

Anglesea Borefield Ecological Monitoring and Assessment Program 2023



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 and Walker G.	
File	Anglesea MAP 2023 Ecology Australia FNL01 3May24	
Bioregion	Otway Plain	
Distribution	Jared Scott	Barwon Water

Document History

Status	Changes	Author	Reviewer	Date
Draft 1	First Draft	Halliday B.T. and Walker G.	Preston T.	27/02/2024
Final	Amendment based on client feedback	Halliday B.T	Preston T.	03/05/2024

Citation: Halliday B.T and Walker G. (2024). Anglesea Borefield Ecological Monitoring and Assessment Program 2023. Report to Barwon Water, Ecology Australia Pty. Ltd., Thomastown, Victoria.

Cover photo: Southern pygmy perch *Nannoperca australis* captured in the Breakfast Creek tributary for the first time in five years – B.T. Halliday

©2024 ECOLOGY AUSTRALIA PTY LTD and BARWON WATER

Except where otherwise specified, ECOLOGY AUSTRALIA PTY LTD ("ECOLOGY AUSTRALIA") and BARWON WATER are the exclusive worldwide owners of all copyright in all content in this document including all schedules, annexures and attachments and including information, data, text, layouts, concepts, maps, diagrams and images in this document ("Document") in such manner as specified in agreements between ECOLOGY AUSTRALIA and BARWON WATER.

No part of this Document may be used, reproduced, copied modified, altered, adapted, compiled, edited, improved, transposed, translated, converted, transmitted, distributed, disseminated, disclosed, saved or stored, by any means, for any purpose except with the prior express written consent of ECOLOGY AUSTRALIA and BARWON WATER.

This Document is solely for use by BARWON WATER. Neither ECOLOGY AUSTRALIA or BARWON WATER warrants or accepts any responsibility with respect to the accuracy or completeness of this Document as used or relied upon by third parties.

The contents of this Document may include information from or views of third parties ("Third Party Information") that has been reproduced or compiled by ECOLOGY AUSTRALIA for BARWON WATER. Third Party Information does not necessarily reflect the views or beliefs of ECOLOGY AUSTRALIA, ECOLOGY AUSTRALIA's employees or contractors or BARWON WATER. Neither ECOLOGY AUSTRALIA or BARWON WATER accepts any responsibility or makes any warranties with respect to the accuracy or completeness of Third Party Information.

ECOLOGY AUSTRALIA and BARWON WATER exclude and disclaim all liability to any person for any consequences, including losses, damages, costs and expenses, arising directly or indirectly from use of this Document (in part or in whole).

Contents

Acknowledgments	1
Summary	2
1 Introduction	4
1.1 Aquatic ecology	4
2 Methods	6
2.1 Macroinvertebrate surveys	6
2.2 Macroinvertebrate identification	6
2.3 Macroinvertebrate data analysis	7
2.4 Fish surveys	7
3 Results	9
3.1 Macroinvertebrates	9
3.2 Southern pygmy perch	10
3.3 Otway bush yabby	11
3.4 Water quality	12
3.5 Aquatic monitoring sites	13
3.5.1 Breakfast Creek and tributaries	13
3.5.2 Salt Creek	17
3.5.3 Lower Anglesea River Wetlands	20
4 Discussion	23
4.1 Recommendations	24
5 References	25

Tables

Table 1	Macroinvertebrate indices result from all sites, combining the 3 edge samples taken (potential attainment of ERS objectives indicated by green and non-attainment by red). Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with BCT1 and SC1 and objectives for shallow inland wetlands with outflow (wetland) were compared with W2/3.	9
Table 2	In situ water quality results and environmental reference standard (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) and for shallow inland wetlands with outflow (wetland). Potential attainment of ERS objectives indicated by green and potential non-attainment by red.	12

Table 3	Individual macroinvertebrate sample indices results for Breakfast Creek tributary site 1, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).	15
Table 4	Individual macroinvertebrate sample results for Salt Creek, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).	18
Table 5	Individual macroinvertebrate sample results for lower Anglesea River wetland 2/3, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).	22

Figures

Figure 1	Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2023.	5
Figure 2	Southern pygmy perch (male & YoY) from Salt Creek in 2023.	10
Figure 3	Site SC1 (top) and BCT1 (bottom) southern pygmy perch Catch Per Unit Effort (CPUE; fish per trap) summaries 2009–2023.	10
Figure 4	Multiple size classes of Otway bush yabby detected during the 2023 surveys.	11
Figure 5	Otway bush yabby abundances from 2019–2023 comparing bait trapping and dip netting catch for Salt Creek (top) and the Breakfast Creek tributary (bottom). Note: dip netting is fundamentally a presence/absence sampling method.	11
Figure 6	The Breakfast Creek tributary site in 2023, photo taken just upstream of the BCT1 V-notch gauge with the gauge wall visible in the right hand side of the photo.	13
Figure 7	Yearly average SIGNAL2 scores and number of families at site BCT1 from 2014–2023.	15
Figure 8	Length-frequency histogram for the 2023 southern pygmy perch captured at the Breakfast Creek tributary site (BTC1).	15
Figure 9	Length-frequency histogram for the 2023 Otway bush crayfish captured at the Breakfast Creek tributary site (BTC1).	16
Figure 10	Salt Creek in 2023 at site SC1.	17
Figure 11	Yearly average SIGNAL2 scores and number of families at site SC1 from 2014–2023.	18
Figure 12	Length-frequency histogram (top) and Length-weight plot, for those fish large enough to be weighed and including sex (bottom) for the 2023 southern pygmy perch captured at the Salt Creek site (SC1).	19
Figure 13	Length-frequency histogram for the 2023 Otway bush crayfish captured at the Salt Creek site (SC1).	19

Figure 14	Lower Anglesea River wetland 2 site in 2023 (top) compared with 2022 (bottom left) and 2021 (bottom right).	21
Figure 15	Yearly average VLAKES scores and number of families at site Wetland 2/3 since the VLAKES index has been implemented 2022–2023.	22

Appendices

Appendix 1	Results by sample, including genus identifications where identified, for all macroinvertebrate sites sampled in 2022 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).	27
-------------------	---	----

Acknowledgments

Ecology Australia acknowledges the Traditional Custodians of Country throughout Australia, and we pay our respects to their Elders past, present and future.

We gratefully acknowledge the assistance of:

- | | |
|-------------------|--------------|
| - Tom Scarborough | Barwon Water |
| - Jared Scott | Barwon Water |
| - William McCance | Barwon Water |

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). Under the bulk entitlement for the Anglesea borefield, Barwon Water has established a comprehensive Monitoring and Assessment Program (MAP) that has been reviewed by independent experts and approved by the Minister for Water.

The objectives of the MAP are:

1. to protect the environmental values and health of groundwater dependent ecosystems, and
2. to continue to collect data to build our understanding of the long-term sustainability of groundwater resources in the Anglesea area.

Per the updated MAP (revised in 2014) (Victorian Government 2014), Ecology Australia was commissioned to undertake the aquatic monitoring in 2023. Terrestrial ecological monitoring was not required in 2023 as the borefield was not operated. Ecology Australia has undertaken terrestrial monitoring (vegetation and frogs) since 2009 and aquatic monitoring since 2017.

Methods

Aquatic monitoring consisted of spring macroinvertebrate surveys undertaken at 3 sites as well as targeted surveys for southern pygmy perch and Otway bush yabby at 2 sites.

Southern pygmy perch & Otway bush yabby

Southern pygmy perch were recorded in Breakfast Creek, marking their return after a 5 year absence. This pattern of disappearance and reappearance aligns with previous occurrences, hinting at the presence of a stable 'source population' nearby. In Salt Creek, the consistent presence of southern pygmy perch in permanent refuge pools underscores the importance of such habitats for their survival. The Salt Creek population has remained relatively stable over the past 5 years, with increased catch per unit effort (CPUE) recorded following flooding events. The discovery of new recruits in 2023 and breeding indications suggest a self-sustaining population.

Otway bush yabby abundance increased in both Breakfast Creek and Salt Creek in 2023 compared with the previous year and was nearing the highest abundance recorded in the program (2020). Otway bush yabby size shifts over time have not been assessed due to limited length data available. Continuing length data collection within the program will remove this limitation in the coming years. Dip netting has proven effective in assessing yabby populations alongside bait trapping. The presence of young-of-year and juvenile crayfish suggests ongoing recruitment.

Macroinvertebrates

In the past 5 years (2019–2023), variations in the number of families and number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa have been recorded, however no marked trend over time is apparent, with variable wetted habitat availability across sites. While Breakfast Creek and Salt Creek had

sufficient habitat for sampling, Lower Anglesea Wetlands 2 and 3 were drier, limiting sampling. No site met the ERS objective for family diversity, indicating potential ecological stressors. However, Breakfast Creek and Salt Creek met SIGNAL2 objectives, and Wetlands 2/3 met VLAKES objectives. EPT taxa presence was low across all sites, particularly in Wetlands 2 and 3 (absent), suggesting that water quality is not sufficient for these species within the wetland site. The low pH conditions within the sites are the most evident explanation for the macroinvertebrate diversity being lower than ERS objective levels. The trajectory of Wetlands 2/3 macroinvertebrate assemblage with VLAKES objectives was plotted for the first time. Variable sampling effort at Lower Anglesea River Wetlands sites warrants consistent tracking in future.

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 for the Anglesea borefield, Barwon Water has established a comprehensive Monitoring and Assessment Program (MAP) that has been reviewed by independent experts and approved by the Minister for Water.

The MAP has been revised and updated once, in September 2014 under the Bulk Entitlement (Anglesea Groundwater) 2014 (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).

The objectives of the MAP are:

1. to protect the environmental values and health of groundwater dependent ecosystem, and
2. to continue to collect data to build our understanding of the long-term sustainability of groundwater resources in the Anglesea area.

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 2009–2023). The MAP requires aquatic ecological monitoring to be undertaken annually (with an increased number of sites every 3 years), and terrestrial ecological monitoring to be undertaken biennially in the absence of groundwater pumping, and annually during periods of groundwater extraction (Victorian Government 2014). Barwon Water did not operate the borefield in 2023. Therefore, the MAP requirement for terrestrial ecological monitoring was not triggered as it was last completed in 2022 (Ecology Australia, 2023).

1.1 Aquatic ecology

The Aquatic Ecology monitoring component included the annual spring monitoring of macroinvertebrates at 3 sites (figure 1):

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

Additionally, this component included spring sampling of southern pygmy perch *Nannoperca australis* and the *Flora and Fauna Guarantee Act 1988* listed endangered species Otway bush yabby *Georchax tasmanicus* at 2 sites:

- Breakfast Creek tributary 1 (BCT1)
- Salt Creek (SC1)

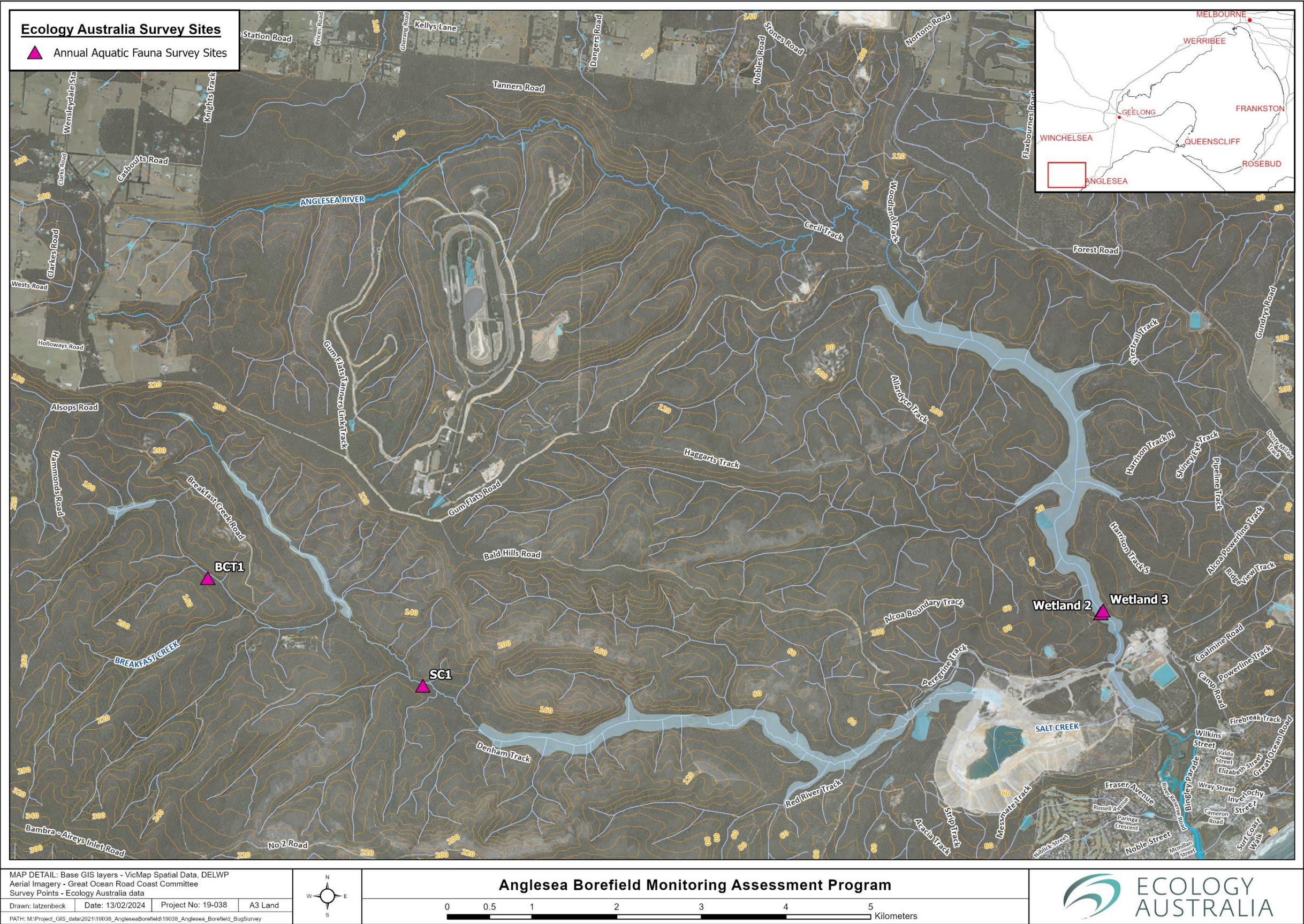


Figure 1 Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2023.

2 Methods

2.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at 3 sites between 16-17 November 2023. As per the established methods for this program (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present, following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2021). A 250 µm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from sites with little to no flow. The sampling objective of the RBA method is to subsample all types of macrohabitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample was collected from 10 m of habitat, which was not necessarily contiguous. The water column and microhabitats present were agitated to dislodge macroinvertebrates, suspend them within the water column and collect them within the net.

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

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

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

Since the detection of Otway bush yabby *Geocharax tasmanicus* in 2017, this species has been monitored concurrently with fish and macroinvertebrates (Ecology Australia 2018-2023). During the 2023 macroinvertebrate surveys all Otway bush yabby (and southern pygmy perch) captured in the sweep nets were biometrically recorded per sweep sample as per section 3.4 increasing the available data for these species.

2.2 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 2021):

- Chironomidae are identified to sub-family

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

2.3 Macroinvertebrate data analysis

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

The following indices were used to analyse macroinvertebrate data:

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

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

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

2.4 Fish surveys

Surveys targeted southern pygmy perch *Nannoperca australis* and Otway bush yabby *Georchax tasmanicus* were undertaken at two sites: BCT1 and SC1 on 16 and 17 November 2023.

Ten bait traps (stretched mesh size of 2 mm and funnel entrances of 40 mm diameter) with 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 2018-2023).

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

3 Results

3.1 Macroinvertebrates

The macroinvertebrate results based on combined sample data from each site are provided in Table 1 (full results provided in Appendix 1). The Salt Creek and Breakfast Creek tributary sites both had sufficient wetted habitat available to collect triplicate edge samples. In contrast, the Lower Anglesea Wetland sites were notably drier than previous years, limiting sampling to a single edge sample each from Wetland 2 and Wetland 3. Typically, these sites are amalgamated, with three samples collected. This was not feasible in 2023 and the sampling included all available wetted habitat during the collection of the two edge samples.

No site met the objective for number of families either for the creek or wetland sites listed in the Environmental Reference Standard (ERS) (Vic. Gov. 2021) (Table 1). The indicative combined sample result (refer to section 2.3) for SIGNAL2 objectives were met for both the Breakfast Creek and Salt Creek at a site and the VLAKES objective was met for the combined wetland 2/3 site. The EPT numbers were low, and none were detected at wetland 2/3. Odonata was only detected within the Breakfast Creek tributary. Individual sample results from each site are presented in section 3.5.

Table 1 Macroinvertebrate indices result from all sites, combining the 3 edge samples taken (green indicates within the ERS objective, red is outside of the objective). BCT = Breakfast Creek Tributary 1, SC1 = Salt Creek 1, W2/3 = Wetlands 2 and 3.

Index	BCT1	SC1	W2/3*	ERS objective [#]
# families (creek)	14	13		20
SIGNAL2	5.1	4.6		3.4
# families (wetland)			6	15
VLAKES			5.5	4.3
EPT	3	2	0	
EPTO	6	2	0	

*Only 2 edge samples were completed in wetland 2/3 (one in each wetland) due to the lack of available habitat.

[#] Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with BCT1 and SC1 and objectives for shallow inland wetlands with outflow (wetland) were compared with W2/3.

3.2 Southern pygmy perch

A total of 67 southern pygmy perch were captured in 2023, 10 from the Breakfast Creek tributary and 57 from Salt Creek (Figure 2–Figure 3). Southern pygmy perch were captured in both bait traps (60 total) and during the dip netting (7 total). 2023 represents the first time in 5 years of monitoring that southern pygmy perch have been found within the Breakfast Creek tributary (Figure 3). In 2023, Salt Creek southern pygmy perch Catch Per Unit Effort (CPUE) was higher than that of the preceding 2 years but remains broadly comparable with the CPUE of the past 5 years (2019–2023) (Figure 3).

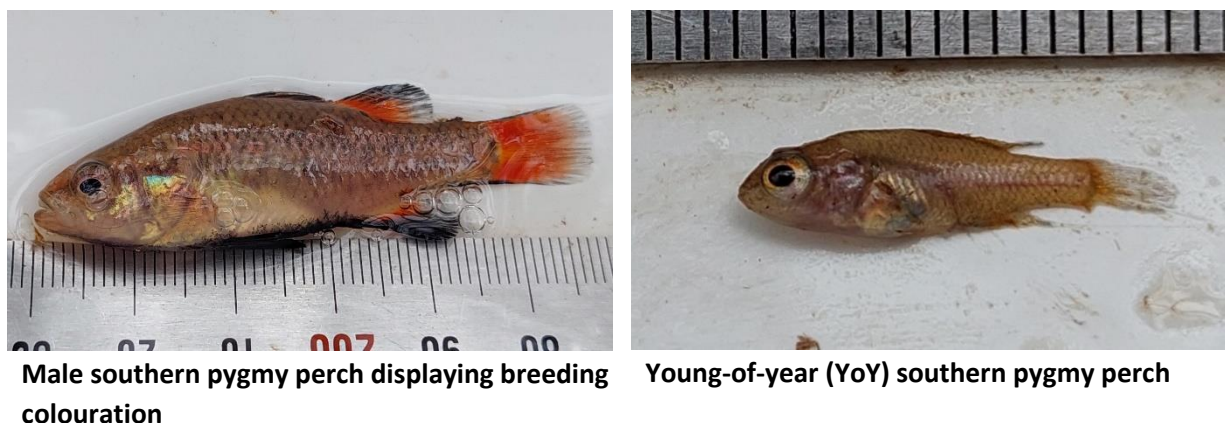


Figure 2 Southern pygmy perch (male & YoY) from Salt Creek in 2023.

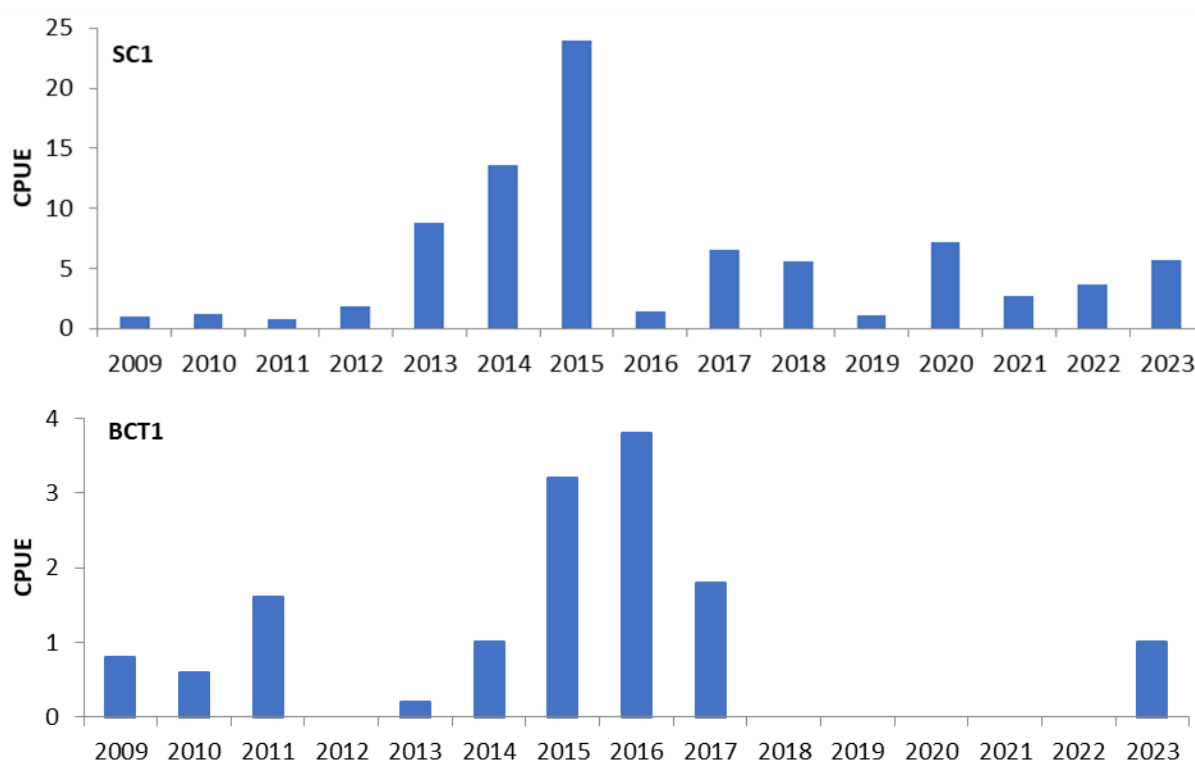


Figure 3 Site SC1 (top) and BCT1 (bottom) southern pygmy perch Catch Per Unit Effort (CPUE; fish per trap) summaries 2009–2023.

3.3 Otway bush yabby

A total of 86 Otway bush yabbies were captured in 2023, with 10 captured at Salt Creek and 76 at the Breakfast Creek tributary (Figure 4). Individuals were captured by both bait trapping (SC1 = 2, BCT1 = 17) and dip netting (SC1 = 8, BCT1 = 59) methods. Otway bush yabby abundances have been low since 2021 at Salt Creek, with record high abundances recorded in 2020 (Figure 5). Abundance at Breakfast Creek was the second highest on record after 2020.



Figure 4 Multiple size classes of Otway bush yabby detected during the 2023 surveys.

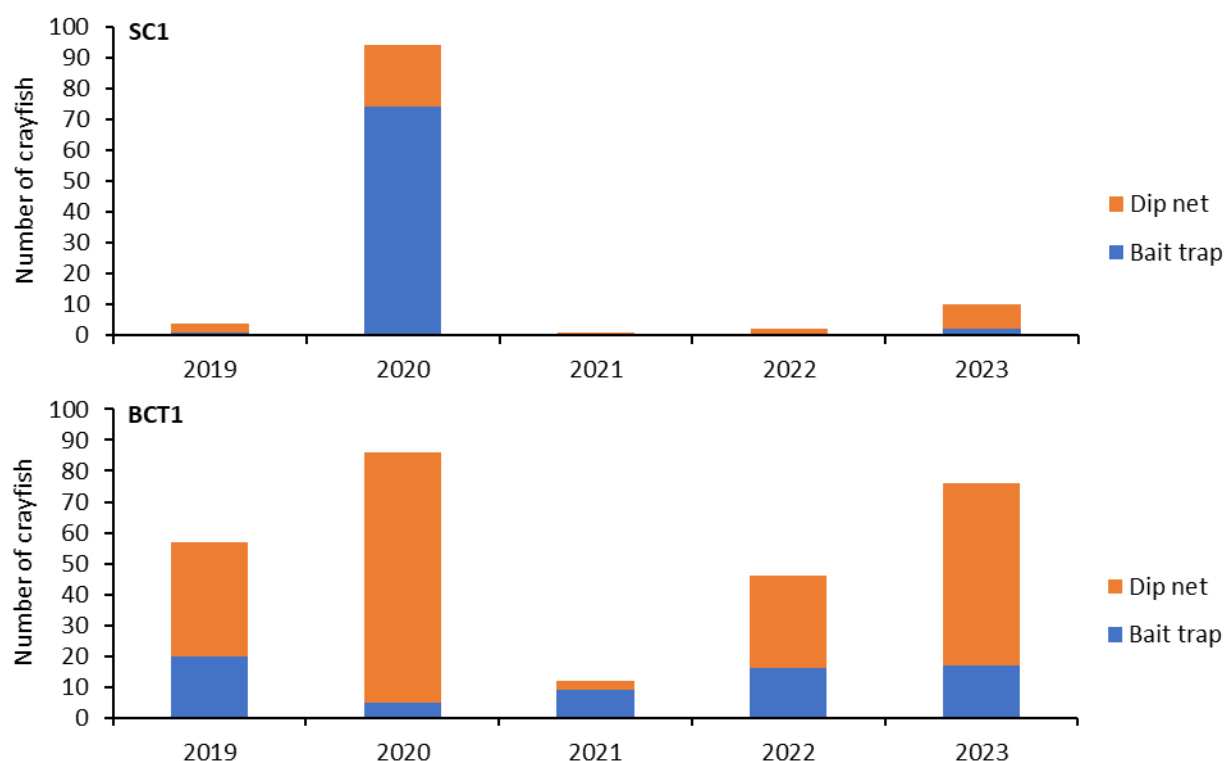


Figure 5 Otway bush yabby abundances from 2019–2023 including data from bait trapping and dip netting catch for Salt Creek (top) and the Breakfast Creek tributary (bottom). Note: dip netting is fundamentally a presence/absence sampling method.

3.4 Water quality

Water quality results were marginally worse compared with the preceding year but broadly consistent with the results from the last 5 years (Ecology Australia 2020–2023) (Table 2). It should be noted that water quality results are highly variable within short temporal periods, and that to assess against ERS indices, a minimum of 11 data points is required from a single year (i.e. to calculate annual percentiles). Thus, the ERS objectives have been provided for context, but the results are not directly comparable to these benchmark levels. Of particular note, pH was low in Breakfast Creek and very low within Wetland 2/3.

Table 2 In situ water quality results and environmental reference standard (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) and for shallow inland wetlands with outflow (wetland) for comparative context.

Objective/Site	Temp (°C)	pH	Conductivity (ms/cm at 25°C)	Dissolved oxygen		Turbidity (NTU)
				mg/L	%	
ERS (creek)*	n/a	6.8-8	≤2	n/a	≥70	≤25
BCT2	14.28	5.25	0.246	6.39	61.2	69.8
SC1	15.08	6.09	0.221	7.52	77.2	34
ERS (wetland)*	n/a	6.5-8.5	n/a	n/a	80-120	15
W2/3	14.46	3.22	2.83	3.36	34.3	16.2

*Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) for comparison with BCT1 and SC1 and objectives for shallow inland wetlands with outflow (wetland) for comparison with W2/3.

3.5 Aquatic monitoring sites

3.5.1 Breakfast Creek and tributaries

During the 2023 surveys at Breakfast Creek tributary site BCT1, we observed a narrow, shallow stream with a maximum width of ~1 m (Figure 6). The flow over the V-notch weir was slow. The streambed primarily comprised silt/clay, with some presence of sand, pebbles, and gravel. In terms of habitat for fish and macroinvertebrates, the most prevalent covers, listed in decreasing order, included coarse particulate organic matter (such as leaves and other organic debris), undercut banks, overhanging terrestrial vegetation, woody debris, filamentous algae, and roots.



Figure 6 The Breakfast Creek tributary site in 2023, photo taken just upstream of the BCT1 V-notch gauge with the gauge wall visible in the right hand side of the photo.

The Breakfast Creek tributary site surveyed attained ERS objectives for SIGNAL2 scores for all 3 samples (

Table 3). No other objectives were achieved. The results from 2023 fall within the range of results found for this site previously (Figure 7).

Table 3 Individual macroinvertebrate sample indices results for Breakfast Creek tributary site 1, showing ERS objectives (green indicates within the ERS objective, red is outside of the objective).

Index	Breakfast Creek site BCT1			ERS objective*
	Edge sample 1	Edge sample 2	Edge sample 3	
# Families	9	6	5	20
SIGNAL2	5.2	4.5	5.2	3.4
Abundance	31	13	6	
EPT	2	1	2	
EPTO	4	2	3	

*Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with BCT1.

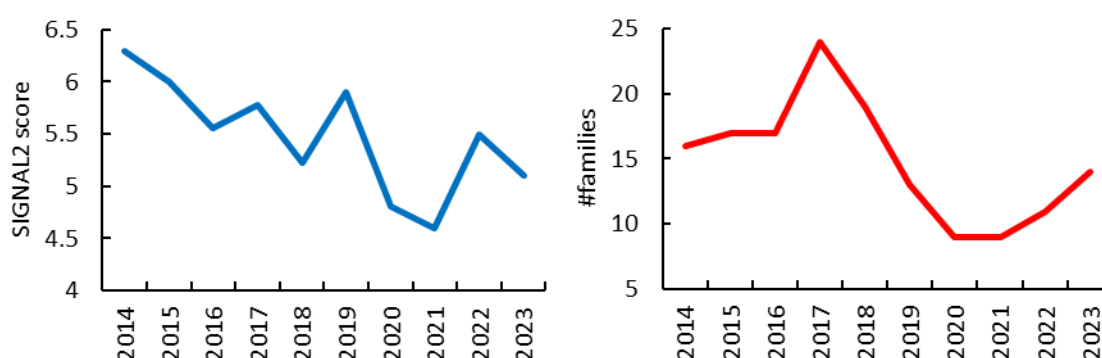


Figure 7 Yearly average SIGNAL2 scores and number of families at site BCT1 from 2014–2023.

As outlined in section 3.2, southern pygmy perch were detected at BCT1 during this round of monitoring. The length frequency histogram shows the population was between 30–37 mm and likely a single cohort of 1+ year old fish (Figure 8). Observations of fish colouration (duller when compared with Salt Creek) and condition (none running ripe) suggested breeding was not occurring or imminent at Breakfast Creek in 2023.

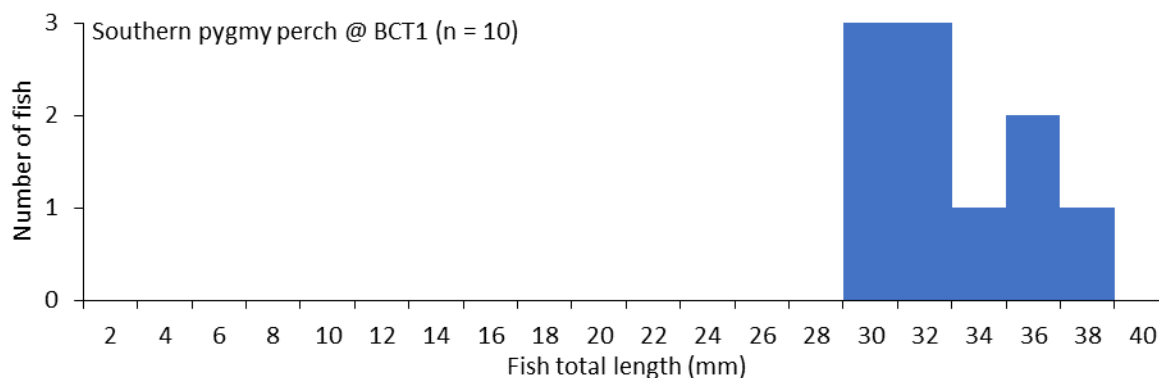


Figure 8 Length-frequency histogram for the 2023 southern pygmy perch captured at the Breakfast Creek tributary site (BCT1).

As outlined in section 3.3, Otway bush yabby continue to be present at the Breakfast Creek tributary site. A significant proportion were juvenile, and this suggests 2023 was another year of successful recruitment, following on from success in the previous year. Individuals ranged in size from 3–20 mm Occipital Carapace Length (OCL) (Figure 9).

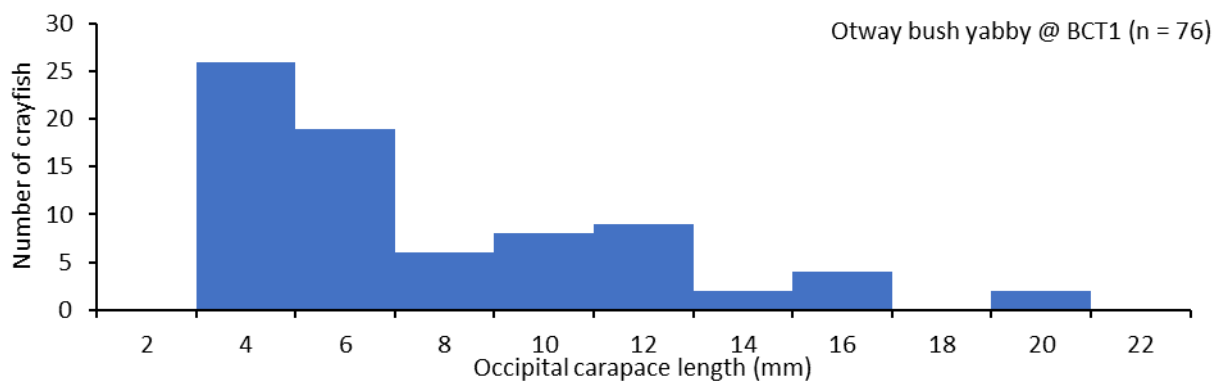


Figure 9 Length-frequency histogram for the 2023 Otway bush crayfish captured at the Breakfast Creek tributary site (BTC1).

3.5.2 Salt Creek

The Salt Creek site is primarily characterized by a large and relatively deep permanent pool, situated within a small and relatively shallow channel (Figure 10). This location has had water present at each site visit since least 2017, and may be regarded as a permanent refuge. The substrate is composed of silt/clay. Flow was observable from the pool entrance to exit, albeit reduced compared to the flows seen in 2021–2022, at a slow velocity in 2023. In comparison to previous years, particularly between 2017 and 2020, the extent of lentic habitat has decreased, aligning more closely with conditions observed in the wetter 2021–2022 years. The amount of loose silt is also comparable to that of 2021–2022, marking a significant reduction from earlier years. Notably, aquatic macrophytes continue to be absent from the pool.



Figure 10 Salt Creek in 2023 at site SC1.

The Salt Creek site attained ERS objectives for SIGNAL2 score for all 3 edge samples (Table 4). No other relevant objectives were achieved. The results from 2023 fall within the range of results found for this site previously (Figure 11).

Table 4 Individual macroinvertebrate sample results for Salt Creek, showing ERS objectives (green indicates within the ERS objective, red is outside of the objective).

Index	Salt Creek site SC1			ERS objective*
	Edge sample 1	Edge sample 2	Edge sample 3	
# Families	7	11	8	20
SIGNAL2	4.0	4.7	4.0	3.4
Abundance	42	52	58	
EPT	1	2	1	
EPTO	1	2	1	

*Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with SC1.

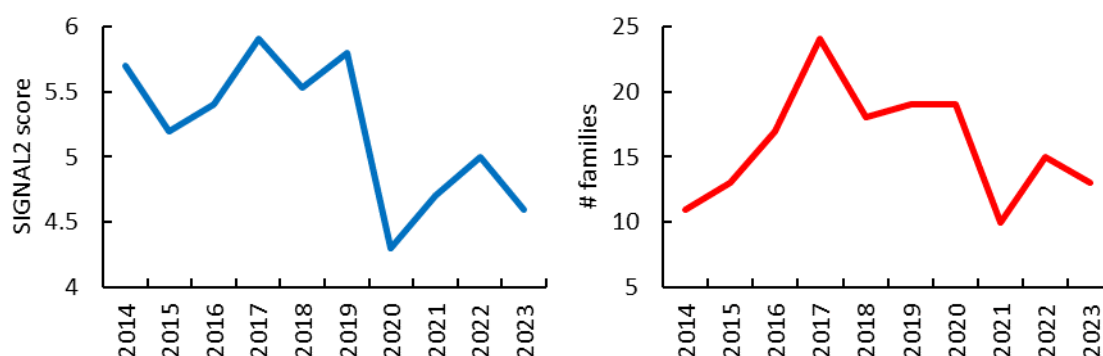


Figure 11 Yearly average SIGNAL2 scores and number of families at site SC1 from 2014–2023.

As outlined in section 3.2, southern pygmy perch were detected in comparable abundance to the previous 5 years. The length frequency histogram shows the population was between 14–76 mm and likely consisted of multiple cohorts of fish including young-of-year fish (Figure 12). Young-of-year fish were last recorded at this site in 2021. Observations of the fish colouration and condition (some were ‘running ripe’) at time of capture suggests that breeding was still occurring or imminent in 2023. The length-weight plot shows a population that includes both males and females throughout size range, with a small number of larger females at the larger size, typical of southern pygmy perch population demographics (Figure 12). There was a minor bias towards males captured at Salt Creek in 2023, with 29 males and 19 females captured.

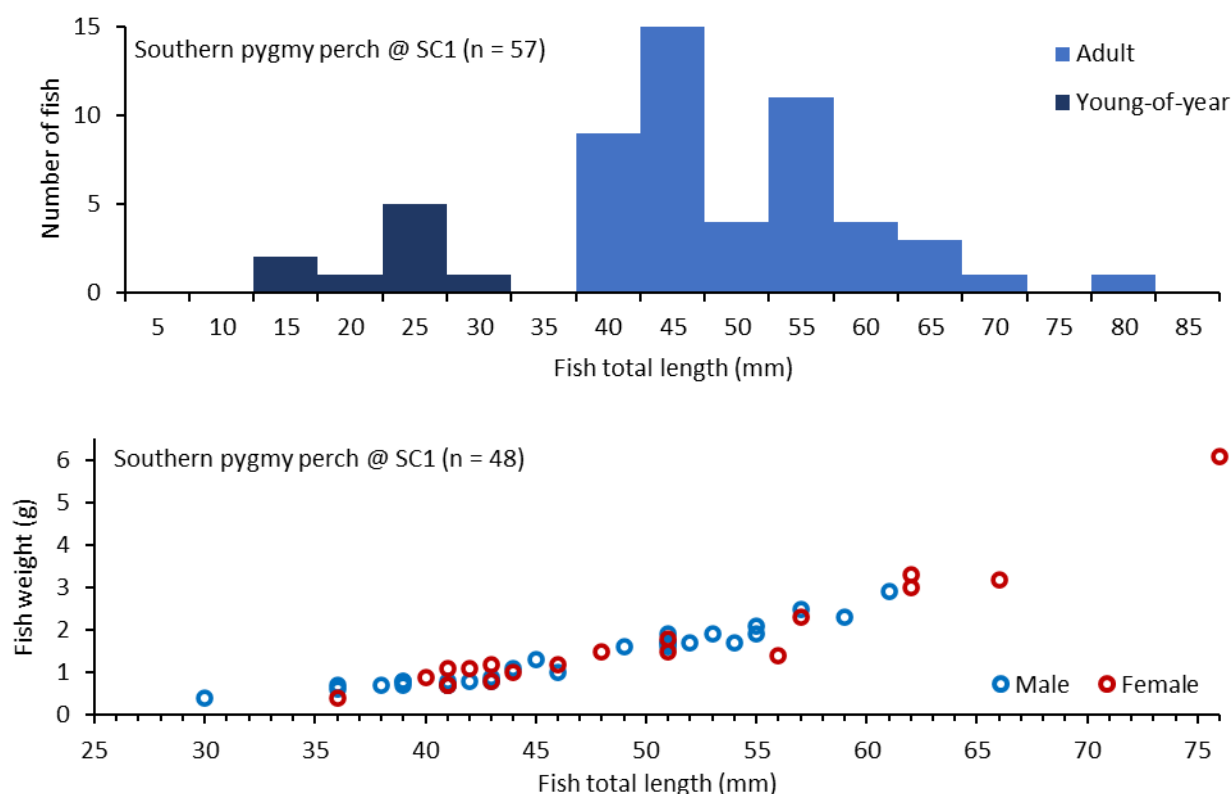


Figure 12 Length-frequency histogram (top) and Length-weight plot, for those fish large enough to be weighed and including sex (bottom) for the 2023 southern pygmy perch captured at the Salt Creek site (SC1).

As outlined in section 3.3, Otway bush yabby continue to be present at the Salt Creek site. A significant proportion were juvenile, and this suggests recent recruitment success. Individuals ranged in size from 3–18 mm Occipital Carapace Length (OCL) (Figure 13).

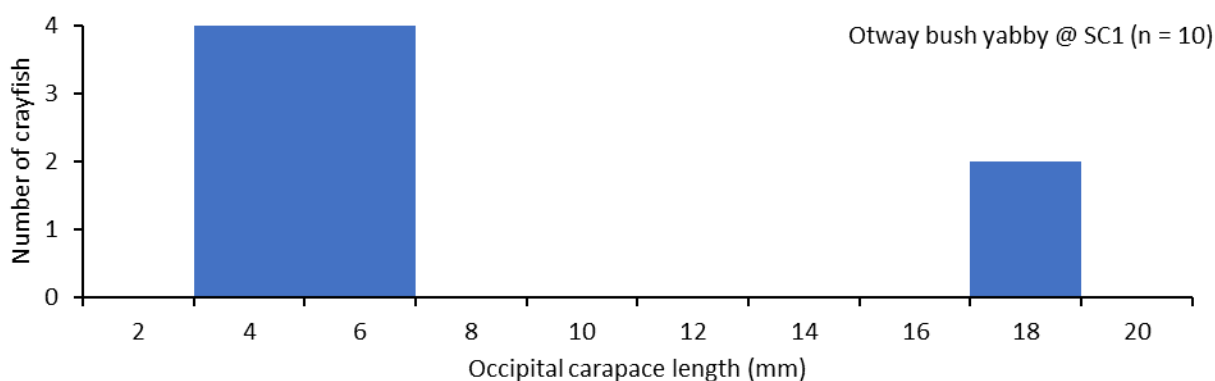


Figure 13 Length-frequency histogram for the 2023 Otway bush crayfish captured at the Salt Creek site (SC1).

3.5.3 Lower Anglesea River Wetlands

In 2023, visual differences were observed in the water levels and filamentous algae cover at Lower Anglesea River wetland 2/3 compared to the period from 2017 to 2022 (Figure 14). During the 2023 survey, wetland 2 exhibited nearly dry conditions, with no flow passing into or through the pool. Wetland 2 and wetland 3 were disconnected as no flow was passing through the culvert under the road. This contrasts sharply with conditions in 2022, where wetland 2 had continuous flow and was considerably full, with flow through the culvert connecting wetland 2 and wetland 3. Wetland 3 had no flow this year and was reduced to only a single pool downstream of the culvert extending ~ 5 m; no other water was present.

In the pool of wetland 2, filamentous algae covered 100% of the area, with arrowgrass *Triglochin* sp. emerging through the algae bed and scattered throughout the remnants of the pool. In contrast, wetland 3 showed no presence of algae or macrophytes, although there was a substantial load of coarse particulate organic matter (CPOM) in the form of leaves and flowers from the surrounding tree canopy, primarily composed of tea-tree and paperbark trees. The substrate in both wetlands was predominantly clay/silt.

No southern pygmy perch or Otway bush yabby were detected. This is consistent with the findings of previous years.

**2023****2022****2021**

Figure 14 Lower Anglesea River wetland 2 site in 2023 (top) compared with 2022 (bottom left) and 2021 (bottom right).

The single edge sample taken within each of the wetlands was within the VLAKES objective. No other relevant objectives were achieved. VLAKES scores and number of families has been similar between the 2 years since the VLAKES index has been implemented for the Lower Anglesea River Wetlands site (*Environmental reference standards (ERS) objectives shallow inland wetlands with outflow (wetland) were compared with W2/3. Figure 15).

Table 5 Individual macroinvertebrate sample results for lower Anglesea River wetland 2/3, showing ERS objectives (green indicates within the ERS objective, red is outside of the objective).

Index	Lower Anglesea River Wetlands		ERS objective*
	Wetland 2	Wetland 3	
# Families	3	6	20
VLAKES	5.3	5.5	3.4
Abundance	57	164	
EPT	0	0	
EPTO	0	0	

*Environmental reference standards (ERS) objectives shallow inland wetlands with outflow (wetland) were compared with W2/3.

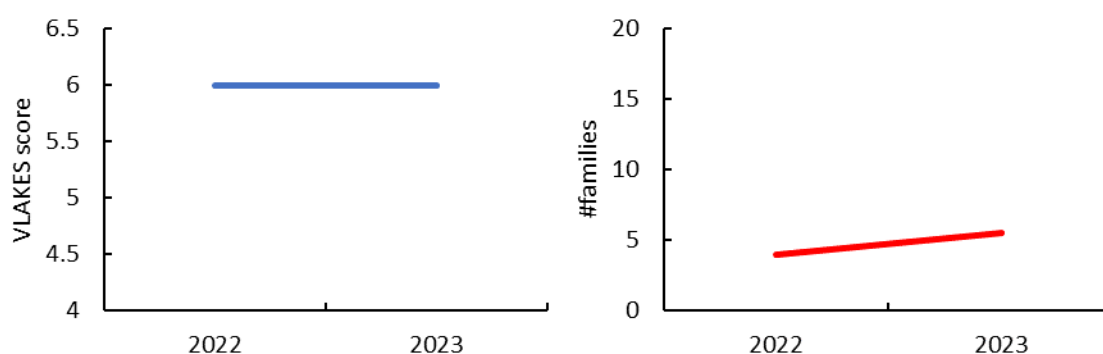


Figure 15 Yearly average VLAKES scores and number of families at site Wetland 2/3 since the VLAKES index has been implemented 2022–2023.

4 Discussion

Macroinvertebrate results were within the range of those previously recorded at all sites. The 2023 survey revealed variations in the availability of wetted habitat across the surveyed sites. While Breakfast Creek and Salt Creek tributaries had sufficient wetted habitat to collect triplicate edge samples, Lower Anglesea Wetlands 2 and 3 were markedly drier than in previous years. This limitation resulted in a reduced sampling effort, with only single edge samples collected from each wetland. The 2023 survey found that none of the sampled sites met the objective for the number of families outlined in the Environmental Reference Standard (ERS). This suggests potential ecological stressors impacting the macroinvertebrate communities within these habitats. However, the Breakfast Creek and Salt Creek sites were within the SIGNAL2 objectives and Wetland 2/3 were within VLAKES objectives, stated within the ERS. This suggests some resilience in these systems despite lower values recorded compared with those when sampling commenced in 2014 at Breakfast Creek and Salt Creek. The presence of EPT (and EPTO) taxa, an indicator of water quality and habitat integrity, was notably low across all sites, with none detected in Wetlands 2 or 3. The low abundance and diversity (as at the creek sites) or absence (as at the wetland sites) of EPT taxa suggests poor water quality or degraded habitat at these sites effecting the ability of the sensitive taxa to persist. The low pH conditions within the sites, which was particularly acidic at the wetland site (pH = 3.22), remain the most evident explanation for the depauperate EPTR and overall macroinvertebrate assemblage, as low pH has been demonstrated to have a negative effect on macroinvertebrate diversity in previous studies (e.g., Courtney and Clements 1998, Tripole et al. 2008).

It is important to note that the sampling effort at the Lower Anglesea River Wetlands sites has varied over time. Typically, Wetlands 2/3 are combined during annual surveys (except in the current year due to limited wetted habitat availability), while Wetlands 2 and Wetlands 3 are surveyed separately every three years, and Wetland 1 was surveyed annually prior to 2017. The inconsistency in the sites surveyed should be addressed during the next review of the Monitoring and Assessment Program (MAP), and the trajectory of wetland sites should be tracked over time, comparing against VLAKES objectives.

Southern pygmy perch were rediscovered within the Breakfast Creek tributary for the first time since 2017. This aligns with previous instances where the population vanished for several years before reappearing, as documented in reports from 2013 to 2015 (GHD, 2013–2015). The recurring disappearance and reappearance strongly suggest the existence of a more favourable and potentially permanent habitat supporting a stable population, referred to as a 'source population', located somewhere nearby. Southern pygmy perch typically exhibit recruitment and dispersal behaviours following flood events (Tonkin et al., 2008), with the environmental conditions of the preceding two years (2021–2022) likely providing suitable conditions for such dispersal. Given the genetic distinctiveness of the population within the Anglesea catchment (Cesar, 2012), it is imperative to safeguard populations in both Breakfast Creek and Salt Creek. To further understand and conserve these populations, we recommend increased efforts to locate the source population and potential refuges for southern pygmy perch. Once identified, these areas should be integrated into monitoring programs as essential components for the ongoing conservation and management of this species in the region.

The consistent presence of southern pygmy perch within the permanent refuge pool in Salt Creek underscores the importance of such habitat for the species' persistence. The southern pygmy perch population has remained broadly comparable over at least the last 5 years. The detection of new

recruits at Salt Creek, alongside breeding indicators (colouration and ripe fish) and good fish condition, demonstrates ongoing recruitment, contributing to this population's stability. The ongoing monitoring of Salt Creek provides evidence of long-term persistence and recruitment of southern pygmy perch population, indicating a self-sustaining population. This reaffirms the significance of maintaining suitable habitat conditions, particularly refuge pools and hydrological requirements to support breeding (Tonkin et al. 2008), to support the long-term persistence of southern pygmy perch populations.

Abundance of Otway bush yabbies was the second highest on record after 2020 in both Breakfast Creek and Salt Creek. Currently, it is not feasible to analyse the change in occipital carapace length over time due to insufficient data. Despite the primary focus on presence/absence, dip netting is proving as informative (if not more) as the bait trapping in most years regarding the Otway bush yabby population biological data. Therefore, it is recommended to continue using both methods to collect Otway bush yabby biological data for future assessments. The detection of young-of-year and juvenile crayfish at both Breakfast Creek and Salt Creek suggests that recruitment is occurring at both locations. This species can complete its life cycle in both permanent and intermittent habitats. The wetter conditions in 2021–2022 should have provided dispersal opportunities, potentially leading to larger and more widespread populations which may be detected during the next triennial survey (which increases dip netting coverage from 3 to 11 sites). Low pH levels (< 3.5), particularly within the lower Anglesea River wetlands, may hinder the spread of Otway bush yabby within the Anglesea catchment. However, the species has been identified in lower pH waterbodies within the same catchment, indicating potential local adaptation to prevailing conditions (Ecology Australia 2020–2021).

4.1 Recommendations

The Monitoring and Assessment Program (MAP) is currently under review. All recommendations from previous monitoring reports should be given consideration as part of this review process.

5 References

- Barwon Water (2021) Anglesea borefield, Barwon Water, available at:
<https://www.yoursay.barwonwater.vic.gov.au/anglesea-borefield> (accessed February 2021)
- Cesar (2012) Population Genetics of the Breakfast Creek Tributary southern pygmy perch (*Nannoperca australis*) Unpublished report prepared for Barwon Water. (Cesar: Parkville)
- Chessman (2003) New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research*, 2003, **54**, 95–103.
- Courtney L.A. & Clements W.H. (1998) Effects of acidic pH on benthic macroinvertebrate communities in stream microcosms. *Hydrobiologia* **379**, 135–145.
- Ecology Australia (2009) Anglesea Borefield Flora and Fauna monitoring. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2011) Anglesea Borefield Flora and Fauna monitoring: Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2012) Anglesea Borefield Flora and Fauna monitoring: 2011-12. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2013a) Anglesea Borefield Flora and Fauna monitoring: 2012-13. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2013b) Anglesea Borefield Bulk Entitlement Review: Terrestrial Ecology Assessment. Report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2014) Anglesea Borefield 2014 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2015) Anglesea Borefield 2015 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2016) Anglesea Borefield 2016 Terrestrial Ecology Revised Monitoring Assessment Program. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2017) Anglesea Borefield Ecological Monitoring and Assessment Program 2017. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2018) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2018. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2020) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2019. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2021) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2020. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2022) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2021. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- Ecology Australia (2023) Anglesea Borefield MAP - Aquatic Ecological Monitoring 2022. Unpublished report prepared for Barwon Water. (Ecology Australia Pty Ltd: Fairfield)
- EPA (2010) Environmental quality guidelines for Victorian lakes. Publication 1302, February 2010 (Environment Protection Authority Victoria: Southbank).
- EPA (2021) Guideline for Environmental Management (GEM) – Rapid bioassessment methodology for Rivers and Streams. Publication 604.2, April 2021. (Environment Protection Authority Victoria: Southbank)

- GHD (2013) 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
- 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
- MDFRC (2013) Draft index of keys. Murray-Darling Freshwater Research Centre: Wodonga
- Tonkin Z, King A.J and Mahoney J (2008), Effects of flooding on recruitment and dispersal of the Southern Pygmy Perch (*Nannoperca australis*) at a Murray River floodplain wetland. *Ecological Management & Restoration*, **9**: 196-201
- Tripole S., Vallania A. & Corigliano M. (2008) Benthic macroinvertebrate tolerance to water acidity in the Grande river sub-basin (San Luis, Argentina). *Limnetica*, **27**, 29-38
- Victorian Government (2009) Bulk Entitlement (Anglesea Groundwater) Order 2009, Victorian Government Gazette, No S 224 Tuesday 30 June 2009. Victorian Government Gazette
- Victorian Government (2014) Bulk Entitlement (Anglesea Groundwater) Order 2009, Victorian, 6 revised, September 2014. Victorian Government
- Victorian Government Gazette (2021) Environment reference standard. S245 26 May 2021

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

Species		Lower Ang wetlands			SC1				BCT1			
Family	Genus	Wetland 2	Wetland 3	T	E1	E2	E3	T	E1	E2	E3	T
<i>Acarina</i>	sp.								1			1
<i>Chironominae</i>	sp.					10	14	24				
<i>Culicidae</i>	sp.	7	3	10					1		1	2
<i>Dixidae</i>	sp.				1			1				
<i>Dytiscidae</i>	sp.	20	29	49	15	2	4	21		6	1	7
<i>Gripopterygidae</i>	<i>Illiesoperla</i>										1	1
<i>Gyrinidae</i>	sp.		3	3								
<i>Hydrochidae</i>	sp.		1	1								
<i>Janiridae</i>	sp.		75	75								
<i>Lepidoptera</i>	sp.									1		1
<i>Leptoceridae</i>	<i>Lectrides</i>								1			1
<i>Leptoceridae</i>	Unidentified*					1		1				
<i>Leptoceridae</i>	<i>Triplectides</i>				1	1	1	3	20	3	1	24
<i>Nannochoristidae</i>	sp.					1	2	3	1			1
<i>Odonata (Epiprocta)</i>	Unidentified#								1			1
<i>Orthocladiinae</i>	sp.				1	3		4	2	1		3
<i>Paramelitidae</i>	sp.		1	1	22	22	27	71				
<i>Physidae</i>	sp.				1		1	2				
<i>Scirtidae</i>	sp.	30	52	82								
<i>Simuliidae</i>	sp.					1		1				
<i>Tanyderidae</i>	sp.					4		4				
<i>Tanypodinae</i>	sp.				1	5	2	8		1		1
<i>Telephlebiidae</i>	<i>Austroaeschna</i>								1	1	2	4
<i>Veliidae</i>	sp.					2	7	9	3			3

* Specimen too damaged to take to lower taxonomic resolution.

Specimen too immature to take to lower taxonomic resolution.