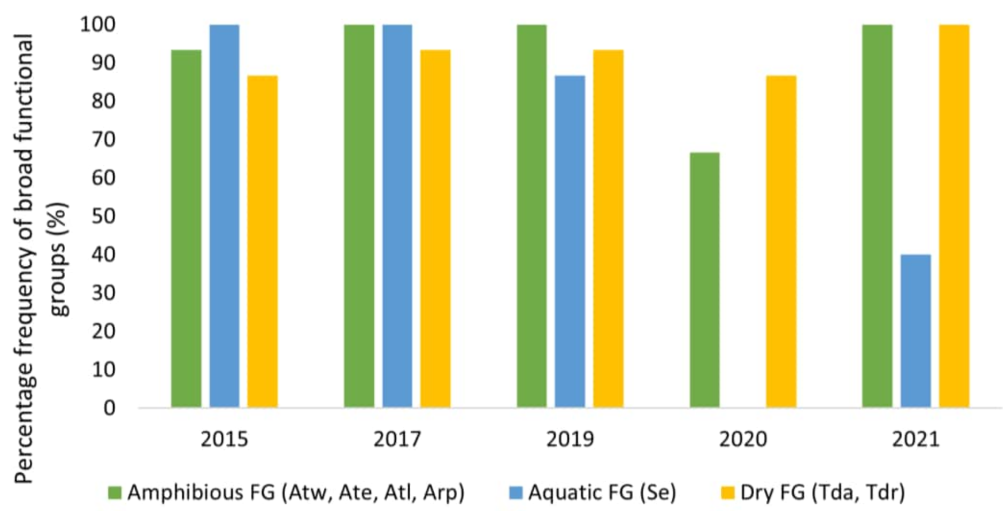
Comments
During the first survey, 2 southern brown tree frogs were heard calling greater than 300 m away from the site. During the second survey between 1-5 were heard within 100 m of the site.

Figure 18 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, 2021 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

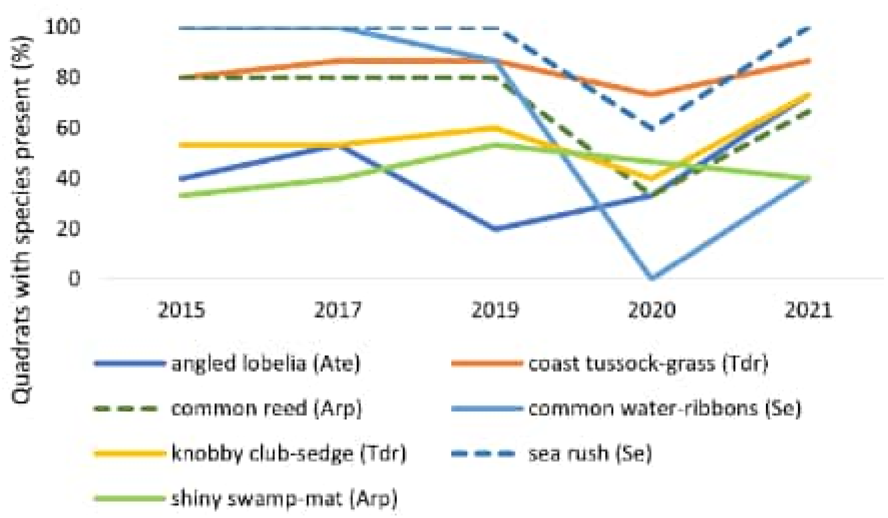
LAR3 vegetation and frog summary data

A.

B.



C.



D.

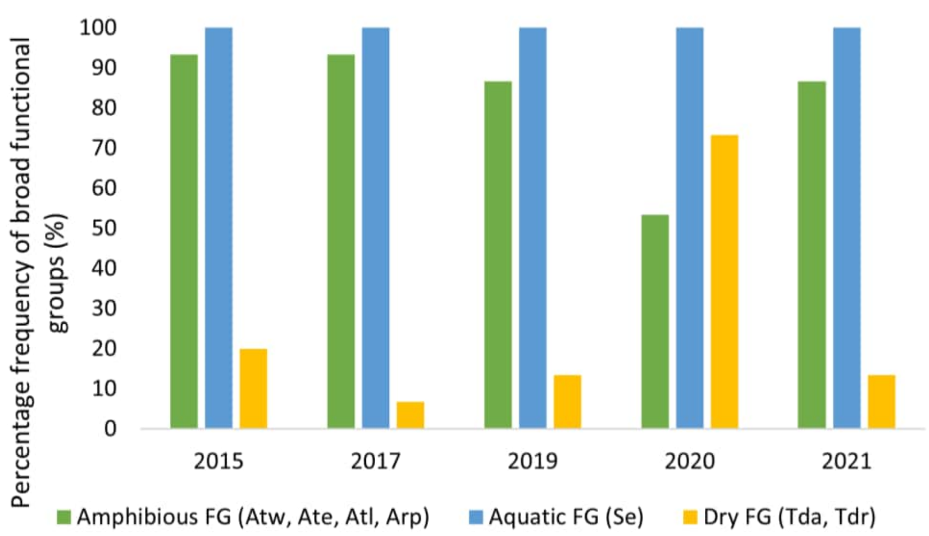
LAR3: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
Slow-flowing creek 10 m to 12 m wide, 1 – 1.5 m deep. Emergent and floating vegetation was absent. Emergent vegetation formed <5% of the area. The site is fringed by 70–100% cover of dominated by *Juncus*.					
LAR3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
1		0		5-10	2
LAR3: Water quality parameters					
Survey 1					
pH	3.9	Turbidity	0 NTU	Water temperature	15 ℃
EC	1.58 µs/cm	Salinity	0.07%	Dissolved Oxygen	12.06 mg/L
Survey 2					
pH	4.05	Turbidity	2 NTU	Water temperature	23.4 ℃
EC	12.7 µs/cm	Salinity	0.73%	Dissolved Oxygen	15.6 mg/L
Comments					
A single southern brown tree frog was heard calling more than 300 m away from the site during the first survey. Between 5-10 pobblebonks were heard calling during the second survey within 100 m of the site.					

Figure 19 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, 2021 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

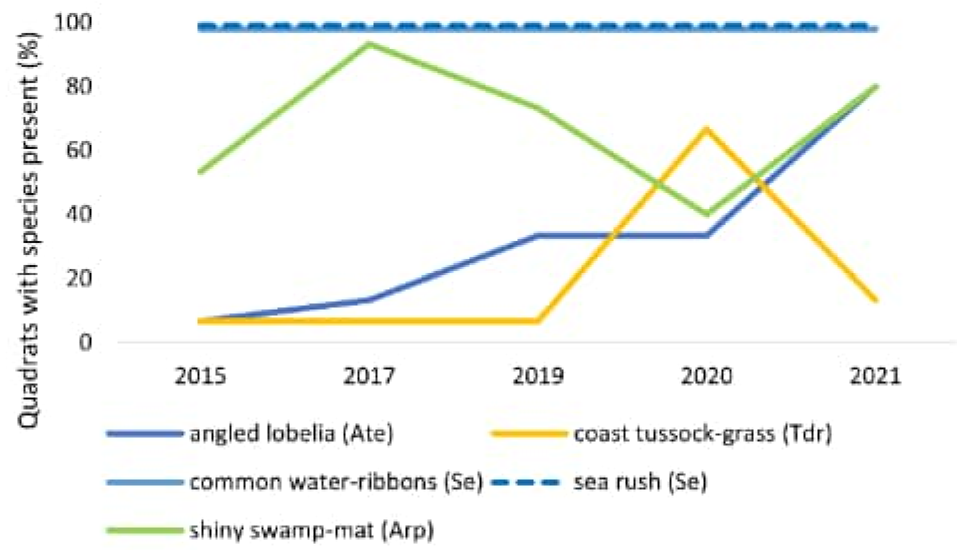
LAR4 vegetation and frog summary data

A.

B.



C.



D.

LAR4: General habitat description					
Ecological Vegetation Class (EVC)		Heathy Woodland			
Wetland permanence		Permanent			
This 10-12 m wide section of creek is up to 2 m deep and is fringed by revegetation (70–100%) along the west bank consisting of: Goodenia and prickly tea-tree with some other species forming an understory. 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 with emergent vegetation.					
LAR4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
1		0		0	1
LAR4: Water quality parameters					
Survey 1					
pH	3.51	Turbidity	0 NTU	Water temperature	15 ℃
EC	1.78 µs/cm	Salinity	0.08%	Dissolved Oxygen	13.02 mg/L
Survey 2					
pH	4.01	Turbidity	2 NTU	Water temperature	22.9 ℃
EC	12.5 µs/cm	Salinity	0.71%	Dissolved Oxygen	15.5 mg/L
Comments					
A single southern brown tree frog was heard calling more than 100 m away on both survey occasions.					

Figure 20 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, 2021 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 7. Due to the very wet winter/spring in 2021 all sites had sufficient water to collect triplicate edge samples. No site met the objective for number of taxa listed in the State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018; Table 7). The Breakfast Creek sites were the most diverse, followed by the upper Anglesea River sites and lower Anglesea River wetland 1. SIGNAL2 score objectives were met for all Breakfast Creek and tributary sites, Salt Creek and lower Anglesea River wetland 2 and 3. The number of Ephemeroptera, Plectoptera and Trichoptera (EPT) objective was met for one site, the most upstream Breakfast Creek site BC1. While not achieving the objective, all remaining Breakfast Creek and tributary sites, as well as Salt Creek sites, recorded EPT taxa, however, EPT were absent at all upper and lower Anglesea River sites. Overall, with nine of a possible 33 objectives met, the results are either the same when compared with 2021 for the sites BCT1, SC1 and W2/3 (2 objectives achieved among the 3 sites) (Ecology Australia 2021) or better than the 2018 results for all 11 sites (3 objectives achieved among the 11 sites) (Ecology Australia 2019). Individual sample results from each site are presented in section 3.7.

Table 7 Site macroinvertebrate indices result from all sites, combining the three edge samples taken (non-attainment of SEPP (W) objectives indicated by shading).

Index	BC1	BC2	BC3	BCT1	BCT2	SC1	UAR2	UAR1	W1	W2	W3	SEPP (W) objective*
# taxa	19	15	15	9	11	10	14	13	13	7	6	20
SIGNAL2	5.5	4.7	4.5	4.6	4.5	4.7	3.3	2.6	3.1	3.9	3.5	3.4
EPT	6	4	4	3	3	1	0	0	0	0	0	6*
EPTO	7	4	4	3	3	1	2	0	0	1	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

a.

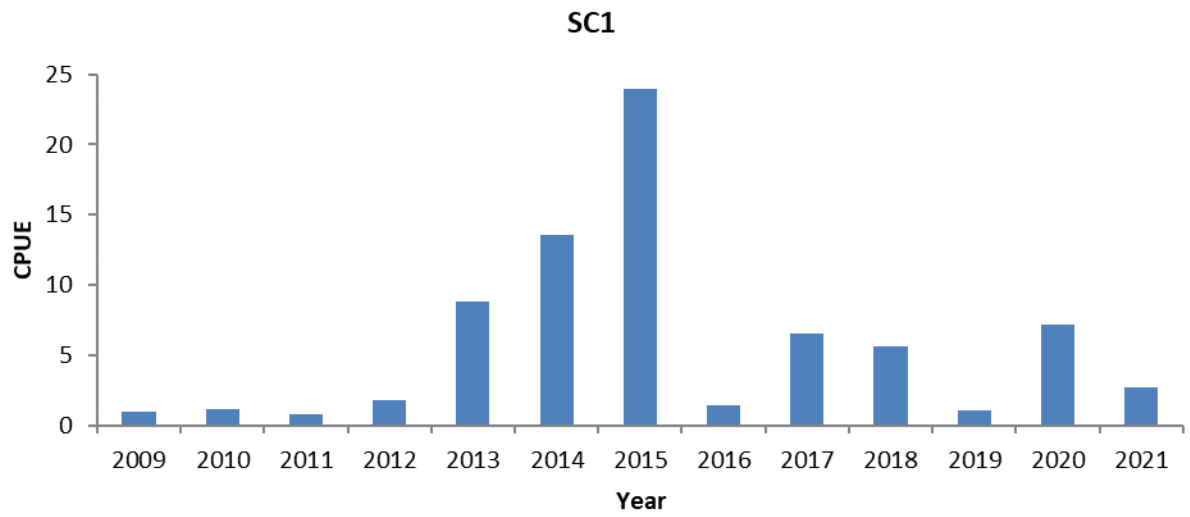
b.

Figure 21 Site SC1 on 16 (a; flowing overbank) and 30 (b; water level receded) November 2021.

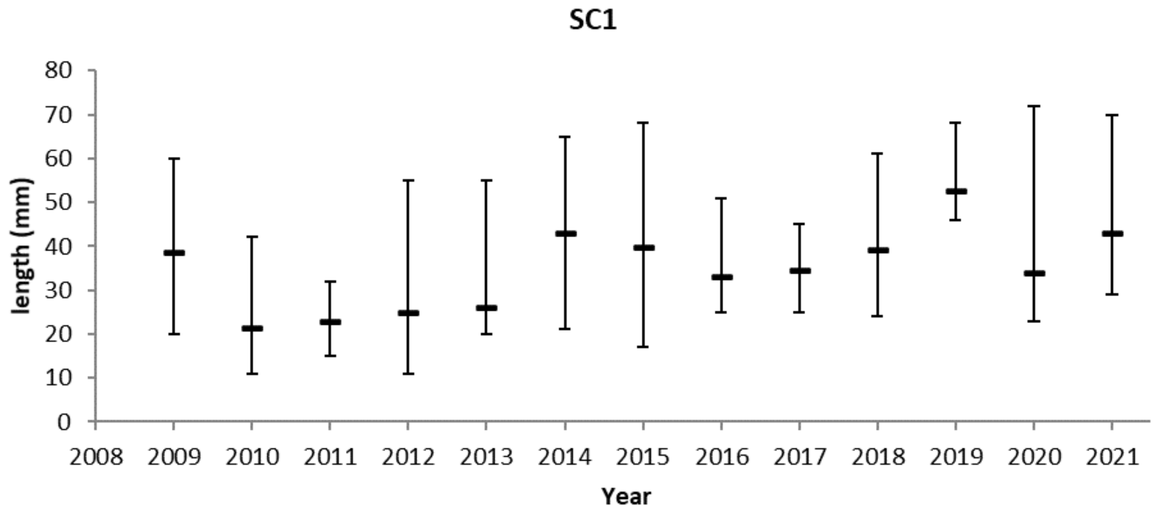
3.4 Southern Pygmy Perch

A total of 27 southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (Figure 22–Figure 24). The 2021 southern pygmy perch Catch Per Unit Effort (CPUE) from Salt Creek was substantially lower than recorded in 2020, but remains substantially higher than that detected in 2019. Young-of-year fish (i.e. fish considered to be less than one year of age) were detected at SC1, which indicates that fish are breeding and that juvenile fish are surviving. This is the second year in a row that young-of-year fish have been detected within Salt Creek. 2021 was the fourth consecutive year that southern pygmy perch were not recorded at the Breakfast Creek tributary site.

Figure 22 Southern pygmy perch from Salt Creek.



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 23 Site SC1 Southern Pygmy Perch spring CPUE (a), and length (b) summary 2009–2021.

3.5 Otway Bush Yabby

Otway bush yabby *Geocharax tasmanicus* is a small freshwater crayfish listed as Endangered under the FFG Act 1988. Otway Bush Yabby was detected at two of the three surveys locations where the species has been detected annually since 2017 (Ecology Australia 2018–2020). In 2021, Otway bush yabby was detected at six of the 11 sites (the one in three-year macroinvertebrate sampling was undertaken in 2021) (Figure 24). Otway bush yabby was only detected in the bait traps in 2021 at SC1 with a total of nine being captured. This is a substantial reduction on the number captured in previous years, although it should be noted that RBA sampling is essentially a presence/absence sampling method.

Figure 24 Otway bush yabby from Breakfast Creek.

3.6 Water quality

Water quality results were consistent with results from previous years (GHD 2010–17, Ecology Australia 2018–2021; Table 8). It should be noted that water quality results are highly variable within short temporal periods, and that to assess against SEPP (W) indices, a minimum of 11 data points is required from a single year (i.e. top calculate annual percentiles). Thus, the SEPP (W) objectives are only able to be compared against the results to provide context. For all Breakfast Creek and tributary sites, SEPP (W) was potentially met for conductivity, but was only potentially met for dissolved oxygen at one of the five site and pH at two sites. At the Salt Creek site, the SEPP (W) was potentially met for conductivity and dissolved oxygen, but not for pH. At the two upper Anglesea River sites, the SEPP (W) was potentially met for conductivity, but not for dissolved oxygen at the most downstream of these sites and not for pH at both sites. The lower Anglesea River wetland sites all failed to potentially meet any SEPP (W) objectives.

Table 8 In situ water quality results and SEPP (W) objectives (potential non-attainment of SEPP (W) objectives indicated by red shading).

Site	Temperature (°C)	Conductivity (µs/cm)	Dissolved oxygen mg/L	%Sat	pH
SEPP (W) objective		≤2000 (75th percentile)		≥70 (25th percentile	6.8-8 (25th -75th percentile)
BC1	16.4	477	8.35	87.5	7.3
BC2	11.69	380	1.12	10.5	6.4
BC3	12.19	488	6.49	62.4	6.81
BCT1	11.5	245	2.1	19.9	4.85
BCT2	11.52	236	1.98	18	4.85
SC1	10.85	264	7.11	72	5.85
UAR1	13.85	121	8.66	86	6.43
UAR2	12.84	580	0.67	6.6	5.87
W1	13.46	2320	2.47	24.1	3.27
W2	14.45	3520	0	0	3.25
W3	15.09	3460	0	0	2.98

3.7 Aquatic monitoring sites

3.7.1 Breakfast Creek and tributaries

Figure 25 Breakfast creek in 2021, photo taken at the most downstream site BC3.

Breakfast creek (BC1–3) and its tributary (BCT1–2) consisted of a narrow, relatively shallow channel with a maximum width of 3.0 m at site BC2, and more typically was <1.5 m wide. The maximum depth of any site was ~0.75 m (site BC3). Flow characteristics at the sites were determined to be between no flow and moderate flow, with a greater proportion of no flow being recorded at BC1 (the most upstream site) and progressively increasing the proportion of slow and moderate flows as sites moved downstream, with BC3 having the most rapid flow. Only the most upstream site (BC1) was a series of pools along the length of the surveyed reach, with all other sites continuous. The substrate was predominantly silt/clay, with some sand, pebble and gravel present, except for the most upstream site BC1, where the majority of the site was bedrock. 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), overhanging terrestrial vegetation, loose silt lying on the surface, overhanging bank, woody debris, filamentous algae, roots, and moss.

All Breakfast Creek sites achieved the SEPP (W) objective for SIGNAL2 score (Table 9). No other objectives were achieved on a sample-by-sample basis. Despite the lower number of overall taxa, it is promising that EPT taxa were again detected at all Breakfast Creek and tributary sites and make up a good proportion of the taxa detected.

Table 9 Individual macroinvertebrate sample indices results for all Breakfast Creek and tributary sites, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives).

Index	BC1			BC2			BC3			BCT1			BCT2			SEPP (W)*
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	
# taxa	10	8	12	12	7	6	7	9	9	5	5	7	4	8	4	20
Abundance	100	122	187	85	78	42	99	104	80	14	12	15	10	21	28	NA
SIGNAL2	5.6	5.6	5.3	4.8	5.1	5	5.9	4	4.4	3.8	5.4	5.4	5.8	4.8	4.8	3.4
EPT	3	3	3	3	2	2	3	1	2	2	2	3	2	3	2	6*
EPTO	4	4	4	3	2	2	3	1	2	2	2	3	2	3	2	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

No Southern Pygmy Perch were detected at BCT1 during this round of monitoring. This is the fourth year in a row that this species has not been detected at BCT1. Previous reports have highlighted that there may have been a recruitment failure at this site in 2017. Otway bush yabby were captured only in low abundance in 2021, with abundance being highest at site BCT1and individuals ranging in size from 6–23 mm occipital carapace length (OCL) (Figure 26).

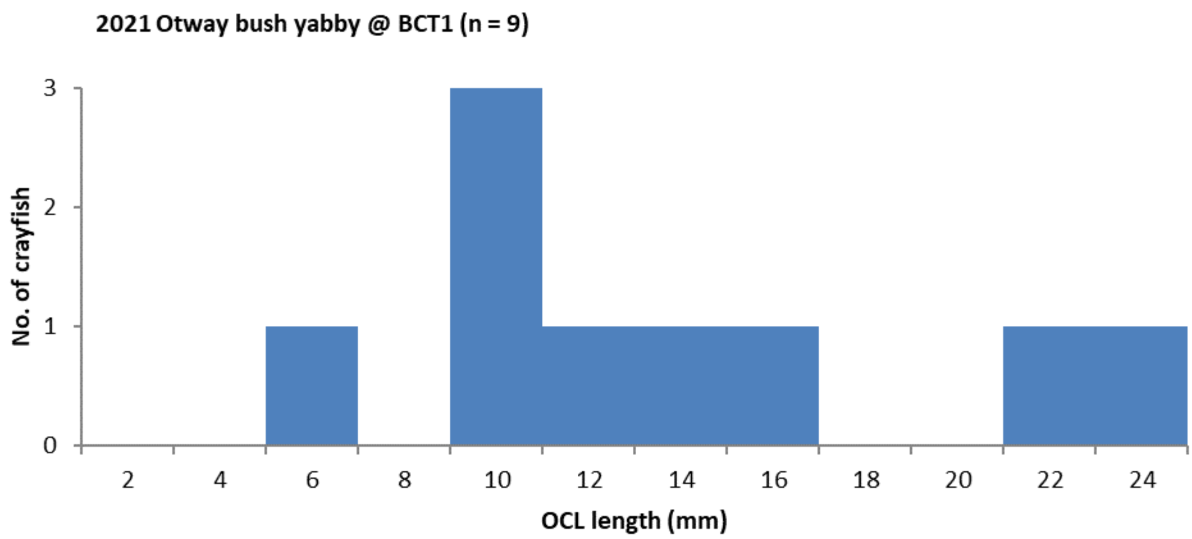


Figure 26 Length-frequency histogram for the 2021 Otway bush crayfish captured at Breakfast Creek site BCT1.

3.7.2 Salt Creek

Figure 27 Salt Creek in 2021 at site SC1.

Salt Creek was sampled at one site, SC1, which of all the sites (aside from lower Anglesea River wetland 1) had the largest surface area of water and appears to be permanent. The substrate was silt/clay and there was water flowing into and out of the large pool. Despite the flow through the pool there were still sections of lentic (still) habitats. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, was Coarse Particulate Organic Matter (CPOM; e.g. leaves, branches and other organic debris), overhanging terrestrial vegetation, aquatic vegetation, overhanging bank and logs. The loose silt that has been dominant at this site in previous years was absent and likely flushed through with the high flows in 2021. The dominant aquatic vegetation taxa were *Juncus* spp. and *Carex* spp.

Salt Creek attained SEPP (W) objectives for SIGNAL score for all two of three edge samples, however, did not attain SEPP (W) goals for all other indices (Table 10). This result represents a slight decline for the Salt Creek site when compared with 2020 (Ecology Australia 2021). Otway bush yabby were not detected during the fish survey at Salt Creek; however, they were present in the macroinvertebrate survey samples in very low abundances. Although quantitative sampling methods were not used, this represents a potential decrease in abundance when compared with record high numbers detected in 2020 (Ecology Australia 2021).

Table 10 Individual macroinvertebrate sample results for Salt Creek, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	SC1			SEPP (W) objective*
	E1	E2	E3	
# taxa	8	9	3	20
Abundance	29	51	6	-
SIGNAL2	5	4.3	3.7	3.4
EPT	1	0	0	6*
EPTO	1	0	0	-

The CPUE of southern pygmy perch at SC1 was about one third that of the previous year. The length frequency histogram again shows two cohorts, those larger and older fish, around 70 mm and those younger fish around 30–50 mm (Figure 28). This histogram and the results from 2020 indicate that recruitment has occurred for two consecutive years. Southern pygmy perch typically reach maturity at approximately 30–33 mm (Knight 2008) (conservatively set at 30 mm for the histogram). The smallest length detected were smaller than 30 mm, indicating that young of year fish are present within the system.

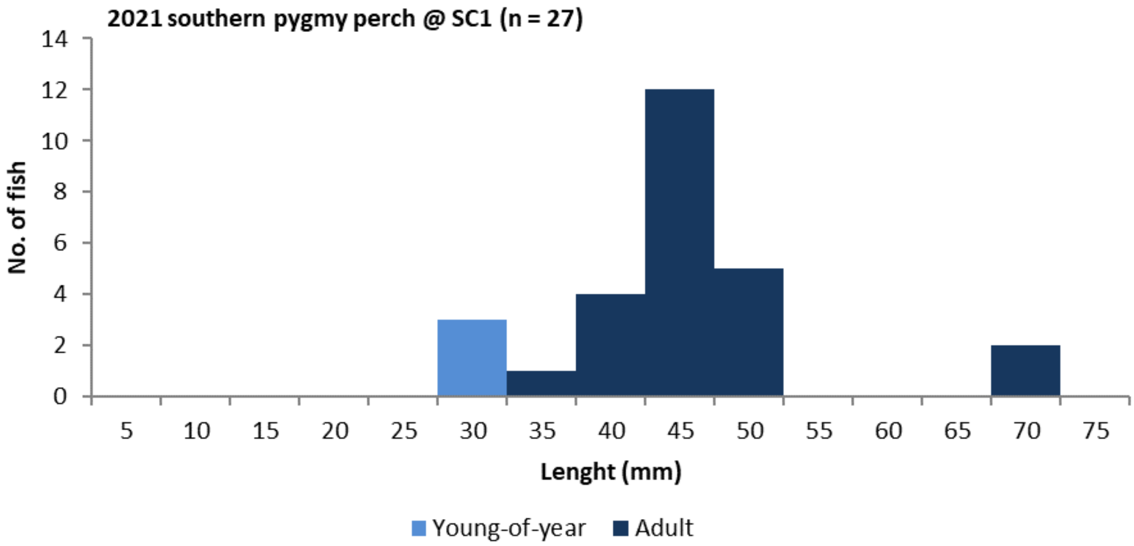


Figure 28 Length-frequency histogram for the 2021 southern pygmy perch captured at Salt Creek site SC1.

3.7.3 Lower Anglesea River Wetlands

Figure 29 Lower Anglesea River wetlands at site wetland 2 in 2021.

In 2021, Lower Anglesea River wetland 1 differed substantially from 2017 (Figure 30). The entire site at wetland 1 was inundated to the bank high water mark, and the depth averaged 0.5 m for the majority of the wetland, with a maximum depth of ~1.0 m. The substrate was predominantly clay/silt, with *Juncus* spp., paperbark and tea-tree throughout the site.

a) 2018 b) 2021

Figure 30 Lower Anglesea River Wetlands at site wetland 1 in 2018 (a) compared with 2021 (b).

Lower Anglesea River wetland 2 and 3 were similar in 2021, aside from the large, still pool (Figure 29), there was flow moving through both sites, more so in wetland 3 than 2. The large pool in wetland 2 was densely dominated by algae and *Triglochin* spp., which was the most abundant macrophyte at both wetland 2 and 3. The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment.

Lower Anglesea River wetland 3 was sampled separately in 2021 as a result of the wet winter/spring in 2021 and achieved SIGNAL 2 objectives for all three replicates. However, given the low number of taxa and absence of EPT taxa at this site, this result should be treated with caution (Table 11). No other objectives were achieved for any other lower Anglesea River wetland sites on a sample-by-sample basis despite the abundant macroinvertebrate assemblage at wetland site 3. These results are also difficult to compare with previous results, as the most recent results either combined wetland 2 and 3 (e.g. Ecology Australia 2021) and/or were unable to sample wetland 1 because it was dry (e.g. Ecology Australia 2019). No Otway bush yabby were detected at any of the Lower Anglesea River wetland sites (Note: they have not been previously detected at this site and were not expected in 2021).

Table 11 Individual macroinvertebrate sample results lower Anglesea River wetlands 1–3, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	W1			W2			W3			SEPP (W) objective*
	E1	E2	E3	E1	E2	E3	E1	E2	E3	
# taxa	9	5	8	6	3	4	5	1	4	20
Abundance	136	124	125	19	49	30	39	23	15	NA
SIGNAL2	2.9	3.2	3.1	4	3.3	3.3	3.8	6	3.5	3.4
EPT	0	0	0	0	0	0	0	0	0	6*
EPTO	0	0	0	1	0	0	0	0	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

3.7.4 Upper Anglesea River

Figure 31 Upper Anglesea River in 2021 at the most upstream site UAR1.

Both upper Anglesea River sites were flowing in 2021. The substrate was predominantly silt/clay, with some gravel and sand present (especially at UAR2). The main instream habitats providing habitat for macroinvertebrates were coarse particulate organic matter (especially leaf litter, but also small branches and branch piles), macrophytes, larger snags, trailing bank vegetation and overhanging banks. The loose silt described as dominating the cover in 2017 at these sites was absent in 2021, likely flushed through the river from the high flows in winter/spring 2021. The dominant aquatic vegetation types were submerged, or feather-like vegetation, *Triglochin* spp., *Carex* spp., an unknown grass-like submerged vegetation and *Myriophyllum* spp. Upper Anglesea River site 1 was immediately downstream of a road crossing, and Upper Anglesea River site 2 was immediately upstream of a road crossing and had numerous bike trails/tracks in the close vicinity, both likely to increase sedimentation of the river.

No Macroinvertebrate SEPP (W) objectives were met for any upper Anglesea River sites on a sample-by-sample basis (Table 12). This result indicates that these sites have potentially degraded slightly since they were last sampled in 2018 (where some SIGNAL based objectives were met) (Ecology Australia 2019). Otway bush yabby, however, was present in low abundances at both sites.

Table 12 Individual macroinvertebrate sample results upper Anglesea River sites, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	UAR2			UAR1			SEPP (W) objective*
	E1	E2	E3	E1	E2	E3	
# taxa	7	7	9	5	7	6	20
Abundance	14	43	23	20	21	60	NA
SIGNAL2	2.9	3.3	2.9	3	2.3	2.7	3.4
EPT	0	0	0	0	0	0	6*
EPTO	0	0	2	0	0	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

4 Discussion

4.1 Vegetation

In the Anglesea Swamp sites, overall species richness within the wetland communities (Aquatic Sedgeland EVC and Swamp Scrub EVC) showed little change from previous years and dominant species remained present at all sites. 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. Site LAR4 has decreased in total number of species since the revised MAP commenced. The species which have dropped out of 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 continue to be recorded in all Estuary sites except LAR4 (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 and 2020).

Overall, the frequency of aquatic functional groups has decreased across the Anglesea Swamp which is shown by the decrease in average frequency of the aquatic functional group across all sites between 2017 and 2019. Aquatic functional groups 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 2021 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 two 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. Whilst yearly rainfall across 2020 (713 mm) and 2021 (726 mm) was higher than average, the overall percentage of Aquatic functional groups remains lower than pre-2019 levels despite showing a slight increasing trend each year. This may be due to a lag time for vegetation to respond to increase water availability.

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.* that appears to respond quickly to changes in available water and tends to increase in frequency after yearly rainfall increases.

Based on observations at two sites, it appears that several dominant species have died back in recent years (Appendix 6 and 7). 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 continue to be recorded and have increased in one site in the Anglesea Swamp (first recorded in 2016). 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 largescale 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

Results of the 2021 frog surveys as part of the Anglesea MAP are consistent with previous years, with low numbers and diversity of frogs recorded across both the Anglesea Swamp and Anglesea Estuary

(Table 6, Figure 29). Frogs were heard within 100m of the study sites in all 4 of the estuary sites, but only at half of the swamp sites. However, at the swamp sites, with the exception of AS6, frogs were heard calling more than 100m away from the sites suggesting frogs occur in the greater swamp area. The low recorded species richness and abundance of frog is likely correlated with the quality of frog habitat in the study area, with the recorded species the more ubiquitous species found in Victoria.

The persistence of frog populations depends on the ability of individual species to produce subsequent generations that will be able to themselves reproduce the following generation of individuals. The ability of frogs to successfully reproduce depends on the availability of suitable aquatic habitat at the breeding site. One of the key requirements for successful breeding in frogs is the hydroperiod. Although the hydroperiod will vary between species, adequate water needs to be available for long enough to raise the next generation to maturity. For instance, southern bullfrog tadpoles typically require a period for development of up to six months to reach maturity. Hence, this species needs standing water for more than half a year for successful reproduction (Anstis 2013). The decrease in water level observed at the swamp site is likely to have impacted the southern bullfrog this season. Conversely, common eastern froglet tadpoles can reach maturity in only four to six weeks, and as a result can survive in small, highly intermittent waterbodies with less stable conditions (Lane and Mahony 2002; Hazell et al. 2003; Anstis 2013). This makes this species less susceptible to water level changes as successful breeding can be completed before the water dries completely.

During the 2021 surveys water depth changed significantly between the two surveys, to the extent that sites were either dry or were very shallow. The number of frogs heard calling from the site as opposed to frogs heard > 300m away, suggests the sites where call surveys were undertaken were no longer suitable to sustain frogs.

In addition to the physical water availability, water quality changes can occur because of changes in water level. Besides temperature, pH and salinity are two parameters that can significantly affect successful reproduction. For instance, acidic water can negatively impact the survival and growth of both frog eggs and developing tadpoles. Striped marsh frog eggs experience 100% mortality at pH below 4.0 (Barth and Wilson 2010). Across the swamp sites, pH was below 4 at all sites. This may have affected the reproductive effort of the related brown tree frog.

Similarly, the survival of southern brown tree frogs declined in elevated saline conditions (Chinathamby et al. 2006), with lower numbers of southern bullfrogs recorded in stormwater ponds with elevated salinity (Hamer et al. 2012). High saline levels may negatively impact adult frog populations, making them more prone to desiccation.

Detection of frogs is closely linked to antecedent weather conditions. Climatic occurrences such as rainfall can induce frog calling particularly near or in the breeding season. Should monitoring occur in less favourable calling times, species richness and abundance could be missed. Possibly the use of audio recorders could improve the chance of capturing frog calls. Audio analysis can be time consuming but can provide a longer seasonal dataset.

Much of the discussion above is linked to aquatic habitat parameters – things like water quality, seasonality of water in wetlands or temperature. More detailed surveys of water quality parameters, including water depth and seasonality. These are the parts of the habitat that can potentially be manipulated to provide conditions for improved frog populations.

4.2.1 Comparisons with citizen science in 2021

In 2021 there was a strong local community interest in changes in the frog population in the Coogoorah park wetland near the Anglesea wetland frog monitoring sites. Barwon Water provided Ecology Australia with information from the local community and citizen science groups which suggested a general decline in the frog population in the Coogoorah park wetland.

These findings were noted by the citizen science group following observations of a significant decline in the chorus of frogs compared to that of previous years at the Coogoorah park wetland. However, those parts of the Coogoorah park wetland surveyed by the citizen science group differs from those areas surveyed under the MAP and are predominantly fed by localised stormwater runoff and not the perched water table. As such, due to differences in water quality between the sites examined by the citizen scientists and Ecology Australia, a difference in frog calling behaviour is unsurprising.

Further, while the citizen science observations do differ from those of the Ecology Australia monitoring, the annual monitoring conducted by Ecology Australia has changed little over the past few years, suggesting the frog populations within the MAP monitoring area has not changed substantially from previous years. The information provided by the citizen science group could be used to better understand the frog population dynamics within the greater Anglesea region and could potentially be used as an external reference to compare the frog population within the MAP area. Further, based on the citizen science groups findings we would recommend that relevant management groups for the Coogoorah park wetland area undertake frog monitoring to gain a better understanding of the frog population to determine if there has been a decline and the extent of any decline in this area.

4.3 Aquatic Ecology

The macroinvertebrate monitoring results were relatively consistent with previous years. The Breakfast Creek and tributary sites appear to have marginally improved and the upper Anglesea River sites appear to have marginally declined (C.f. Ecology Australia 2019, 2021). The water levels at all sites were significantly higher in 2021 compared with the previous triennial survey in 2018, with all 11 sites containing sufficient water levels for sampling (wetland 1 was dry in 2018 and wetland 2 and 3 were combined due to low surface water). The Breakfast Creek and wetland 1 sites, which were extensively inundated in 2021, recorded macroinvertebrate abundances and richness similar or higher than those detected in 2018. This suggests that Breakfast Creek has maintained its macroinvertebrate community since the previous triennial surveys. Additionally, it suggests that wetland 1, (which was dry in 2018) has recovered well from the drying, and that the macroinvertebrate community of all other sites have marginally declined. Another factor to consider is the dilution effect from the very wet winter/spring which may have both flushed and diluted the macroinvertebrate assemblage. Habitat was also much more readily available and connected in 2021 compared with 2020 (BCT1, SC1 and W2/3) and 2018 (all other sites). If conditions within the Anglesea catchment remain wet as they were in 2021, we would expect that by 2024 (when the next triennial survey is required to be completed as per the MAP, (Victorian Government, 2014), the macroinvertebrate community within the catchment would have improved.

Southern pygmy perch abundance (CPUE) at site SC1 was considerably lower than in 2020 but remains well above the record low of 2019. This could be due to a reduction in population size, but is more likely a result of dilution (i.e. reduced density) as the water levels and extent of inundated habitat at SC1 were considerably higher in 2021, meaning that the southern pygmy perch population had a greatly increased area of habitat to utilise. The 2021 southern pygmy perch catch included young-of-year and juvenile fish, indicating that this population in continuing to breed in Salt Creek. This is the second year in a row where young-of-year and juvenile fish were detected. Conversely, this was the fourth year in a row that no southern pygmy perch have been detected at BCT1. This result indicates that the Breakfast Creek southern pygmy perch population formerly located in the vicinity of site BCT1 has likely become locally extirpated. A small hope for this population is that it has previously 'reappeared' after several years of no recruitment (GHD 2013–2015). This suggests that the site surveyed is not the Breakfast Creek 'source population'. Previous extirpation and subsequent re-colonisation from a nearby source population have occurred, however, the present 'disappearance' period at this site (2018–2021) is a much longer period than the previous one. The persistence of suitable habitat within drought refuge pools is expected to be the key to ensuring the persistence of source populations. We recommend additional effort occur to determine the ongoing existence of the southern pygmy perch in the Breakfast Creek catchment. Given the population of southern pygmy perch in the Anglesea catchment is genetically distinct (Cesar 2012), it is 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 lower in 2021 compared with 2020, however it should be noted that opportunistic detections during RBA sampling are likely not a reliable indication of abundance. As with the southern pygmy perch, the lower CPUE is most likely due to density related reductions in capture efficiency as a result increased water levels and more extensive available habitat for dispersal following a wetter than average winter/spring in 2021. All sites where Otway bush yabby were detected in 2021 were flowing and suitable habitat was abundant. Small, young-of-year/juvenile, individuals were detected in 2021, indicating this species is continuing to recruit. This species can complete its life cycle in both permanent and more intermittent habitats and the 2021 conditions provide the 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, Otway bush yabby was detected in areas of lower pH (as low as 4.85 in this present year and 4.2 in 2020; Ecology Australia 2020) hinting that the Anglesea catchment population may be adapting to lower pH conditions. The pH conditions within the lower Anglesea River wetland sites have also improved compared with previous years and continuing improvements may lead to pH becoming suitable for Otway bush yabby in coming years. However, the increased connectivity and available habitat may also result in recolonisation of fish (potentially including eels), which could have a detrimental effect on the Otway bush yabby population.

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 following the 2021 event below:

- It may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, as the new SEPP (W) indices for macroinvertebrates are based on single samples, there is greater importance in collecting higher quality individual samples. The trade-off of this approach in terms of reduced replication and reduced data compatibility also requires consideration. The suitability of this change being made permanent would best be considered as part of a review of the MAP.

- Given the recent failures to detect southern pygmy perch at BCT1, it would be beneficial to survey additional/alternative locations on Breakfast Creek to establish if a population persists. In addition, it would be beneficial to reassess the catchment as a whole for additional populations. This has not been done since 2012 and would ideally focus on historic records from Anglesea River and associated wetlands and Breakfast Creek, identification of refuge pools in the Breakfast Creek catchment, and investigation of known refuge pools throughout Salt Creek and Anglesea River (as identified in GHD 2010). As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population. This results in a high level of vulnerability for this genetic lineage. This assessment can be undertaken at any time but would ideally be undertaken in late summer/autumn in terms of maximising capture rates.
- Otway bush yabby has been an informal target species for this project since 2019. It is recommended that Otway bush yabby be formalised as an additional target species within the MAP during the next review. The Otway bush yabby population has shown signs of stability and growth since 2019. While the present study detected Otway bush yabby in low abundance, their presence/absence at all triennial macroinvertebrate survey sites was recorded during the survey and effort should be made to continue detection of these species at all of these sites in the future. This effort should further be expanded by including this species in any expanded southern pygmy perch catchment scale assessment, as the survey methodology would be identical (i.e. bait traps) and cost-effective. Increased effort should provide a better understanding of the population size, distribution and demographics.

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.

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 (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).]

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).)

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)

EPA (2003) Guideline for Environmental Management: Rapid Bioassessment for Rivers and Streams. Publication 604.1, October 2003. (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.

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 (2018) State Environment Protection Policy (Waters). S499 23 October 2018

Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Swamp, native plant species and Functional Groups (native plant species only) spring 2021

Status	Scientific name	Common name	Functional group	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	Banksia marginata	silver banksia	Tdr			✓		✓	
	Cassytha glabella	slender dodder-laurel	Tdr		✓		✓	✓	✓
	Cassytha pubescens	downy dodder-laurel	Tdr			✓			
	Chorizandra australis	southern bristle-sedge	Se			✓			✓
P	*Cryptostylis subulata*	large tongue-orchid	Se			✓			
	Cycnogeton procerum sp. aff.	common water-ribbons	Se	✓	✓	✓		✓	✓
	Eleocharis sphacelata	tall spike-sedge	Se		✓				
	Empodisma minus	spreading rope-rush	Ate		✓		✓	✓	✓
P	*Epacris obtusifolia*	blunt-leaf heath	Atw				✓	✓	✓
vu	*Eucalyptus falciformis*	western peppermint	Tdr			✓			
	Gahnia radula	thatch saw-sedge	Tdr			✓			
	Gahnia sieberiana	red-fruit saw-sedge	Ate	✓		✓		✓	✓
P	*Gleichenia dicarpa*	pouched coral-fern	Ate		✓		✓	✓	✓
	Isolepis inundata	swamp club-sedge	Atl		✓				
	Juncus procerus	tall rush	Ate	✓					
	Lepidosperma longitudinale	pithy sword-sedge	Ate					✓	✓
	Leptospermum lanigerum	woolly tea-tree	Atw					0	✓
	Leptospermum spp.	tea-tree	T	✓	✓	✓	✓	✓	✓
	Machaerina arthrophylla	fine twig-sedge	Se	✓	✓			✓	✓
	Machaerina juncea	bare twig-sedge	Ate		✓				✓
	Machaerina tetragona	square twig-sedge	Se			✓	✓	✓	
P	*Melaleuca squarrosa*	scented paperbark	Atw	✓	✓	✓	✓	✓	✓
	Opercularia varia	variable stinkweed	Tdr			✓			
	Platylobium obtusangulum	common flat-pea	Tdr			✓			

Status	Scientific name	Common name	Functional group	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	Pteridium esculentum subsp. *esculentum*	austral bracken	Tdr		✓	✓			
	Rhytidosporum procumbens	white marianth	Tdr			✓			
	Schoenus brevifolius	zig-zag bog-sedge	Atw		✓	✓	✓	✓	✓
P	*Sprengelia incarnata*	pink swamp-heath	Ate				✓	✓	
	Xyris operculata	tall yellow-eye	Ate				✓		✓
Number of species per site				**6**	**12**	**16**	**10**	**14**	**15**
Total number of species				**29**					

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Estuary, plant species and Functional Groups (native plant species only) spring 2021

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
#	*Acacia longifolia* subsp. *longifolia*	sallow wattle	NA	☐	☐	✓	☐
#	*Acacia longifolia* subsp. *sophorae*	coast wattle	NA	✓	☐	☐	☐
*	*Aira elegantissima*	delicate hair-grass	NA	☐	☐	✓	☐
*	*Anthoxanthum odoratum*	sweet vernal-grass	NA	☐	☐	✓	☐
	Cycnogeton procerum sp. aff.	common water-ribbons	Se	✓	✓	✓	✓
*	*Erigeron* sp.	fleabane	NA	☐	☐	✓	☐
	Eucalyptus ovata subsp. *ovata*	swamp gum	Tda	✓	☐	✓	☐
	Ficinia nodosa	knobby club-sedge	Tdr	☐	☐	✓	☐
	Gahnia sieberiana	red-fruit saw-sedge	Ate	✓	☐	☐	☐
*	*Gladiolus* sp.	gladiolus	NA	☐	☐	✓	☐
	Goodenia ovata	hop goodenia	Tdr	✓	✓	✓	☐
	Goodenia radicans	shiny swamp-mat	Arp	☐	✓	✓	✓
*	*Holcus lanatus*	Yorkshire fog	NA	✓	☐	✓	☐
	Isolepis inundata	swamp club-sedge	Atl	✓	☐	☐	☐
	Juncus kraussii subsp. *australiensis*	sea rush	Se	✓	✓	✓	✓
	Lachnagrostis filiformis	common blown-grass	Tdr	☐	✓	☐	☐
	Leptinella longipes	coast cotula	Arp	☐	✓	✓	✓
	Leptospermum scoparium	manuka	Tda	✓	✓	☐	☐
	Leptospermum sp.	tea-tree	NA	☐	☐	✓	☐
	Lobelia anceps	angled lobelia	Ate	✓	✓	✓	✓
	Myoporum insulare	common boobialla	Tda	☐	✓	☐	☐
	Phragmites australis	common reed	Arp	✓	✓	✓	☐
*	*Plantago coronopus*	buck's-horn plantain	NA	☐	☐	✓	☐
	Poa poiformis var. *poiformis*	coast tussock-grass	Tdr	☐	✓	✓	✓
	Senecio glomeratus	annual fireweed	Tdr	☐	✓	✓	☐
*	*Symphyotrichum subulatum*	aster-weed	NA	☐	✓	☐	☐
*	*Vulpia bromoides*	squirrel-tail fescue	NA	☐	☐	✓	☐
Number of species per site				**11**	**13**	**20**	**6**
Total number of species				**27**			

Appendix 3 Results by sample, including genus where identified, for the Breakfast Creek and tributary sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		BC1				BC2				BC3				BCT1				BCT2			
Family/sub-family	**Genus**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**
Acarina	sp.			1	**1**											1	**1**				
Carabidae	sp.										1		**1**								
Ceratopogonidae	sp.			1	**1**																
Chironomidae	sp.															1	**1**				
Chironominae	sp.	5	10		**15**	1			**1**			2	**2**		4				6	3	**9**
Culicidae	sp.										1		**1**	3			**3**				
Curculionidae	sp.																		1		**1**
Diptera	sp.																		1		**1**
Dixidae	sp.			1	**1**																
Dytiscidae	sp.	8	3	11	**22**	5	9	3	**17**	10	7	2	**17**	1			**1**			1	**1**
Elmidae	sp.					1			**1**												
Gripopterygidae	*leptoperla*									2			**2**		3	3	**3**	6	6	13	**25**
Hydrobiosidae	*Taschorema* complex	1			**1**					1			**1**		1				1		**1**
Hydrochidae	sp.			1	**1**	1			**1**												
Hydrophilidae	sp.			1	**1**						1		**1**								
Janiridae	sp.							1	**1**					5		3	**8**	1			**1**
Koonungidae	sp.					1			**1**												
Leptoceridae	*Leptorussa*					1			**1**			2	**2**								
Leptoceridae	*Triplectidina*			2	**2**																
Leptoceridae	*Tripletides*	44	39	27	**110**	1		1	**2**					3		2	**5**	1	2	8	**11**
Leptoceridae	sp.			103	**103**																
Leptophlebiidae	*Ataloplebia*		1		**1**																
Leptophlebiidae	*Nebiosphlebia*		56		**56**																
Leptophlebiidae	*Nousia*			30	**30**	54		23	**77**	78	74	56	**208**								
Leptophlebiidae	sp.	32			**32**		49		**49**												
Oligochaeta	sp.						2		**2**			2	**2**								
Orthocladiinae	sp.			1	**1**							2	**2**								
Polycentropodidae	*Neurecipsis*													1		1	**2**				
Scirtidae	sp.	5		3	**8**	15	11	9	**35**	2	10	9	**21**					1			**1**
Simuliidae	sp.	1	4		**5**	1	1	2	**4**	2	3	1	**6**		1	1	**1**		1		**1**
Tanypodinae	sp.	1	4		**5**	2			**2**	3	4	1	**8**								
Telephlebiidae	*Austrochna*	1	3		**4**																
Telephlebiidae	sp.			2	**2**																
Tipulidae	sp.	1			**1**	1	2		**3**		1		**1**								
Trichoptera	sp.						2		**2**												
Veliidae	sp.														1				1		**1**
Total		**99**	**120**	**184**	**403**	**84**	**76**	**39**	**199**	**98**	**102**	**77**	**277**	**13**	**10**	**12**	**25**	**9**	**19**	**25**	**53**

Appendix 4 Results by sample, including genus where identified, including genus identifications where possible, for the Salt Creek and upper Anglesea River sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		SC1				UAR2				UAR1			
Family/sub-family	**Genus**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**
Acarina	sp.	2	1	1	**4**								
Carabidae	sp.									1	2		**3**
Ceinidae	sp.					1		1	**2**			7	**7**
Chironomidae	sp.									15	9		**24**
Chironominae	sp.					2	3	1	**6**			3	**3**
Culicidae	sp.						1		**1**		1		**1**
Dolichopodidae	sp.									1	1		**2**
Dugesiidae	sp.											1	**1**
Dytiscidae	sp.	1	21	1	**23**		11	5	**16**	1	2	24	**27**
Elmidae	sp.					1	1		**2**				
Eusiridae	sp.	5	4		**9**		12		**12**				
Glacidorbidae	sp.		1		**1**								
Hydrochidae	sp.	1	5		**6**			3	**3**	1			**1**
Hydrophilidae	sp.					1		2	**3**		2		**2**
Koonungidae	sp.					3	12	3	**18**				
Lepidoptera	sp.		1		**1**								
Leptophlebiidae	sp.	3			**3**								
Lestidae	sp.							1	**1**				
Notonectidae	sp.					1			**1**			1	**1**
Oligochaeta	sp.										2		**2**
Paramelitidae	sp.					4			**4**				
Planorbidae	sp.						1	3	**4**				
Scirtidae	sp.	8	4		**12**							21	**21**
Tanypodinae	sp.	1	1		**2**								
Telephlebiidae	*Austrochna*							1	**1**				
Veliidae	sp.	7	11	1	**19**								
Total		**28**	**49**	**3**	**80**	**13**	**41**	**20**	**74**	**19**	**19**	**57**	**95**

Appendix 5 Results by sample for the lower Anglesea River wetland sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		W1				W2				W3			
Family/sub-family	**Genus**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**	**E1**	**E2**	**E3**	**T**
Acarina	sp.			1	**1**								
Ceratopogonidae	sp.	1	2		**3**	2			**2**				
Chironomidae	sp.	19	25		**44**	1	10	3	**14**				
Corixidae	sp.	43	51	67	**161**								
Culicidae	sp.	55	39	25	**119**	5	7	1	**13**	4		4	**8**
Curculionidae	sp.			1	**1**								
Dytiscidae	sp.	4		15	**19**								
Elmidae	sp.					1			**1**				
Hydraenidae	sp.							1	**1**				
Hydrochidae	sp.									1			**1**
Hydrophilidae	sp.											1	**1**
Hygrobiidae	sp.			1	**1**								
Nanophyidae	sp.									1			**1**
Noteridae	sp.	1			**1**								
Notonectidae	sp.	1			**1**								
Odonata	sp.					1			**1**				
Scirtidae	sp.	10	5	2	**17**	8	30	22	**60**	31	21	6	**58**
Tipulidae	sp.			10	**10**					1		1	**2**
Veliidae	sp.	1			**1**								
Total		**135**	**122**	**122**	**379**	**18**	**47**	**27**	**92**	**38**	**21**	**12**	**71**

Appendix 6 Examples of plant species die back at site AGP2_2014 including A. fine twig – sedge *Machaerina arthrophylla*, B tall rush *Juncus procerus* and C. spreading rope - rush *Empodisma minus.*

A.

B.

C.

Appendix 7 Dead patches of square twig-sedge *Machaerina tetragona* at site AS2