Snowy 2.0 Threatened Fish Management Plan

2024/2025 Annual Report

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Front cover photo: Lizzie Pope and Peter Cowper (Snowy Hydro) releasing Macquarie Perch into the upper Murrumbidgee River NSW (Luke Pearce).

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Executive Summary

This report, which has been endorsed by the Expert Advisory Committee, provides a record of the activities undertaken and an evaluation of the progress that has been achieved under the Snowy 2.0 Threatened Fish Management Plan for the 2024/25 reporting period.

All activities from the 2024/25 Annual Implementation Plan (AIP) were carried out.

Excellent progress has been made towards aims, objectives and targets set within AIP. Given that 2024/25 was only the second year of implementation not all of the aims, objectives and targets have yet been reached, however the establishment of the programs and activities over the past two years, sees the program well placed to meet these, and ultimately achieve the overall goal of the program "to build resilience in and minimise impacts on, Macquarie Perch and Stocky Galaxias populations within the upper Murrumbidgee Catchment."

Annual monitoring was undertaken for both Stocky Galaxias and Macquarie Perch. Stocky Galaxias monitoring at both locations continued to show low catch rates similar to those recorded in 2024. These low catch rates have met trigger levels to initiate further investigations. Macquarie Perch numbers were at a record high with good recruitment and distribution.

Initial catchment surveys have been undertaken to identify potential additional populations and potential reintroduction sites. A total of 110 priority sites were assessed for Stocky Galaxias and 14 priority sites for Macquarie Perch. No additional Macquarie Perch populations were identified. Additional galaxiid populations were identified during the surveys of the upper Murrumbidgee, Tumut and Goodradigbee catchments. Morphology and genetic assessment to determine whether these populations are Stocky galaxias are pending.

Captive breeding continued for both Macquarie Perch and Stocky Galaxias, with 300 Stocky Galaxias produced by Charles Sturt University and a captive population maintained. Due to concerns with the suitability of the Eucumbene Borrows for additional releases, the Stocky Galaxias produced were utilised for thermal tolerance experiments. The fish remaining from these experiments have continued to be held and maintained at CSU. It is intended that these fish will be released later in 2025 into a priority reintroduction site identified in the catchment surveys during 2024/25.

Captive breeding of Macquarie Perch continued at the Narrandera Fisheries Centre (NFC). A total of 300 juvenile Macquarie Perch were produced. The captive population was maintained and added to with additional broodfish collected from other populations under the program to increase numbers and the genetic diversity of the captive population. Trial spawning of wild collected Macquarie Perch broodfish showed some promise. Despite low production, there were significant learnings that will inform and improve the process in future. With multiple fish spawning and over 300,000 eggs produced, the potential value of the program is evident.

A major investment into the construction of eight new ponds at the Narrandera Fisheries Centre occurred. These new ponds will enable the housing of increased numbers of Macquarie Perch broodfish, the on growing of future broodfish and larval production which will be required as production increases.

Macquarie Perch produced via the captive breeding program were released to Winburndale Dam, a priority refuge site located in the Macquarie Catchment. Translocations occurred for Macquarie Perch, with fish being translocated from Cataract Reservoir near Sydney into five locations in the upper Murrumbidgee River for genetic enhancement of the population.

Ongoing temperature monitoring has continued to show high water temperatures at the Eucumbene Borrows. Therefore no further releases of Stocky Galaxias are proposed at the site at this stage. Further improvements in water security and flow are continuing at the site under a federal government grant which may improve flows and temperature. The site will continue to be monitored for both water temperature and fish.

Expenditure for the 2024/25 financial year came in slightly under the forecast and allocated budget.

1. Introduction

Snowy 2.0 is a pumped hydro expansion of the Snowy Mountains Scheme, which will hydrologically link the existing reservoirs of Talbingo and Tantangara, via underground tunnels and an underground power station, that will be owned and operated by Snowy Hydro Limited (Snowy Hydro).

The transfer of water between these reservoirs and catchments brings with it the risk of transfer of pest fish and pathogens which are currently not present within the upper Murrumbidgee Catchment (Baumgartner et al 2016 and Ning et al 2019), and which may impact the threatened fish species Macquarie Perch (*Macquaria australasica*) and Stocky Galaxias (*Galaxias tantangara*) if planned controls fail, and pest species spread beyond Tantangara Reservoir.

Snowy Hydro comprehensively assessed the likelihood of these potential impacts and options to avoid transfer of pest fish through Snowy 2.0 as well as options to minimise potential impacts (EMM 2018, EMM 2020). Details about relevant biosecurity controls are provided in the Snowy 2.0 Biosecurity Risk Management Plan (BRMP).

In addition, the Snowy 2.0 Threatened Fish Management Plan (TFMP) was developed to minimise the impact of the development on threatened fish species and their habitat, particularly the Macquarie Perch, Stocky Galaxias and Murray Crayfish. A key part of this plan is a captive breeding program for the Macquarie Perch and Stocky Galaxias involving the spending of $5 million over 5 years from the commencement of the program that provides for:

- → Mid to Upper Murrumbidgee Catchment;
- → habitat surveys to identify suitable receiving sites for stocking insurance populations of Stocky Galaxias and Macquarie Perch;
- → captive breeding, stocking, and monitoring of Macquarie Perch and Stocky Galaxias with the aim of achieving self-sustaining populations of these species;
- → habitat enhancement for the Macquarie Perch in the mid-Murrumbidgee Catchment.

The TFMP contains broad management objectives and is based on several underpinning plans and strategies developed for each species: Macquarie Perch (Lintermans et al. 2022a, b; Lyon et al. 2022; Tonkin et al. 2022); Stocky Galaxias (Raadik and Lintermans 2022a, b; Raadik et al. 2022; Stoessel and Raadik 2022). These detailed documents contain objectives, methods, and outputs for each species, and as such, along with the TFMP, provide the direction and detail for the implementation of the captive breeding program ('the program') under the TFMP. The activities of the TFMP align with the conservation and management actions identified in the Macquarie Perch recovery plan and the Stocky Galaxias conservation advice.

The 2024/25 Annual Implementation Plan (AIP) for the Snowy 2.0 TFMP was developed and approved by the Expert Advisory Committee (EAC) and is available on the Snowy Hydro website (see Section 2).

Under the TFMP, Snowy Hydro also undertakes population monitoring and surveillance for Murray Crayfish (*Euastacus armatus*). The results of this monitoring are also reported in this document.

This report summarises the activities and results of the actions that were undertaken in 2024/25 as outlined in the AIP.

2. Expert Advisory Committee

The Snowy 2.0 TFMP Expert Advisory Committee (EAC) consists of Chair Barry Buffier, NSW Fisheries Scientific Committee Member, Dr Nick Whiterod, Freshwater Fish Specialist Scientist Dr Tarmo Raadik and Specialist Scientist Dr Natalie Moltschaniwskyj. The committee provides ongoing critical oversight, advice and guidance for the planning and implementation of the Snowy 2.0 TFMP.

The EAC met on a quarterly basis, and at other times as needed, to review the program progress, priorities, and finances. The committee provided invaluable insight and advice on many critical issues and decisions to ensure the most appropriate approach to deliver the best outcomes and value for money.

In addition, the EAC also reviewed and provided feedback on all planning and monitoring documents developed and undertaken as part of the implementation of the TFMP.

During the course of the 2024/25 program Natalie Moltschaniwskyj resigned as Chief Scientist for NSW DPIRD. Natalie, with the support of NSW Department of Primary Industries and Regional Development (NSW DPIRD), has agreed to continue as an independent specialist scientist representative on the EAC.

Snowy Hydro provides administrative support to the EAC and the membership with this role currently being fulfilled by Lizzie Pope. Luke Pearce represents NSW DPIRD, providing reports and updates undertaken under the TFMP.

3. Results

3.1 Population Monitoring

3.1.1 Stocky Galaxias

Aim and Objectives

The overall aim of the Stocky Galaxias monitoring is to provide baseline, comparable data on the species, to inform decisions on management intervention for the long-term survival of the species. Specific monitoring objectives as outlined in the 2024/25 AIP and whether these objectives have been met is provided as follows:

The persistence of Stocky Galaxias (presence and breeding).

The monitoring undertaken showed persistence of Stocky Galaxias at both Tantangara Creek and Sallys Flat Creek. Juvenile (Young of Year (YOY)) fish were captured in both reaches of Sally's Flat Creek and captured or observed at Top Flat of Tantangara Creek. There were no YOY detected at Bottom Flat in Tantangara Creek during this monitoring season.

The population trajectory (is the population increasing, stable or decreasing) and variability (significant change from normal).

As it is only the 2nd year of dedicated monitoring, it is hard to ascertain the trajectory of these populations. It was found that catch rates at Sally's Flat Creek in late-March 2025 were lower compared to early-February 2025 however the same trend was not evident for Tantangara Creek. Tantangara Creek again had a very low abundance of fish for the 2nd year, in particular at Bottom Flat which supports the hypothesis of a population decline.

The status of the Stocky Galaxias populations (incorporating measures of abundance, distribution, reproduction, fish health and demographics).

The low numbers of Stocky Galaxias detected in Tantangara Creek in both 2024 and 2025 are of concern.

The Stocky Galaxias catch rate at Tantangara Creek in 2025 was low in both sampling events (Feb & March) and varied in Sallys Flat Creek with higher rates in February than recorded in March, however, were similar to numbers from 2024.

Fish health was assessed via visual examination. Digenean trematode metacercaria were visible on fish from Sally Flat Creek, but none were observed at Tantangara Creek. Intensity of the infection was generally low.

The status of identifiable threats at Stocky Galaxias locations (e.g. riparian erosion, instream sedimentation, riparian vegetation condition with respect to ability to trap sediment).

A rapid, visual assessment of potential threats did not reveal any critical or new threats to the Stocky Galaxias populations at either location.

The persistence and establishment of any new translocations of the species into the catchment.

To date, Stocky Galaxias have only been translocated and stocked into the Eucumbene Borrows, a purposely constructed habitat below the Eucumbene Dam wall. Monitoring at Eucumbene Borrows has detected low numbers of Stocky Galaxias, with three observed in May 2024, 14 observed and one captured in November 2024 and none captured or observed during monitoring in May 2025.

The fish spawned in 2024 are being held over at CSU's purpose-built facilities until November 2025 to allow time for assessment of potential translocation sites following catchment surveys undertaken in March/April 2025.

Incursions of exotic fish species (Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*)), or invasive native species Climbing Galaxias (*Galaxias brevipinnis*) into known Stocky Galaxias populations.

No pest fish were detected by the electrofishing monitoring undertaken in 2025.

Triggers for further investigations and/or identified management interventions to mitigate potential sudden declines because of identified threats (e.g., Redfin Perch fish invasion, drought, fire).

Monitoring for Stocky Galaxias in 2025 has met trigger levels under several TARP Criteria set out in the Monitoring Program. Surveys suggest there has been a decline in the Stocky Galaxias population at Tantangara Creek and a lack of recruitment in 2025 at Bottom Flat in Tantangara Creek.

There were no threats identified requiring intervention regarding water quality, fire or drought or predatory fish invasion.

Stocky Galaxias monitoring in Tantangara Creek and Sallys Flat Creek for the 2024/25 season was undertaken by Mark Lintermans and Hugh Allan, a detailed report is provided as Appendix A.

A summary of the major findings of this monitoring and report is as follows:

Monitoring was undertaken at Tantangara Creek and Sallys Flat Creek as recommended by Raadik and Lintermans (2022) in early February and late March/early April 2025. Two rounds of sampling were undertaken in 2025, to quantify if the declines detected in the previous year may have been a seasonal effect due to sampling efficiency or seasonal changes in abundance. Sampling was undertaken at two sites in Tantangara Creek (Top Flat and Bottom Flat) with backpack electrofishing, with a similar methodology applied at Sallys Flat Creek, with two sites sampled (Lower and Upper).

A total of 415 fish were caught or observed with 361 confidently identified to species across all sites and reaches. A total of 205 Stocky Galaxias and 92 Mountain Galaxias were captured from Sallys Flat Creek, with 64 Stocky Galaxias captured (and 50 observed) from Tantangara Creek. At Sallys Flat Creek, where both Mountain Galaxias and Stocky Galaxias are present, 54 Galaxias of uncertain species were caught with another 77 fish observed (Table 1). Stocky Galaxias comprised 69% of the species identified fish caught at Sallys Flat Creek.

Table 1. Raw catch data for both Tantangara Creek and Sallys Flat Creek

Total number (all shots combined) of Stocky Galaxias, Mountain Galaxias and unidentified galaxiids (*Galaxias spp.*) captured at each site and reach as part of 2025 monitoring. Numbers in brackets are observed fish. * Includes 30 young-of-year observed, reproduced from Lintermans and Allan (2025).

Site	Reach	Month	No. efish shots	Stocky Galaxias (*Galaxias tantangara*)	Mountain Galaxias (*Galaxias olidus*)	Unidentified *Galaxias* spp.	Total catch	
Sallys Flat Creek	Lower	Feb	–	3	68	70	24 (51)	162 (51)
	Upper	March	3	40	14	3	57	
		Feb	3	67	8	23 (26)	98 (26)	
		March	3	30	–	4	34	
Tantangara Creek	Bottom Flat	Feb	–	5	5 (1)	–	–	5 (1)
	Top Flat	April	5	7	–	–	7	
		Feb	3	29 (38*)	–	–	29 (38*)	
		April	5	23 (11)	–	–	23 (11)	
Total fish		Feb		169 (39*)	78	47 (77)	294 (116*)	
		March/ April		100 (11)	14	7	121 (11)	

The results for the 2024/25 season at Bottom Flat at Tantangara Creek presented in Lintermans and Allan (2025) again showed low Stocky Galaxias catch rates in both February and March/April sampling events similar to levels recorded in 2024. These numbers are lower than those recorded in previous sampling events undertaken prior to the TFMP monitoring. It was also found that overall abundance was lower in April 2025 than February 2025, indicating that the hypothesis surrounding seasonal sampling in 2024 was partially correct.

In Tantangara Creek, there was a concerning decline in the Stocky Galaxias catch rate at Bottom Flat compared to previous years as well as no recruitment detected at Bottom Flat in April 2025.

The 2025 Stocky Galaxias monitoring has met trigger levels under several of the Trigger Action Response Plan (TARP) criteria from Raadik and Lintermans (2022). However, there is uncertainty as to at what spatial scale the criteria are to be applied, there is also uncertainty regarding the appropriateness of the response actions and the metrics at which the trigger criteria are measured.

In light of this uncertainty, it is recommended that the nature and scale of any additional monitoring to be undertaken, and consideration of potential interventions, be determined by holding a workshop. Suitably qualified experts will be asked to review the TARP criteria triggers, define metrics for measuring decline and agree on a plan for the next season of monitoring.

3.1.2 Macquarie Perch

Macquarie Perch monitoring of the upper Murrumbidgee River population was undertaken by Mark Lintermans, a detailed report of the results is provided as Appendix B.

Macquarie Perch monitoring of the two reference sites in the Abercrombie River was undertaken by NSW DPIRD. A summary of the major findings of the upper Murrumbidgee River and Abercrombie River results are provided below with additional detail provided in Appendix C.

Aim and Objectives

The overall aim of the Macquarie Perch monitoring is to provide baseline, comparable data on the species, to inform decisions on management intervention for the long-term survival of the species. Specific monitoring objectives as outlined in the 2024/25 AIP and if these objectives have been met is provided as follows:

The persistence of Macquarie Perch (is the species still present and breeding at sites where it has been recorded since 1998?).

Macquarie Perch were in very high abundance this season with a total of 434 individuals captured and were recorded at eight of the nine sites on the Murrumbidgee River including all the core sites and the lower fringe site. As with last season, the only fringe site where the species was absent was the most upstream site.

The population trajectory (is the population increasing, stable or decreasing?) and variability (significant change from normal).

The combined abundance of Macquarie Perch sampled (434) in 2025 is the highest on record with the previous highest tally being 197 in 2021. This increase in abundance was largely driven by the high abundance of YOY and 1+ fish recorded.

The status of the Macquarie Perch population (incorporating measures of abundance, distribution, reproduction and demographics).

The status of the Macquarie Perch population in the upper Murrumbidgee River in 2025 is secure and thriving with the highest number of fish captured on record. Recruitment has occurred at majority of sites with many YOY and 1+ fish present. It is also showing a good population structure with all size classes surveyed including YOY, 1+, subadult and adult fish.

The persistence and establishment of any new translocations of the species into the catchment.

There has not been any establishment of new populations at this stage in the project. This is likely to occur from year 3 onwards, however is dependent on the catchment surveys undertaken this season identifying suitable receiving locations.

Incursions of Redfin Perch into the upper Murrumbidgee Catchment.

No Redfin Perch were detected in the upper Murrumbidgee Catchment as part of the 2025 surveys. NSW DPIRD also undertook eDNA sampling at 14 sites in the Upper Murrumbidgee that did not detect any Redfin Perch DNA at those sites.

Triggers for further investigations and/or identified management interventions to mitigate potential sudden declines because of identified threats (e.g., Redfin Perch fish invasion, drought, fire).

The 2025 Macquarie Perch monitoring found that there were no triggers or additional threats that would trigger management intervention.

Upper Murrumbidgee River

Monitoring was undertaken in the upper Murrumbidgee consistent with the recommendations provided by Lintermans et al (2022), (see Appendix B for detailed methodology). A total of nine sites (seven core sites and two fringe sites) were sampled, with sampling being conducted in March 2025.

A total of 648 individuals of eight species of finfish were sampled with Macquarie Perch being the most abundant species, recorded at eight of the nine sites, followed by the alien Carp (*Cyprinus carpio*), then Mountain galaxiids (*Galaxias olidus*) (Table 2). There was a total of 434 Macquarie Perch recorded across young-of-year, 1+, 2+ and adult size classes. There was only one other native fish caught, a single Murray cod (*Maccullochella peelii*), and relatively few trout recorded. Other non-target, non-fish species were also recorded across all sites (Table 3). In promising results, the combined abundance of Macquarie Perch in 2025, is the highest on record for the Murrumbidgee River sampling.

Table 2. Macquarie Perch monitoring: Fish captured (or observed) in 2025

Site	Macquarie Perch (*Macquaria australasica*)	Mountain Galaxias (*Galaxias olidus*)	Murray cod (*Maccullochella peelii*)	Rainbow trout (*Oncorhynchus mykiss*)	Brown trout (*Salmo trutta*)	Carp (*Cyrpinus carpio*)	Goldfish (*Carassius auratus*)	*Gambusia holbrooki*	Total fish
1	–	3	–	–*	–	–	–	–	3
2	183	6	–	–	–	–	–	–	189
3	22	5	–	1	2	–	–	–	30
4	15	1	–	–	–	–	–	obs	16
5	125	–	–	–	2	45	2	–	172
6	53	–	–	–	–	63	–	–	116
7	4	–	–	–	–	45	1	obs	50
8	31	–	1	–	–	22	1	–	55
9	1	–	–	–	–	14	2	obs	17
Total	434	15	1	1	5	187	6	–	648

* Trout of unknown species observed

Abercrombie River Reference Sites

Sampling was undertaken at the two reference sites on the Abercrombie River in the Lachlan Catchment in early April (8th – 10th), water levels were very low at time of sampling.

A total of 158 individual fish were captured with Macquarie Perch the dominant species accounting for 154 of the total fish at both sites. The size range of Macquarie Perch was from 54-289mm indicating the presence of multiple size classes.

Young-of-year (50-100mm) were present at both Smiths Crossing and Tween Cabin comprising 78% and 92% respectively of total Macquarie Perch captures at each site. The largest Macquarie Perch was captured at Smiths Cabin at 375mm.

No other native species were caught at either site; however, one carp was recorded at Smiths crossing and three recorded at Tween Cabin. Several large carp (500-600mm) were observed at Smiths Crossing site but were not caught in either fyke nets or gill nets.

The overall condition of the Macquarie Perch (Figure C3, Figure C4) was good with no major deformities; however, one fish had some slight caudal fin damage. Anchor worm (*Lernaea cyprinacea*) were recorded on four individual fish but in very low numbers.

One Platypus (*Ornithorhynchus anatinus*) and six Eastern long-neck turtles (*Chelopdina longicollis*) were captured during sampling. All were carefully released unharmed.

Table 3. Fish and non-target animals captured at the Abercrombie River reference sites in 2025 monitoring

Site	Macquarie Perch (*Macquaria australasica*)	Carp (*Cyrpinus carpio*)	Total fish	Long neck turtle (*Chelodina longicollis*)	Platypus (*Ornithorhynchus anatinus*)
Smiths Crossing	50	1	51	6	0
Tween Cabin	104	3	107	0	1
Total fish	154	4	158	6	1

3.2 Translocation

3.2.1 Stocky Galaxias

Translocations of Stocky Galaxias to achieve the objective identified in Raadik et al (2022) *'Improve the conservation status of Stocky Galaxias in the wild to ensure enough viable populations with evolutionary potential exist to support long term persistence'*, rely on understanding critical aspects of the wild populations including population genetics, population size and structure along with identification of receival locations.

Until reintroduction sites have been identified via the catchment surveys, work has been undertaken to establish an *ex situ* constructed habitat at the Eucumbene Borrows. The intention was to use this location to establish an *ex situ* population to act as an insurance population, and potentially a source population, to be used for further translocations in the future if a population established and recruited in sufficient numbers.

The Eucumbene Borrows is a disused quarry site below the Eucumbene Dam wall that was used during the construction of the Eucumbene Dam. The National Parks and Wildlife Service have been undertaking restoration of the site for several years to improve the stability and ecological values of the site.

There are several dams and ponds of varying sizes present on the site that hold and maintain water. Rock lined streams that replicate the habitat of Stocky Galaxias have been constructed to connect three of these ponds and water is reticulated via submersible electric pumps powered by solar panels to replicate the flowing water habitats of Stocky Galaxias.

Temperature monitoring at the Eucumbene Borrows over the past two summers has indicated that the maximum temperatures are likely exceeding the upper thermal tolerance limits of Stocky Galaxias (further temperature details can be found in Appendix D), this is also supported by the fish monitoring at the site which has only detected very low survival rates with the most recent surveys failing to detect any fish at all.

Given these issues, no further releases of captive bred Stocky Galaxias are planned for the Eucumbene Borrows until such a time as either it is demonstrated that the water temperatures are suitable or there is evidence of survival of earlier released fish.

Figure 1. Overview of the Eucumbene Borrows site

To date there have been four translocations/stockings of Stocky Galaxias into the Eucumbene Borrows, see Table 4.

Table 4. Number of Stocky Galaxias released at Eucumbene Borrows

Release date	Number	Source
27 April 2023	78 juveniles	Captive breed CSU
27 April 2023	6 Adult males	Tantangara Creek 2020 fire rescue fish from CSU
27 April 2023	43 YOY	Tantangara Creek
14 May 2024	243 juveniles	Captive Bred CSU

Eucumbene Borrows Monitoring

There have been four formal monitoring events undertaken at the Eucumbene Borrows, with several informal visual surveys undertaken by both National Parks and Wildlife and DPIRD Staff. Monitoring methods include backpack electrofishing of the stream sections, fyke netting of the pond/dam (Table 5) and spotlight (Table 6) and visual surveys of the streams.

Fyke Net Results

Table 5. Eucumbene Borrows Fyke net results

Site	Date	Yabby (*Cherax destructor*)	Stocky Galaxias (*Galaxias tantangara*)
Middle Pond	9 October 2023	34	0
	13 May 2024	42	0
	19 Nov 2024	133	1
	14 May 2025	15	0
Bottom Pond	9 October 2023	52	0
	13 May 2024	10	0
	19 Nov 2024	97	0
	14 May 2025	2	0

One Stocky Galaxias was captured via fyke nets in the Middle Pond in November 2024 measuring 61mm and weighing 2.3g.

Spotlight Survey Results

Table 6. Eucumbene Borrows spotlight survey results

Date	Stocky Galaxias observed
9 October 2023	20
13 May 2024	3
19 Nov 2024	14
14 May 2025	0

Electrofishing Results

Backpack electrofishing has been undertaken on three occasions.

Backpack electrofishing was undertaken along the entire length of both constructed streams on the 14 May 2024 with only one Stocky Galaxias being observed but not captured, this fish was observed in the same pool as two of the three fish that were observed during the spotlight surveys the previous night.

On the 19th of November 2024 one Stocky Galaxias was observed whilst electrofishing the entire length of the constructed streams along with 40 yabbies caught (15 observed).

On the 14th of May 2025, backpack electrofishing was again undertaken by DPIRD staff again along the entire length of the constructed streams. No Stocky Galaxias were caught or observed during the sampling.

Eucumbene Borrows Structural Improvement Works

Following on from the high-water temperatures in Summer 2023/24, structural works and upgrades were implemented at the Borrows to improve water storage, water security and flow on site. These works, funded by the Governments "Saving Native Species" Grant program included repairs to the upstream dam wall to increase storage capacity, diversion of flows into upper storage dam to increase storage capacity, upgraded pumps to increase flows and repairs of the outlet from the lower storage dam to increase capacity and structural stability.

Water temperatures in the Lower and Upper Streams from Nov 2024 to May 2025 (Figure D3) were shown to be slightly lower than those recorded in a similar period from Nov 2023 to May 2024 (Figure D1).

Temperature loggers were redeployed once data was collected from them.

Water temperature within the streams and the ponds at the Eucumbene Borrows will continue to be monitored to evaluate the impacts of the current improvement works on water temperatures. Fish monitoring will also be ongoing to determine if any of the Stocky Galaxias released at the site persist.

3.2.2 Macquarie Perch

The 2024/35 Annual Plan identified the target of 102 Macquarie Perch to be translocated from Cataract Dam and Loddon Creek for release in the upper Murrumbidgee River at three locations (site 2, site 3 and site 4), to build on previous genetic rescue efforts that have occurred in 2020, 2022, 2023 and 2024.

A total of 419 Macquarie Perch were collected during the collection trip to Cateract Reservoir. Fish were collected between the 24th-28th of March and ranged in size from 45-240mm. The high collection rate enabled the translocation target to be increased, which was endorsed by the EAC. Fish were also retained as broodstock at Narrandera Fisheries Centre (NFC).

Following quarantine period at NFC and a subset of fish being examined for external parasites and disease which was shown to be all clear, 300 Cataract Dam fish were released into the upper Murrumbidgee River at five sites (20 at Koonaroo, 120 at Site 3 (Bolaro), 30 at Koomulla and 130 at Site 6 (Kissops Flat) on the 15th April 2025. These sites and the number of fish released at each site was guided by advice from geneticist Alexandra Pavlova. Twenty-four Cataract fish were retained at NFC for additional broodstock.

Whilst not a specific requirement of the Snowy 2.0 TFMP and not funded by the TFMP the opportunity was taken to utilise the additional Macquarie Perch collected from Cataract Reservoir and released them into other remnant populations across NSW, to increase the genetic diversity of these populations and increase the overall genetic health of the species across its range. The fish were released into the Retreat River (25 fish), the Mongarlowe River (21 fish), Adjungbilly Creek (23 fish) and Mannus Creek (25 fish). This represents the largest ever genetic rescue undertaken for Macquarie Perch in NSW and is a great example of how the Snowy 2.0 TFMP is enabling improved recovery outcomes for Macquarie Perch as a species above and beyond what is required under the TFMP.

In addition to the 300 Cataract fish that were released 11 large adult female Macquarie Perch that were collected for spawning experiments from the Cooma Gorge in October 2024, were released post spawning in line with the recommendations by Pavlova et al (2024). At the upstream site of Bolaro, one of these ex-broodfish was recaptured during the monitoring surveys in 2025, demonstrating survival and that it had not moved far from the release location at that time.

Table 7. Macquarie Perch genetic rescue release locations and numbers of fish released

Release Site	Number of Fish	Date	Lat and Long	Source
Koonaroo	30	15 April 2025	-35.865378° 148.809284°	Cataract Reservoir
Site 3 (Bolaro)	120	15 April 2025	-35.973540° 148.813510°	Cataract Reservoir
Koomulla	30	15 April 2025	-36.016015° 148.946739°	Cataract Reservoir
Site 6 (Kissops Flat)	130	15 April 2025	-36.138865° 149.003129°	Cataract Reservoir
Site 3 (Bolaro)	11	18 November 2024	-35.973540° 148.813510°	Upper Murrumbidgee Cooma Gorge (females collected for spawning)

Figure 2. Translocated Macquarie Perch being released at Site 2 by Lizzie Pope (Snowy Hydro) Nick Whiterod (Expert Advisory Committee) and Mark Lintermans (Fish Fondler) in April 2025

Figure 3. Manager of Bolaro Station releasing a large adult Macquarie Perch in November 2024 translocated from the Cooma Gorge

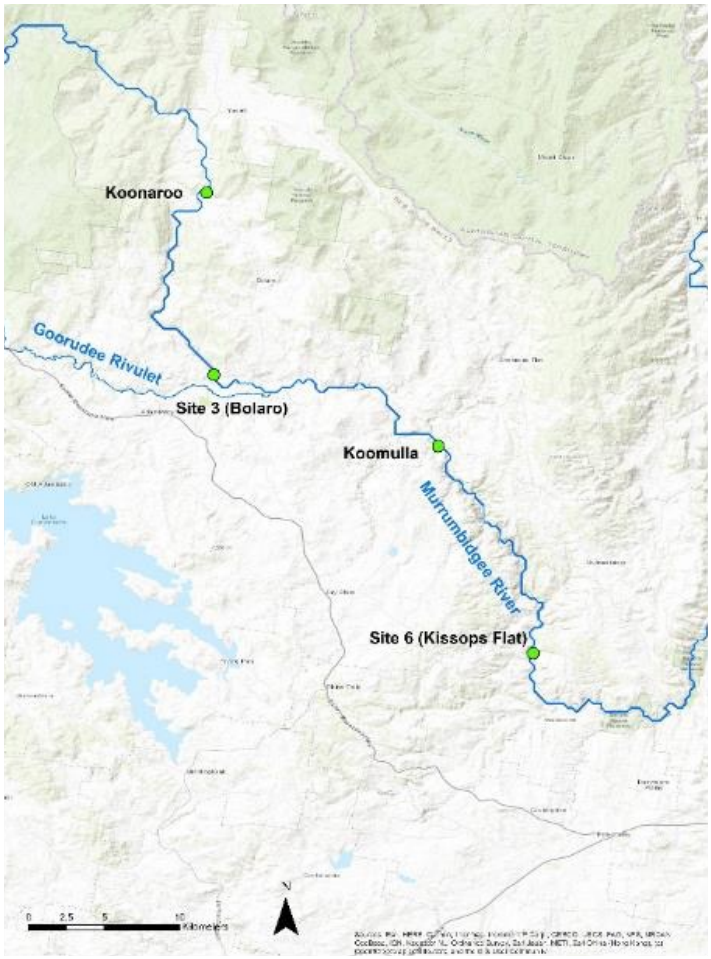

Figure 4. Map showing the 2025 translocation sites

3.3 Captive Breeding

3.3.1 Stocky Galaxias

Captive breeding of Stocky Galaxias and maintenance of the captive population was undertaken by Charles Sturt University (CSU) at the Thurgoona Campus in a purpose-built refrigerated shipping container. CSU have been holding Stocky Galaxias since July 2020, when 16 Stocky Galaxias, rescued post bushfire from Tantangara Creek being held at the Gaden Trout Hatchery at Jindabyne, were transferred to CSU. This original stock was added to in 2021, when a further 23 young of year Stocky Galaxias were collected from Tantangara Creek and added to the captive population. A further nine Young-of-year, again from Tantangara Creek, was added to the captive population in 2023, see Table 8.

Total Stocky Galaxias broodfish currently held at CSU is 39 adults, there was one mortality during the past 12 months, which occurred during the spawning operations, with one male fish not recovering following sedation.

A comprehensive Stocky Galaxias Captive Breeding Manual has been compiled by the team at CSU, detailing the methods and techniques for husbandry and captive breeding of Stocky Galaxias. A copy of the manual can be found in Appendix E.

Table 8. Captive Stocky Galaxias population at Charles Sturt University

	Original number of fish (delivered to CSU or bred)	Current number held at CSU as at June 2025	Fate
2020 Tantangara Creek Bushfire Rescue	16	6	6 males released at Eucumbene Borrows 2023. 4 mortalities.
2021 Tantangara Creek YOY	23	20	3 mortalities
2023 Tantangara Creek YOY	9	9	–
CSU 2022/23 captive bred	n/a	4	78 juveniles released Eucumbene Borrows 2023
CSU 2023/24 captive bred	n/a	0	243 fish released Eucumbene Borrows 2024
CSU 2024/25 captive bred	300	128	Fish to be held until November 2025 prior to release

2024/2025 CSU Stocky Galaxias captive breeding update (Provided by Amina Price, Research Fellow, Charles Strurt University)

Fish were stripped in mid-late November, which is earlier than expected. The fish were ready to be stripped when water temperatures were only just above 8°C. This suggests that the rate of increase and actual temperature is less important than the duration of increase. The eggs incubated well, although similarly to previous years, fertilisation/hatching rates varied enormously among batches.

It appears that timing of stripping must be exact and that there's no way to visually estimate when the optimal time is based on looking at the females. The CSU team think that it would be worth trialling hormone induction (with egg staging), to see whether a better consistency in terms of fertilisation and hatch rates among batches could be achieved.

The number of larvae that hatched was similar to last year (around 500 larvae) however more fish were stripped so the hatch rate would be lower. Unfortunately, most of the larvae from the best batch were deformed and were not viable leaving only about 300 larvae. This is the first time that this has happened, and it is unknown why this occurred.

Due to the uncertainly regarding the thermal suitability of the Eucumbene Borrows and the field assessments and prioritisation process for the catchment surveys not being completed all remaining captive breed juveniles from the 2024 spawning are to be held and on-grown by CSU until November 2025 at which time a suitable reintroduction site will have been identified.

CSU has installed a second shipping container which has doubled their capacity to allow for larval grow out and additional experiments.

Figure 5. Stocky Galaxias eggs in the incubator during the 2024/25 season

Figure 6. The original and second shipping container at CSU used for Stocky Galaxias breeding and experiments

Stocky Galaxias Thermal Tolerance Experiments

Two separate thermal tolerance experiments were undertaken to gain a better understanding of suitable temperature ranges for Stocky Galaxias. These were Optimal Growth experiments and Critical Thermal Maximum (CTmax) experiments. A summary of each experiment and the key findings is provided below; further details can be found in Appendix F.

Optimal Growth Experiments

Optimal growth experiments began on 2 January 2025 when the fish were 13 days post hatch and concluded on the 20 March 2025 when the fish were 90 days post hatch. 50 × 13-day old fish were placed into one of five temperature treatments: 12°C, 17°C, 22°C, 27°C and 32°C.

Key findings:

- → Daily average temperatures must be below 27°C during the larval growth period.
- → Daily average temperature must be below 22°C during the juvenile growth period.
- → Optimal survival and growth of larvae and juveniles occurred at 17°C.

Critical Thermal Maximum Experiments

CTmax experiments were undertaken for the following groups on two age classes 60 days post-hatch and 90 days post-hatch and with two different starting temperatures 12 and 17 degrees. Temperatures were increased from the holding temperature at a rate of 1 degree every 3 minutes until loss of equilibrium (CTmax) occurred. All fish recovered well from these experiments and no mortalities occurred.

Key findings:

- → All fish that were held at 12-13°C, lost equilibrium at between 26-27°C. This was consistent among all age groups.
- → All fish that were held at 17°C lost equilibrium at between 30-31°C. This was for both 60 and 90-day-old fish.
- → Across all age groups and both acclimation temperatures, fish were able to cope with a rapid temperature increases of about 13-15°C.

3.3.2 Macquarie Perch

Pond Infrastructure Upgrades

A major component of the 2024/25 AIP was the construction of eight new Macquarie Perch ponds at Narrandera Fisheries Centre. These ponds will allow the program to increase the numbers of broodfish on site, allow for on growing of subadult fish and increased larval rearing in turn leading to increased production.

NSW DPIRD awarded the contract for design and construct to Boots Civil in July 2024. All eight ponds were completed by June 2025 within the allocated budget.

Macquarie Perch broodfish were transferred into two of the newly constructed ponds in June 2025, with other ponds all being filled.

This the largest single investment in the ongoing captive breeding and conservation of Macquarie Perch ever seen in NSW and it is a critical investment that will assist the long-term conservation efforts for Macquarie Perch into the future well beyond the life of the Snowy 2.0 TFMP.

Bird Netting

DPIRD has been successful in a capital bid for $250,000 for bird netting at NFC. A supplier has been awarded the contract following a tender process and works should begin early in the 2025/26 season, this netting will cover three of the newly constructed ponds between 36-37 as shown in Figure 7.

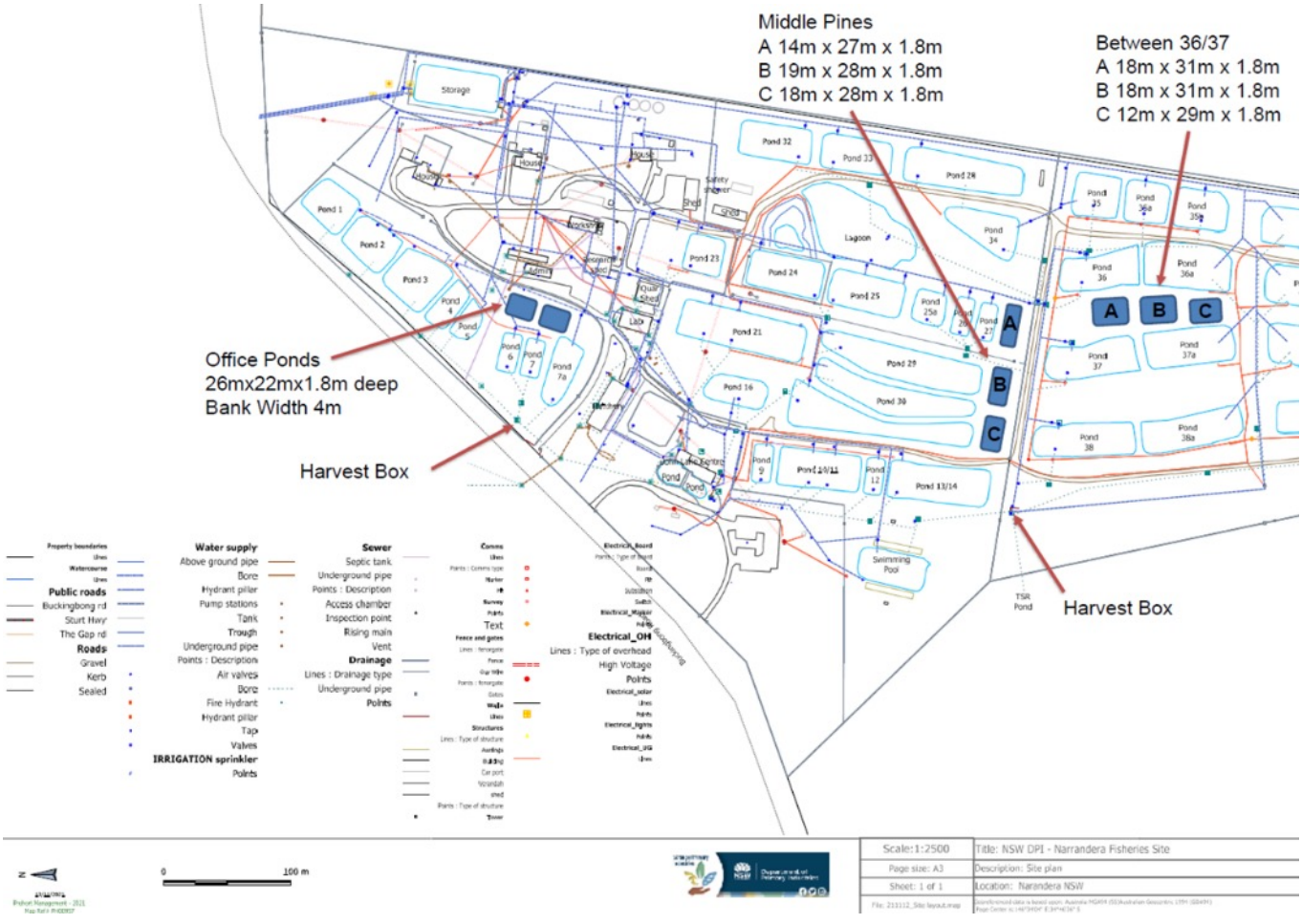

Figure 7. Location of the recently constructed Macquarie Perch ponds at the NFC

Figure 8. Two newly constructed Office Ponds

Figure 9. Pond construction on Middle Pines and Between 36-37 nearing completion in the foreground. The completed Office ponds can be seen full in the background.

Hatchery Upgrades

Several upgrades and modifications have been carried out at the Narrandera Hatchery in preparations for the 2025 breeding season, with improved filtration of river water identified as a critical priority.

Ultraviolet (UV) Sterilizer water filter units have been installed in each of the egg recirculation systems to disinfect water using UV light. This process neutralizes harmful microorganisms such as bacteria and algae, helping to improve egg fertilisation and overall river water quality.

Polypropylene 10-micron filter bags will be used to further filter river water after it passed through the initial sand filtration system.

Figure 10. UV Filter that will be installed in recirculating system.

Captive breeding and maintenance of the captive population of Macquarie Perch was undertaken by DPIRD staff at the NFC in collaboration with the University of the Sunshine Coast as part of the "Cracking the Code" project. A detailed report of the outcomes of the captive breeding program for the 2023/24 season can be found in Appendix 4. The spawning activities undertaken in October 2024 were jointly funded through the Snowy 2.0 TFMP and the Cracking the Code project. The ongoing maintenance of the captive population, collection of additional broodfish, upgrades to the hatchery and maintenance was funded through the Snowy 2.0 TFMP.

During October 2024, staff from DPIRD and University of the Sunshine Coast again used slow release GnRHa implants to induce spawning. The 2024 spawning focus was on determining whether the source water (river vas bore) and water temperature (20°C vs 23°C) influenced the spawning response and success. Broodstock comprised of the following origin: captive held F1's (Abercrombie origin), Dartmouth Reservoir, Cataract Reservoir, F2's (Abercrombie origin) and wild Upper Murrumbidgee River fish.

Based on the results from the 2023 studies groups of 4-5 females and 3-4, males were combined in individual spawning tanks to secure optimal spawning response.

Fish in all tanks spawned following the GnRHa implant, showing no significant effect of water source or temperature on spawning, there were 21 separate spawning events, compared to six spawning in 2023, a total of 315,684 eggs where produced in 2024 (with a fertilisations rates ranging from 0-96%), equating to 15.033 eggs/spawn. This a huge increase on the 62,300 eggs that were produced in 2023. There were significant problems with egg development with most eggs failing to continue development, with only three spawns resulting in hatched larvae, representing approximately 0.5% survival of eggs spawned. This was particularly pronounced in the bore water treatment, where all embryos failed to develop within several days.

A total of 300 juveniles were produced from the 2024 spawnings. Given the low number of larvae produced, they were maintained and fed within the hatchery rather than being stocked into a larval rearing pond and were released into Winburndale Dam in late December 2024.

Broodfish Collection

During the 2024/25 reporting period there has been 29 additional broodfish added to the breeding program at Narrandera Fisheries Centre largely from Cataract Reservoir (24) with five male upper Murrumbidgee collected in October 2024 being also added.

Figure 11. Young 2024 Macquarie Perch larvae eating Artemia in trays.

Wild Broodstock Collection Trial

The addition of wild running ripe broodstock was trialled to potentially increase production and genetic diversity. The collection and subsequent spawning of running ripe Macquarie Perch for captive breeding has been undertaken since the 1960's and is still currently undertaken by the Victorian Fisheries Authority. It had not however ever been attempted for the upper Murrumbidgee River. It was seen as a good opportunity to not only increase our knowledge and understanding but also increase production.

A broodstock collection trip was undertaken in October 2024, the location and timing of the trip was guided by previous studies by van der Meulen et al (2023) that had identified spawning locations and timing within the Cooma gorge section of the upper Murrumbidgee River.

Broodfish collection was undertaken between the 14th-17th of October in the upper Murrumbidgee River between Mittagang (-36.17025 149.09114) and Murrells Crossing (-36.10801 149.12303). The Murrumbidgee downstream of Mittagang enters the Cooma gorge which is a 10km stretch of inaccessible and difficult to access section of the river with no road or vehicle access. Given the limitations with access inflatable white water rafts and a rafting guide was engaged to provide safe passage and sampling through this section of the river. A combination of fyke nets and angling was used to capture broodfish, with fyke nets being set overnight at known spawning locations for three consecutive nights (14th, 15 and 16th Oct) where active fish were observed undertaking courtship behaviour on spawning riffles and retrieved the following day with opportunistic angling undertaken in the vicinity of the spawning locations.

A total of 16 broodfish were collected 11 females and five males all of which were transported back the Narrandera Fisheries Centre on the 17th October 2024.

These 16 fish were incorporated into the broader captive breeding program and assigned randomly into the experimental treatments. Six of the 11 females spawned.

All of the males collected were running milt, before and after being incorporated into the program.

Whilst this trial did not produce high numbers of offspring, it did provide very valuable information that will inform and guide our approach into the future. It was demonstrated that running ripe broodfish can be collected from the upper Murrumbidgee and safely transported back to NFC and these wild fish can be induced to spawn with the GnRH hormone.

The 11 females used for this program where then returned to the upper Murrumbidgee River (see section 4.2.2) in line with the recommendation of Pavlova et al (2024) to increase genetic diversity of the upstream reaches. The five males were retained at NFC as the current captive population has a large female bias and greater number of males are required.

One of the male fish captured had previously been captured and tagged as part of an earlier study, it was captured at the site Long Pool (-36.094148 149.126776) on the 7th of September 2015 and was 373mm in length and weighed 810grams, when captured in October 2024 it was 401mm and 932 grams.

One of the females that was released at the Murrumbidgee River - Bolaro Station site was also recaptured in the monitoring undertaken in April 2025, (see Appendix 2) providing evidence of survival post release and limited movement from the release location as least during the 5-month period after release.

Recommendations

The VFA has a long running and successful program that relies upon the collection of running ripe fish from the wild. For 2025/2026, it is recommended that female wild running ripe Macquarie Perch from the upper Murrumbidgee again be collected for incorporation into the Victorian program for the potential crossing with genetically distinct male Victorian Macquarie Perch (Dartmouth or Yarra origin) as per the recommendations of Pavlova et al (2025).

Figure 12. Rafting guide Richard Swain and NSW DPIRD staff traversing the Cooma gorge to retrieve fyke nets on 15th October 2024.

Figure 13. Rafting guide Richard Swain with one of the broodfish collected from the Cooma gorge being transferred to the transport vehicle.

3.4 Catchment Survey

3.4.1 Stocky Galaxias

The focus of the catchment survey for Stocky Galaxias is twofold:

1. to improve the understanding of the species distribution; and
2. to identify potential reintroduction sites that have suitable habitat are free from predatory fish and have a barrier to prevent the invasion of predatory fish.

The Stocky Galaxias catchment surveys undertaken in early 2025 represents the largest ever single catchment wide systematic galaxias and galaxias habitat survey undertaken in the Murrumbidgee Catchment.

Potential sites were identified initially following the recommendations of Raadik and Lintermans (2022) focusing on desktop analysis utilising contour maps and high-resolution aerial imagery to identify stream reaches where waterfalls were present or likely to occur within the study area. Whilst the use of contour map and aerial imagery was useful it was often inconclusive and very time consuming. To improve efficiency and accuracy the use of Light Detection and Ranging data (LiDAR) and Digital Elevation Models (DEMs) as detailed by Allen et al (2025) were employed to validate existing sites identified and identify any that may have been missed. A full report of the survey is provided in Appendix H.

Following this detailed desktop analysis and development of a detailed dataset 257 potential catchment survey sites were flagged. Sites where trout were known to exist were excluded leaving 171 potential sites to potentially survey.

The 2024/25 AIP set out that 44 priority sites would be assessed in 2024/25, this target was more than doubled with 110 priority sites being surveyed across seven different catchments.

The field surveys took place on the 3rd – 7th March, 10th – 14th March and 7th – 11th April, sites were surveyed by six teams consisting of two people per team, being accessed by multiple means including vehicle, short, medium and long hikes as well as a select few sites via helicopter.

Sites were sampled following an adaptive sampling procedure as outlined in Raadik and Lintermans (2022) with start and end points of each operation recorded, fish assemblages were recorded at each site and classified as either Fishless, Galaxiids, Trout or Trout and Galaxiids (see Table 9 & Figure 14). Highlights of the surveys included finding galaxiid spp that that show characteristics of Stocky Galaxias, with detailed morphology and genetic analysis required to confirm identity, multiple barriers that present very effective barriers to Trout and climbing galaxias incursions and a number of fishless streams.

All sites assessed underwent a prioritisation to identify and quantify which sites and locations had the highest potential for reintroduction sites. The Prioritisation process identified one Priority 1 reintroduction stream, Greenhide Creek - a tributary of Bull Flat Creek in the Goodradigbee River catchment. Whilst this Creek may well be a viable potential reintroduction site, further investigation is required. These include assessing the adequacy of the barrier to predatory fish, more detailed assessment of habitat suitability, confirmation of water security and the additional surveys to confirm absence of trout and other galaxias species is required.

The prioritisation process identified two Priority 2 sites being Rules Creek in the Yarrangobilly River catchment and Cave Creek in the Jounama Creek catchment. Both of the creeks ranked very highly for most criteria assessed and were assigned as Priority 2 sites rather than Priority 1 sites due to catchment size. Of the two systems Cave Creek requires further investigation to determine long term water security whereas Rules has met all the criteria required to be a suitable reintroduction site. Rules Creek, despite having a smaller catchment size, has multiple barriers in excess of 5m head loss, has good water security, is currently fishless above the barriers and has good access for reintroductions and monitoring.

Rules Creek is recommended as the highest priority reintroduction site of those currently assessed. Further monitoring prior to release of Stocky Galaxias is required to establish baseline monitoring sites, protocols, and methodology.

Table 9. Summary results from catchment surveys (for more details see Appendix H)

Fishless	Galaxiids	Trout	Trout/Galaxiids	Dry (Not surveyed)
34	30	41	1	4

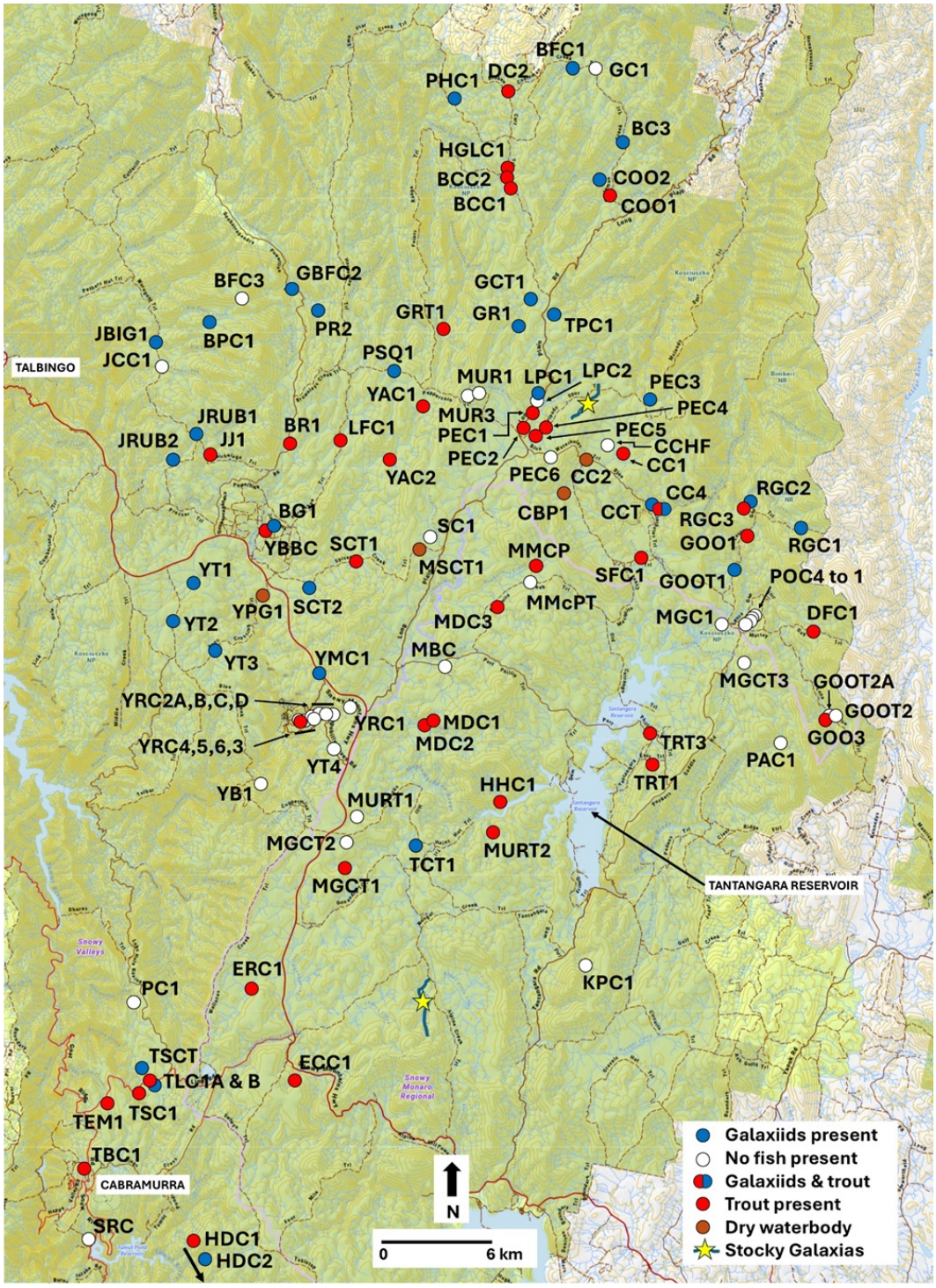

Figure 14. Results of the fauna assessment in Stocky Galaxias catchment surveys 24/25

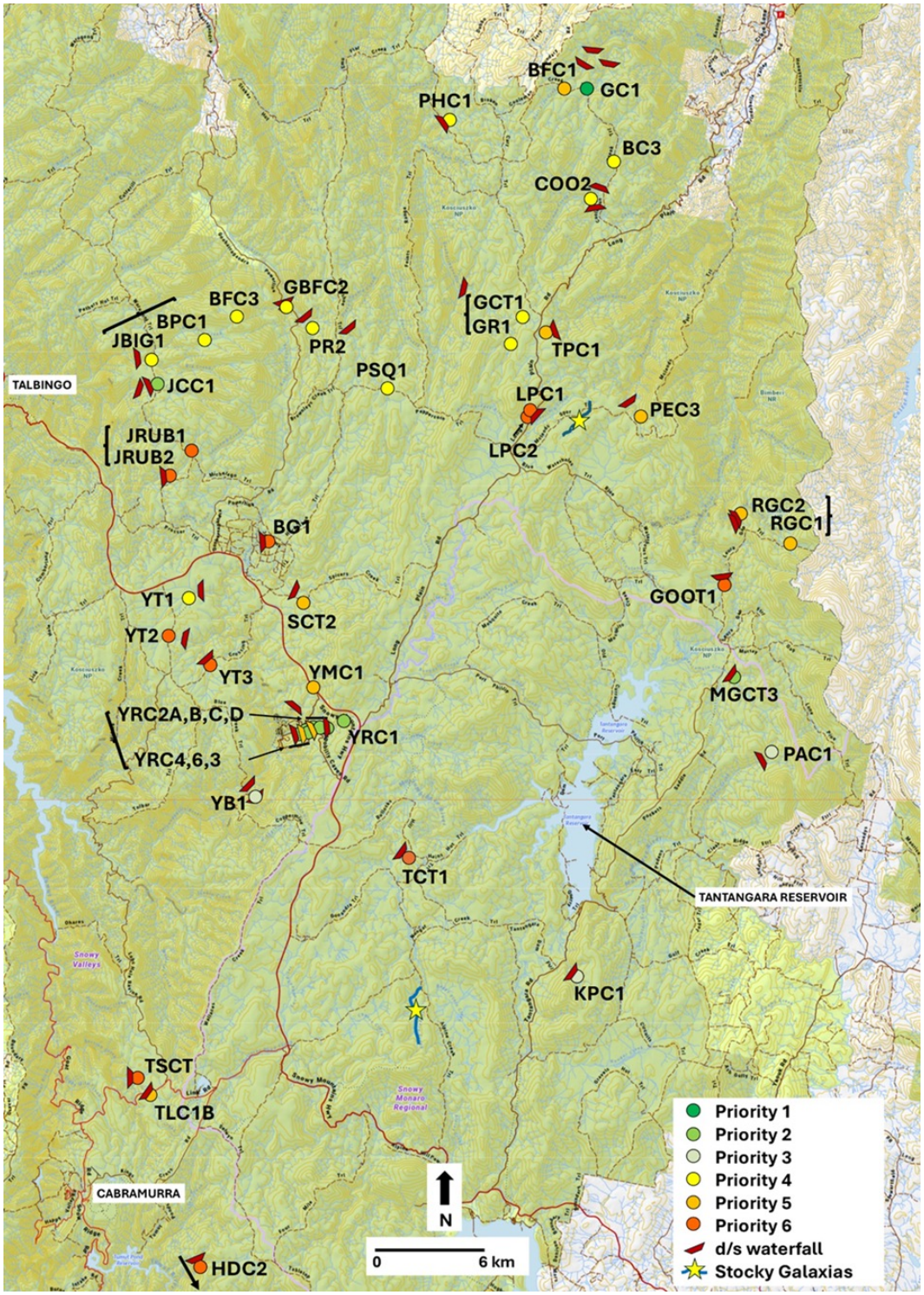

Figure 15. Results of the prioritisation process on sites after those with trout, small catchments, dry sites and those with water security issues removed. Barrier locations included.

3.4.2 Macquarie Perch

The primary focus of the catchment surveys for Macquarie Perch surveys is twofold:

1. to improve the understanding of the distribution if both Macquarie Perch and Redfin; and
2. to identify potential reintroduction sites that have suitable habitat are free from Redfin and have a barrier to prevent the invasion of Redfin should they establish in the upper Murrumbidgee Catchment.

Fourteen potential sites identified following the recommendations of Lintermans et al (2022), five of the original sites were substituted for alternative sites due to issues surrounding access, however the alternative sites remained in the same system as the original sites and as close as possible to the original sites. The 14 sites priority sites were surveyed during September 2024, January and February 2025.

The sites were assessed using a standardised site assessment approach as recommended by Lintermans et al (2022). The survey method included a visual assessment of instream and riparian habitat suitability, stream size, water permanency, and any predator barriers, details on each site assessed can be found in Appendix I.

Environmental DNA sampling for both Macquarie Perch and Redfin was undertaken at each sampling location, a detailed report on the methodology and results can be found in Appendix J. No DNA for either Macquarie Perch or Redfin was detected at any of the sites.

Two additional sites not included in Lintermans et al (2022) have been identified as potential candidate's reintroduction sites, one in the upper Murrumbidgee Catchment (Tantangara Creek), and one in the neighbouring Tumut River Catchment (Doubtful Creek).

A preliminary prioritisation process has been undertaken with the information that is currently available, this prioritisation will require further refinement as more information comes to hand and input from external stakeholders in incorporated into the decision process.

Further barrier assessment is required. It is recommended that that a similar LiDAR-based technique utilising Digital Elevation Models (DEMs) similar to that undertaken for the Stocky Galaxias catchment surveys also be undertaken for the priority Macquarie Perch catchments.

NSW DPIRD has been consulting with the Monaro Acclimatisation Society (MAS) regarding the prioritisation process and the potential impacts of the establishment of Macquarie Perch may have on trout stockings into the future. Whilst the MAS is supportive of the program and the recovery of Macquarie Perch, they also wish to continue to maintain valued recreational fisheries for trout particularly in key highly valued areas. NSW DPIRD will continue to engage with the MAS through the prioritisation process to ensure that their concerns, suggestions and advice are incorporated into the prioritisation process.

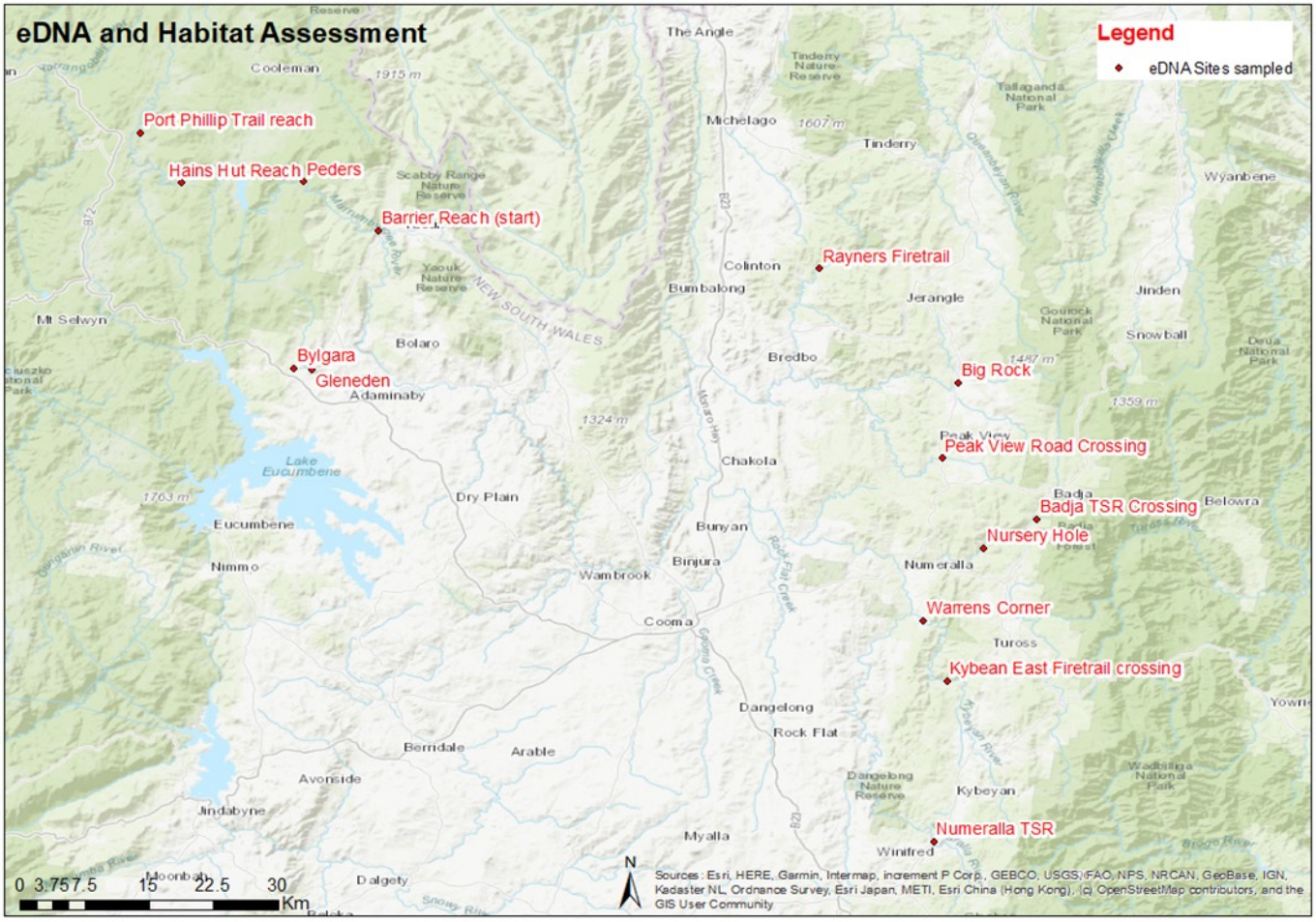

Figure 16. Map of sites assessed in the Macquarie Perch catchment surveys 2024/25.

Table 10. Macquarie Perch catchment survey monitoring sites mesohabitat assessment 2024/25

Preliminary priority locations, green = priority 1, yellow = priority 2 and purple = priority 3.

Site	Waterbody	Pool depth (m)	Pool substrate	Riffle depth (m)	Riffle substrate	Presence of pools / riffles sequence	Connectivity of reach	Flow Rate
Nursery Hole	Big Badja River	4	Bedrock/ Cobble	0.2	Cobble	Yes - large pools	Good	Moderate
Badja TSR Crossing	Big Badja River	3	Cobble	0.2	Cobble	Yes	Good	Moderate
Kybeyan East Firetrail	Kybeyan River	3	Sand/ Bedrock	0.3	Cobble/ Boulder	Yes - large pools	Good	Slow
Warrens Corner	Kybeyan River	2	Gravel/ Cobble	0.5	Gravel/ Cobble	Yes - large pools	Good	Moderate
Peak View Road Crossing	Cowra Creek	2	Bedrock/ Boulder	0.4	Gravel	Yes - large pools, small riffles	Fair	Slow
Big Rock	Bredbo River	1.5	Gravel/ Cobble	0.3	Gravel/ Cobble	Yes - smaller pools. Mostly runs	Good	Fast/ Moderate
Numeralla TSR	Numeralla River	3	Sandy/ Gravel	0.2	Gravel	Yes - large pools, small riffles	Good	Slow
Bylgara	Goorudee Rivulet	1	Bedrock/ Mud	0.3	Cobbles	Yes	Good	Slow
Gleneden	Goorudee Rivulet	1.5	Boulders/ Mud	0.2	Cobble	Yes - smaller pools	Good	Slow
Rayners Fire Trail	Strike-a-light River	2	Gravel/ Cobble/ Bedrock	0.2	Gravel/ Cobble	Yes -not much water	Poor	Slow
Port Phillip Fire Trail Reach	Murrumbidgee River	3	Cobble	0.2	Cobble	Yes	Good	Slow/
Haines Hut	Murrumbidgee River	3	Bedrock	0.3	Cobble	Yes	Good	Moderate
Peders	Murrumbidgee River	0.8	Mud	0.2	Cobble	Yes - large pools, small riffles	Good	Slow
Barrier Reach Start	Murrumbidgee River	3	Cobble/ Bedrock	0.3	Cobble/ Gravel	Yes - large pools	Good	Moderate

Table 11. Macquarie Perch catchment survey monitoring sites habitat assessment 2024/25

Preliminary priority locations, green = priority 1, yellow = priority 2 and purple = priority 3.

Site	Waterbody	Riparian Veg	Shading	Snags	Boulders	Connectivity of Reach	Aquatic Vegetation (instream)
Nursery Hole	Big Badja River	Poor	Poor	Good	Good	Good	Submerged (Milfoil), emergent fringing
Badja TSR Crossing	Big Badja River	Good	Fair	Good	Fair	Good	Submerged (Milfoil)
Kybeyan East Firetrail	Kybeyan River	Good	Good	Good	Good	Good	Submerged (Milfoil)
Warrens Corner	Kybeyan River	Good	Good	Good	Poor	Good	Floatin (Pondweed),submerged (Milfoil) and emergent fringing
Peak View Road Crossing	Cowra Creek	Good	Good	Fair	Good	Fair	Submerged (Milfoil),emergent fringing
Big Rock	Bredbo River	Good	Good	Good	Good	Good	Emergent fringing (Phragmites)
Numeralla TSR	Numeralla River	Good	Good	Good	Good	Good	Submerged (Milfoil), emergent fringing
Bylgara	Goorudee Rivulet	Good	Good	Good	Good	Good	Submerged (Milfoil)
Gleneden	Goorudee Rivulet	Good	Good	Good	Good	Good	Very little
Rayners Fire Trail	Strike-a-light River	Poor	Good	Fair	Good	Fair	Emergent fringing
Port Phillip Fire Trail Reach	Murrumbidgee River	Good	Good	Poor	Good	Good	Submerged (Milfoil)
Haines Hut	Murrumbidgee River	Good	Fair	Poor	Good	Good	Submerged (Milfoil)
Peders	Murrumbidgee River	Fair	Poor	Poor	Poor	Good	Submerged (Milfoil)
Barrier Reach Start	Murrumbidgee River	Good	Good	Good	Good	Good	Submerged, emergent fringing

4. Discussion

4.1 Stocky Galaxias

4.1.1 Population Monitoring

The Stocky Galaxias monitoring in 2025 found that Stocky Galaxias abundance in Tantangara Creek was low in both sampling events and similar to those recorded in 2024 (see Appendix A), with Bottom Flat having a much lower abundance than Top Flat. The catch rate in both 2024 and both sampling events in 2025 recorded much lower catch rates than previously recorded, although it must be acknowledged that the previous sampling undertaken did not follow the same methods. Nonetheless, the low detection rate represents a concerning decline that warrants further investigation. There also appears to have been recruitment failure at Bottom Flat in Tantangara Creek with no Young of Year Stocky Galaxias detected or observed in either the February or April sampling, this is similar to the 2024 results when only a single individual YOY was detected at Bottom Flat.

The 2025 Stocky Galaxias monitoring has met trigger levels under a number of TARP criteria. Findings from both 2024 and 2025 suggest there has been a decline in the Stocky Galaxias population at Tantangara Creek, and lack of recruitment in 2025 at Tantangara Creek Bottom Flat. Monitoring in 2025 did not find any threats requiring intervention around TARP criterion 5 (Water quality decline) 6 (Fire or drought), and 7 (Predatory fish invasion).

4.1.2 Captive Breeding

Captive breeding was undertaken by CSU with the progeny of the program utilised for thermal tolerance experiments to gain greater insight into the upper thermal tolerance of the species. This will inform future decisions regarding thermal suitability of reintroduction locations. Without a reintroduction site identified, the decision was made to continue to hold the remaining fish following the experiments at CSU until the first round of catchment surveys had been completed and priority introductions sites identified. With the first round of catchment surveys now completed and at least two potential introduction sites identified it is proposed that the progeny of the 2024 breeding season be released into the highest priority introduction site in November 2025 after further assessment of the sites and appropriate approvals are in place.

4.1.3 Translocation

No translocation for Stocky Galaxias was undertaken in 2024/25 reporting period.

4.1.4 Catchment Survey

The 2024/25 Stocky Galaxias catchment surveys have shown very exciting and promising results with several fishless sites identified as potential re-introductions sites. In addition to these, there were also numerous sites identified with existing galaxiid populations and effective predator barriers. There is still further work required in undertaking morphology and genetics work to determine is some of the populations identified may indeed be Stocky Galaxias or other novel taxa within the Mountain Galaxias complex.

4.2 Macquarie Perch

4.2.1 Population Monitoring

The 2025 Snowy 2.0 TFMP Macquarie Perch population monitoring recorded exceptionally high abundance of Macquarie Perch which exceeded the number of Macquarie Perch captured in 2024 and is by far the highest catch rate recorded in the upper Murrumbidgee. Macquarie Perch were caught across all the core sites and the downstream fringe site with the only site they were absent from was the upstream fringe site. Good recruitment was again seen across all the core sites with good numbers of YOY and 1 + fish. The 2025 monitoring found there were no new or exacerbated threats or other triggers that require intervention under the Trigger Action Response Plan.

4.2.2 Captive Breeding

The GnRHa implants, developed and produced by the Sunshine Coast University, were successful in inducing captive held Macquarie Perch to spontaneously spawn in tanks within the hatchery environment. Whilst production was low for the 2024 spawning period with only 300 juveniles produced, the potential and capacity of the process and the program was demonstrated with 21 individual spawning events producing a total of 315,684 eggs, greatly exceeding previous year's production.

Highlights of the 2024 Macquarie Perch spawning season at Narrandera Fisheries Centre

Achievements:

- → 80% of broodfish with initial oocytes >1300um diameter spawned after implantation with slow-release GnRHa implants and held in tanks in groups of 8-10 fish
- → There was no difference in spawning of broodfish when held in 20°C or 23°C
- → Experiments determined that bore water should not be used for future spawning activities
- → External screen egg harvesters were effective at self-harvesting eggs
- → Controlled environment rooms and RAS improved water quality of egg incubation trays
- → Safe and cheap chemicals were identified to replace formalin for control of fungus infection of eggs

Problems:

- → Condition of broodfish harvested from ponds was significantly lower than in 2023
- → Most fertilised eggs failed to develop and hatch – it is hypothesized that this may have been due to poor egg quality.

4.2.3 Translocation

Two separate translocations were undertaken under the program during 2024/25. The first, in November 2024, released 11 large mature female Macquarie Perch into the upstream section of the population. These fish had been collected from the Cooma Gorge and utilised for captive breeding. They were released further upstream to increase genetic diversity. The second translocation, in April 2025, released 300 Macquarie Perch, collected from Cataract Reservoir, into four locations accross the upper Murrumbidgee to boost numbers and genetic diversity. This exceeded the target set in the 2024/25 AIP which was to translocate 100 Macquarie Perch across three sites.

The success of the program will be determined by the collection of genetic data during future popoluation surveys. This data will inform whether the translocated fish have survived and whether they have contributed to breeding, thus increasing the population's genetic diversity and fitness. This data may not be available for some time. However, the recapture of one of the translocated fish from the November release at the release location during population sampling, demonstrated that at least one of the translocated fish had survived and remained within the vicinity of the release location at least in the short term.

4.2.4 Catchment Survey

The 2024/25 Macquarie Perch catchment surveys did not detect any additional remnant Macquarie Perch populations outside the current known distribution, nor were any Redfin detected within the catchment. Several potential reintroduction locations have been identified both within the upper Murrumbidgee Catchment and in adjoining catchments. Further work is required to quantify barriers to predatory movement along with further engagement with key stakeholders to ensure their ongoing support for identified priority reintroduction sites and the broader program.

5. Recommendations for 2025/26 Implementation Period

5.1 Stocky Galaxias

5.1.1 Population Monitoring

→ The monitoring approach developed and applied for the 2024 and 2025 monitoring should be adopted as the protocol for future monitoring.

→ Review and refine the Trigger Action Response Plan, including the spatial scale by which the "Triggers" are applied, the metrics by which the triggers are measured, the appropriateness of the "Response" actions and a review of the currently used baseline at which declines are measured against, incorporating all available data. This review will provide an updated TARP for consideration and endorsement by the EAC.

→ Undertake recommended response monitoring as defined in the TARP review.

5.1.2 Captive Breeding

→ Continue the current captive breeding program at CSU with the current broodfish for the 2025 breeding season.

→ Collect an additional 90 Stocky Galaxias broodfish from Sallys Flat Creek as part of the annual monitoring for inclusion in the 2026 captive breeding program, these fish all be genotyped to ensure they are Stocky Galaxias.

5.1.3 Translocation

→ Develop a translocation strategy/plan in line with the recommendations of Raadik et al (2022), incorporating the information from the current genetic assessment and the results of the catchment surveys undertaken in 2024/25, by April 2026.

→ Release the currently held captive bred Stocky Galaxias from CSU into the priority re-introduction site identified during the catchment survey, by the end November 2025.

→ Release of 2025 captive bred Stocky Galaxias from CSU into the priority re-introduction sites identified during the catchment surveys by the end of April 2026.

5.1.4 Catchment Survey

→ Undertake morphological and genetic analysis of the Galaxias voucher specimens collected from priority locations during the 2024/25 surveys to verify species identification, by the end of March 2026.

→ Undertake further detailed assessment of the Priority 1 and Priority 2 sites identified in the 2024/25 surveys by the end of March 2026.

→ Complete assessment of remaining 55 priority sites identified in the 2023/24 AIP by the end of April 2026.

5.2 Macquarie Perch

5.2.1 Population Monitoring

- → Monitoring should be repeated in 2026 using the same sites and method as undertaken previously.
- → Review and refine the Trigger Action Response Plan, including the spatial scale at which the “Triggers” are applied, the appropriateness of the “Response” actions. This review will provide an updated TARP for consideration and endorsement by the EAC.
- → Develop a proposal to identify key spawning locations.

5.2.2 Captive Breeding

- → Continue captive breeding of Macquarie Perch at the NFC.
- → In addition to proposed captive breeding at NFC, undertake a trial to collect wild female Macquarie Perch broodfish from the upper Murrumbidgee and cross them with male Victorian Macquarie Perch at the VFA Snob’s Creek hatchery.
- → Continue to build broodfish numbers and incorporate Macquarie Perch from Victoria into the captive population as recommended by Pavlova et al (2025).
- → Identify appropriate pond stocking densities, allocate Macquarie Perch broodfish into ponds at or below these densities post 2025 captive breeding.

5.2.3 Translocation

- → Continue genetic rescue/enhancement of the upper Murrumbidgee River population with fish sourced from Cataract Dam by collecting 100 Macquarie Perch from Cataract Dam for release in the upper Murrumbidgee.
- → Utilise suitable admixed Macquarie Perch from the captive breeding program at NFC, if available, to enhance the genetic diversity of the upper Murrumbidgee River Macquarie Perch population.
- → Utilise suitable admixed Macquarie Perch from the captive breeding program at NFC to stock into appropriate reintroduction locations identified by the catchment surveys.

5.2.4 Catchment Survey

- → Undertake a more detailed assessment of the Priority 1 sites identified in the 2024/25 surveys
- → Engage directly with the Monaro Acclimatisation Society to obtain their feedback, input and extensive local knowledge into the prioritisation process.
- → Undertake a detailed Digital Elevation Modelling utilising LiDAR of the catchment to identify potential predatory fish barriers.
- → Undertake further surveys including eDNA of priority streams outside the upper Murrumbidgee Catchment including, Doubtful Creek, Tantangara Creek and the Queanbeyan River.

6. Expenditure

Expenditure for the 2024/25 came in under budget, with a total expenditure of $1,113,940 for the year, $104,336 under the forecast budget of $1,218,276. The majority of the savings were delivered by efficiencies that were able to be delivered in DPIRD staffing and operating costs.

There was an additional $30,000 allocated during the latter part of the year for the CSU team to continue to hold the captive breed Stocky Galaxias from 2024. This was because the original plan of release into the Eucumbene Borrows was deemed not appropriate due to poor survival of the previous releases and high temperatures recorded at the site. It was agreed that the best outcome was to continue to hold these fish at CSU for release into the priority re-introduction location identified in the catchment surveys in November 2025.

Table 12. Breakdown of forecast and actual expenditure for 2024/25 financial year

Activity	Forecast 24/25	Actual Expenditure 24/25
Macquarie Perch		
Population monitoring, surveillance and research	$71,000	$84,000
Habitat Surveys	$53,821	$52,345
Captive Breeding, stocking and monitoring	$710,688	$609,624
Habitat Enhancement	$0	$0
Stocky Galaxias		
Population monitoring, surveillance and research	$50,000	$49,654
Habitat Surveys	$213,128	$168,678
Captive Breeding, stocking and monitoring	$119,639	$149,639
Total	**$1,218,276**	**$1,113,940**

7. Murray Crayfish Sampling

The Nature Glenelg Trust were enaged by Snowy Hydro to undertake sampling of Murray Crayfish in Talbingo reservoir. A summary of the sampling results is provided here with the full report available in Appendix K.

Annual sampling in Talbingo Reservoir has been undertaken since 2019. Fourteen sites throughout the reservoir were surveyed. An additional two locations within the area to be impacted by the project were also sampled in order to capture and relocate any individuals that may be present. The number of Murray Crayfish sampled in 2025 was the same as 2024 and higher than 2023, however it was lower than historical surveys. The presence of berried females provides a positive indication of ongoing species recruitment and anticipated persistence in Talbingo Reservoir.

An electrofishing survey was also undertaken in the Yarrangobilly River and Wallaces Creek. One Murray Crayfish was observed but no Murray Crayfish were sampled, however previously low numbers have been detected. The inclusion of these sites in annual monitoring can be challenging due to variable river heights and flow, however, it is important when considering changes in the status of the overall population over time and space.

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Appendix A

Stocky Galaxias population monitoring report

Snowy 2.0 Stocky Galaxias monitoring at Tantangara Creek and Sallys Flat Creek 2025

Mark Lintermans and Hugh Allan

September 2025

Fish Fondler Pty Ltd
Research, Monitoring, Advice
for threatened freshwater fish

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This research was conducted on Walgalu country.

Cover photo: The sampling reach at Tantangara Creek Bottom flat. Photo Mark Lintermans.

Introduction

The Stocky Galaxias *Galaxias tantangara* is a highly threatened freshwater fish, that was only described as a distinct species in 2014 (Raadik 2014). It is a small species with a maximum total length of 114 mm with most adults being 60-90 mm long (Allan et al. 2021). It is listed as critically endangered by the Australian Society for Fish Biology (Lintermans 2019); in New South Wales (NSW FSC 2016), the IUCN Red List (Lintermans & Allan 2019) and the Environment Protection and Biodiversity Conservation Act 1999 (TSSC 2021). The species is considered one of the top 22 most imperiled freshwater fish species in Australia (Lintermans et al. 2020) and is one of the most imperiled vertebrates in Australia (Garnett et al. 2022). The species was originally described from Tantangara Creek in the upper Murrumbidgee catchment upstream of Tantangara Reservoir (Raadik 2014) and for many years this stream was considered the only population of the species (NSW FSC 2016; Lintermans and Allan 2019). The species was listed as a priority species for recovery action following the 2019-20 bushfires (Legge et al. 2020, 2022), and has been subsequently listed as one of the 100 priority species under the National Threatened Species Strategy (Australian Government 2021) and subsequently the 110 priority species under the National Threatened Species Action Plan (DCCEEW 2022).

A second population was discovered serendipitously (via genetic analysis of finclips) in late 2020 whilst investigating bushfire impacts on spiny crayfish, with this second Stocky Galaxias population occurring in the upper Goodradigbee catchment at Sallys Flat Creek (Lintermans et al. 2021) (Figure 1). The population at Sallys Flat Creek is approximately 30 km as the crow flies but ~350 km by stream distance from the Tantangara Creek population (Lintermans et al. 2021). In January 2021 follow up sampling to collect additional voucher specimens confirmed that Stocky Galaxias were present and also confirmed that Mountain Galaxias *G. olidus* co-occurred with Stocky Galaxias. Both species were collected from a single location in Sallys Flat Creek, approximately 720 m upstream of a series of large waterfalls and cascades that plummet approximately 25 m in elevation down to its junction with the trout-infested Peppercorn Creek (Allan & Lintermans 2021; Lintermans et al. 2021). Sallys Flat Creek upstream of these waterfalls is trout-free. Sallys Flat Creek is considerably smaller than Tantangara Creek, and while both galaxiids are restricted to the stream above the waterfall, Stocky Galaxias is distributed along the

length of Sallys Flat Creek upstream of the waterfall, while Mountain Galaxias is confined to the larger downstream reach and is absent from the smaller upstream reach (Lintermans 2022a). A subsequent population estimate has shown that the Sallys Flat Creek population is large, with of the order of 10,000 individuals in early 2023 (Lintermans & Allan 2023).

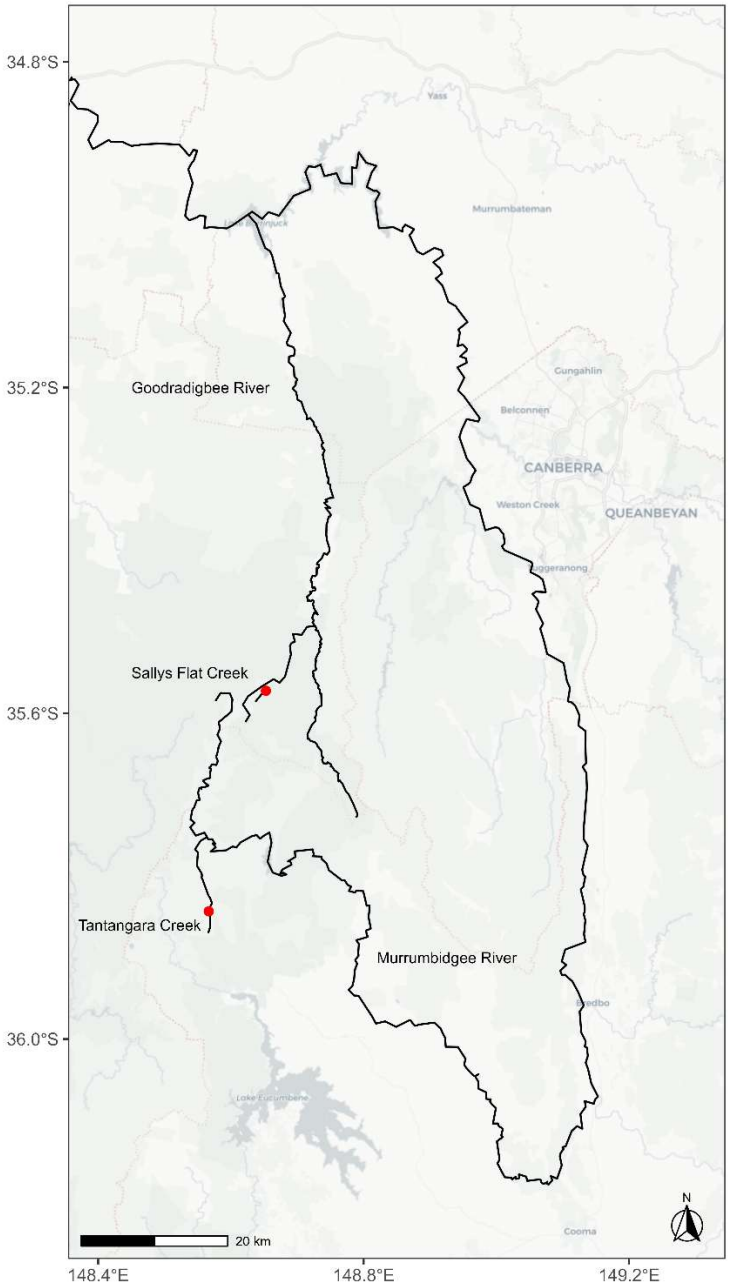

Figure 1: Location of Tantangara Creek and Sallys Flat Creek, with sites ~30 km apart as the crow flies, but ~350 km apart by river.

Snowy Hydro Limited received approval in 2020 to construct a new large-scale pumped hydro-electric storage and generation scheme (Snowy 2.0), to increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme. This will involve the connection of the existing Talbingo and Tantangara reservoirs via a series of underground pipes and an underground power generation station. Water will be transferred in both directions between the reservoirs, which are in separate river catchments. One of the threatened fish species potentially at risk from these water transfers (Cardno 2019) is Stocky Galaxias (NSW FSC 2016; Lintermans and Allan 2019; TSSC 2021). As part of the NSW and Commonwealth approvals for Snowy 2.0, the preparation of a Threatened Fish Management Plan including a series of monitoring requirements for threatened and alien fish were mandated (see Snowy Hydro 2023). As a component of this Threatened Fish Management Plan, a monitoring plan for Stocky Galaxias was developed in 2020–21 and finalised in 2022 (Raadik and Lintermans 2022). In 2024 monitoring of both sites reported fish in low abundance and a possible decline in population abundance at both creeks, and it was hypothesized that this either reflected a true decline in abundance or was a sampling artefact associated with later than previous sampling (Lintermans and Allan 2024). To investigate whether the lower abundance detected in 2024 was a sampling artefact, both populations were recommended to be sampled twice in 2025: in early February and early April (Lintermans and Allan 2024). This report presents the implementation and results of the second year of the Stocky Galaxias Monitoring Plan (SGMP).

The SGMP originally focused on the then-only known population of the species at Tantangara Creek. Although it is noted that "…the described methods may also be relevant to other populations which may be discovered or established by translocations" (Raadik and Lintermans 2022), the Sallys Flat Creek population is only partially included in the SGMP, as it was discovered after the SGMP was prepared; a "single population" is still referred to in parts of the document (Snowy Hydro 2023). As in 2024, the 2025 Stocky Galaxias population monitoring adopted the overarching aim, philosophy and approach outlined for the Tantangara Creek site.

SGMP Objectives

The overall aim of the SGMP is "To provide baseline, comparable data on the species, to inform decisions on management intervention for the long-term survival of the species" with specific SGMP objectives to provide baseline, comparable data on:

1. The persistence of Stocky Galaxias (presence and breeding).
2. The population trajectory (is the population increasing, stable or decreasing) and variability (significant change from normal).
3. The status of the Stocky Galaxias population (incorporating measures of abundance, distribution, reproduction, fish health and demographics).
4. The status of identifiable threats at Stocky Galaxias locations (riparian erosion, instream sedimentation, riparian vegetation condition with respect to ability to trap sediment).
5. The persistence and establishment of any new translocations of the species into the catchment.
6. Incursions of exotic fish species (Brown Trout *Salmo trutta*, Rainbow Trout *Oncorhynchus mykiss*, or invasive native species such as Climbing Galaxias *G. brevipinnis*) into Stocky Galaxias populations.
7. Metrics informing triggers (as part of a TARP) for identified management interventions to mitigate potential sudden declines because of identified threats (e.g. fish incursion, fire, drought).

Trigger Action Response Plan (TARP)

Additional to the SGMP objectives outlined above, the SGMP details a decision-making framework for additional sampling in response to deviations from a 'normal' condition in Stocky Galaxias population metrics (Raadik and Lintermans 2022) or other threats identified in the routine surveillance monitoring. This framework is known as the Trigger Action Response Plan (TARP) and identifies the following criteria:

1. Decline in relative population abundance.
2. Decline in fish condition.

3. Decline or loss of recruitment.
4. Genetic decline.
5. Water quality decline.
6. Fire or drought.
7. Predatory fish invasion.

As noted in 2024 (Lintermans and Allan 2024), not all sampling requirements of the SGMP or TARP are addressed or fulfilled in the current sampling (e.g. eDNA monitoring of predatory fish invasion, establishment of translocated populations). This report details the 2025 monitoring program for both populations (Tantangara Creek and Sallys Flat Creek) in early February and late March/early April 2025 and outlines the findings in line with their associated SGMP objectives and/or TARP triggers.

Methods

As recommended by Raadik and Lintermans (2022), sampling was carried out by conducting replicate 30 m electrofishing shots with a backpack electrofisher. Sampling was conducted in early February and late March/early April 2025 with the recommended sampling effort deployed at Top flat (3x 30 m shots) and Bottom flat (5x 30 m shots) in Tantangara Creek (Raadik and Lintermans 2022; Table 1; Table 2; Figure 2).

As no sampling effort was specified by Raadik and Lintermans (2022) for Sallys Flat Creek, the sampling approach employed in the 2024 sampling was repeated with the site sampled at two reaches (Upper reach and Lower reach) with three electrofishing shots per reach (Table 2). Both reaches at Sallys Flat Creek were upstream of the McLeods Trail Crossing (Figure 3).

Table 1: Recommended sampling effort for Tantangara Creek (from Raadik and Lintermans 2022). Note that Reach 1 in the table refers to Top flat and Reach 2 refers to Bottom flat.

Sampling type	Frequency	Location/Area	Method	Duration/Level of Effort	Parameters measured
Routine Surveillance Monitoring					
Population monitoring	Annually in autumn (March/April).	Tantangara Creek: 2 sites - Reach 1 (3 sections, 90 m) Reach 2 (5 sections, 150 m).	Backpack electrofishing	0.75 day per site (up to 2 days Tantangara Creek). Continuous electrofishing per section to cover all habitat, single electrofishing run per section, fish processed before commencing next section.	No. of fish; length and weight; visual assessment for parasites; WQ* and stream characteristics; visual threat assessment.
Population genetics	Collected and analysed every 3 years during population monitoring or as per TARP	As above	Caudal fin clipping	1.5–2.0 hrs per site. Fin clips to be collected from up to 90 individuals per site (Note: up to 45 individuals per reach at Tantangara Creek, 90 individuals total).	Using SNP data: Genetic diversity; effective population size; parentage analysis

Table 2: Sampling dates and number of electrofishing shots for each site and reach, and coordinates for the downstream start point of the first shot of each reach.

Site	Reach	No. efish shots	Dates sampled	Latitude	Longitude
Sallys Flat Creek	Lower	3	03-04/02/2025; 31/03/2025	-35.57234	148.6528
	Upper	3	04/02/2025; 31/03/2025	-35.57612	148.6481
Tantangara Creek	Bottom flat	5	05/02/2025; 01/04/2025	-35.84308	148.5667
	Top flat	3	05/02/2025; 01/04/2025	-35.84907	148.5692

Sampling was conducted by a two-person team using a Smith Root Model LR20b backpack electrofisher (typical electrofisher settings: 990 V, 90 Hz, 25% duty cycle) with each shot consisting of a single electrofishing run of continuous fishing covering all habitats. Captured fish were processed before commencing the next shot. The required three or five shots in each reach at each site were consecutive (i.e. shots were immediately adjacent to each other).

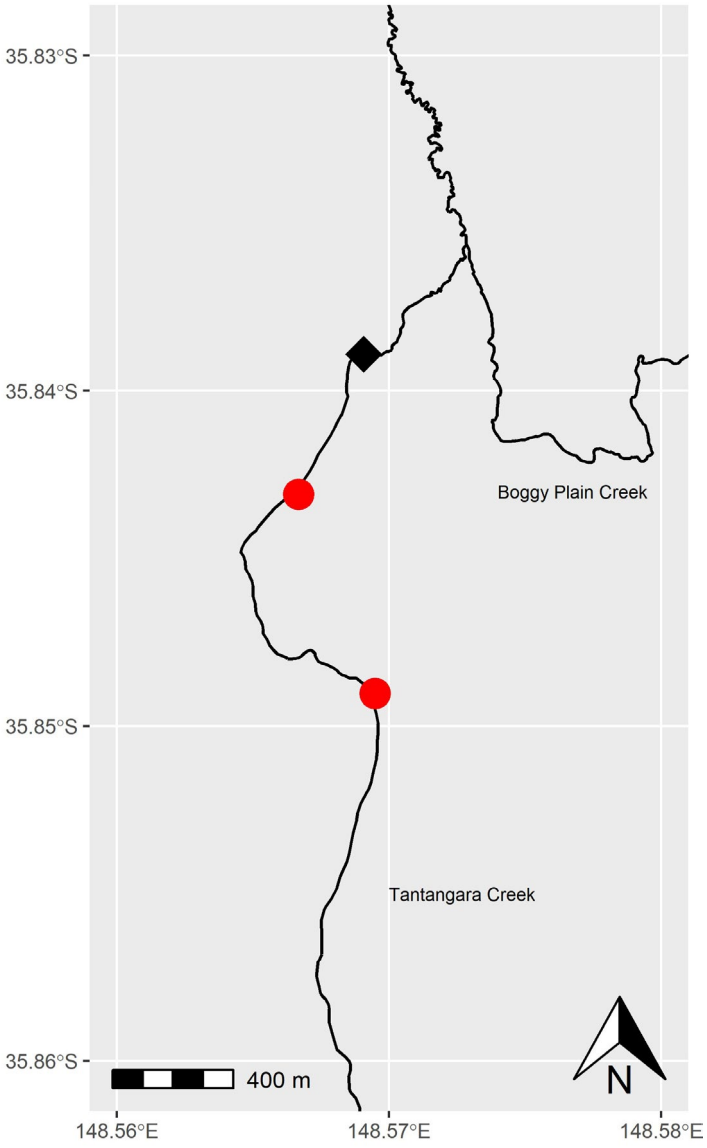

Figure 2: Location of sampling conducted at Tantangara Creek showing the start of electrofishing for each reach (red circles) and the location of the barrier waterfall (black diamond).

Routine water quality measurements were taken at each site. pH was measured with Machery-Nagel test strips; conductivity and surface water temperature were measured with a Eutech Expert CTS meter; dissolved oxygen was measured by titration with a Visocolor HE SA 10 kit; turbidity was measured with a turbidity tube.

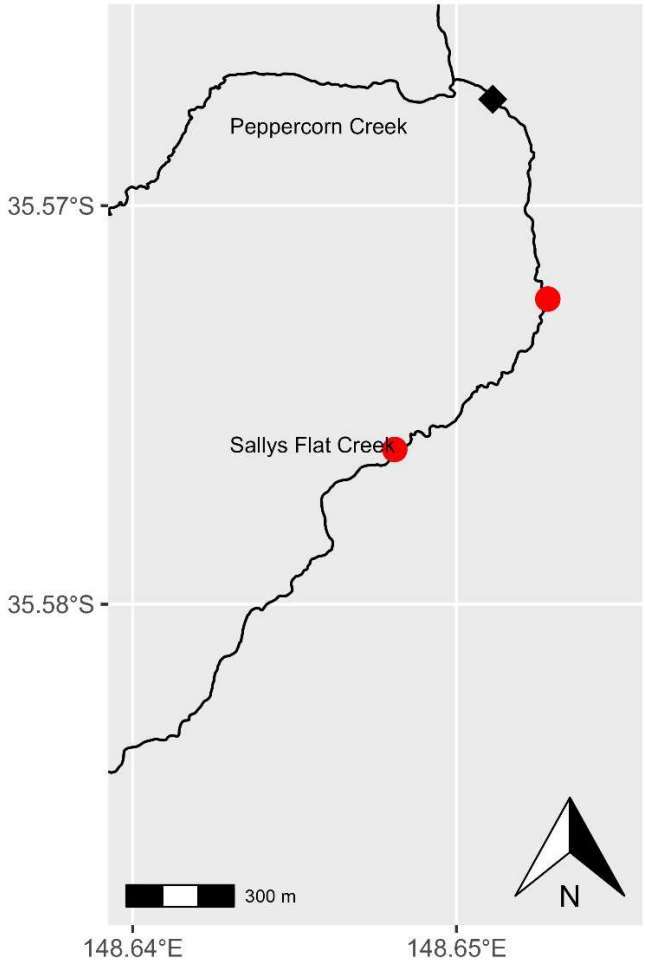

Figure 3: Location of sampling conducted at Sallys Flat Creek showing the start of electrofishing (red circles) for both the Lower and Upper reaches. Black diamond shows the location of barrier waterfalls.

At each reach stream width in the sampled areas was measured, and a stream depth was recorded at a fixed location (marked with a permanent steel post). Also, at each reach categorical habitat descriptors were noted (Appendix 1) and a rapid, visual assessment of potential threats was undertaken.

Fish were identified to species where possible (see below) and all captured fish were measured (Length Caudal Fork, LCF in mm). Stocky Galaxias were weighed to the nearest 0.1 g, and Fulton's condition factor (K) was calculated for each fish where $K = 100*W/L^3$, where W is the total weight of the fish in grams and L is its LCF in cm (Fulton, 1904; Nash et al. 2006). All Stocky Galaxias ≥ 40 mm LCF had a small section of the caudal fin removed as a genetic sample. Fish were examined for externally visible parasite loads, and all fish were released alive in the 30 m section where they were captured. While fish sexual maturity was not the focus of the current sampling, the presence of ripe males was noted by applying slight pressure on the fish's ventral surface when testes were visible through the abdominal wall (Allan et al. 2021).

Captured *Galaxias* at Sallys Flat Creek were identified based on two major characteristics (Figure 4, Lintermans et al. 2021):

- Stocky Galaxias have grey mottling pattern extending onto the top of head, cheeks and jaw, and no distinct barring on the body, and
- Mountain Galaxias have no mottling on top of head, cheeks and jaw, and mostly have conspicuous barring on the body, although some Mountain Galaxias have no body patterning or barring.

Small individuals (< 40 mm LCF) are difficult to confidently identify to species, and these individuals were recorded as *Galaxias* spp.; as a result, fish of this size class were not always captured, and were also simply recorded as observed *Galaxias* spp.

Figure 4: The two species of Galaxias *present at Sallys Flat Creek; Mountain Galaxias (top) and Stocky Galaxias (bottom). From Lintermans et al. 2021; Photo: Tarmo A. Raadik.*

Stocky Galaxias is the only fish species present at Tantangara Creek (Figure 5), and therefore did not need to be identified to discern it from Mountain Galaxias like in Sallys Flat Creek.

Figure 5: A large Stocky Galaxias from Tantangara Creek Top flat (Photo Hugh Allan).

Results and Discussion

As noted earlier, not all SGMP Objectives are evaluated as part of this monitoring report.

SGMP Objectives

Objectives 1 & 3 - Population persistence and status

Abundance and distribution

A total of 415 fish were caught (or observed *Galaxias* spp.) with 361 confidently identified to species across all sites and reaches. At Sallys Flat Creek, fifty-four *Galaxias* of uncertain species were caught with another 77 fish observed (Table 3). A total of 205 Stocky Galaxias and 92 Mountain Galaxias were captured from Sallys Flat Creek, and 64 Stocky Galaxias captured (and 50 observed) from Tantangara Creek. Stocky Galaxias comprised 69 percent of the species-identified fish caught at Sallys Flat Creek.

*Table 3: Total number (all shots combined) of Stocky Galaxias, Mountain Galaxias and unidentified galaxiids (Galaxias spp.) captured at each site and reach as part of 2025 monitoring. Bracketed numbers are observed fish. * = includes 30 young-of-year observed.*

Site	Reach	Month	No. efish shots	Stocky Galaxias caught (or observed)	Mountain Galaxias caught	Total no. of *Galaxias* spp. caught (or observed)	Total catch
Sallys Flat Creek	Lower	Feb	3	68	70	24 (51)	162 (51)
		March	3	40	14	3	57
	Upper	Feb	3	67	8	23 (26)	98 (26)
		March	3	30	-	4	34
Tantangara Creek	Bottom flat	Feb	5	5 (1)	-	-	5 (1)
		April	5	7	-	-	7
	Top flat	Feb	3	29 (38*)	-	-	29 (38*)
		April	5	23 (11)	-	-	23 (11)
			Total fish Feb	169 (39*)	78	47 (77)	294 (116*)
			Total fish March/April	100 (11)	14	7	121 (11)

The Stocky Galaxias catch rate in 2025 at Tantangara Creek was low in both monthly samples, and at similar levels to those recorded in 2024 (Lintermans and Allan 2024). Sampling conducted at Tantangara Creek in 2016-2018 to collect specimens for reproductive investigations reported mean Stocky Galaxias density of 1.18 fish/m captured during single-pass electrofishing, although large variation was observed over the course of this study (min 0.02, max 17.00 fish/m, see Allan 2018). The large variation was likely a product of sampling conducted across all seasons of the year, and at a range of varying habitat types in Tantangara Creek where backpack electrofishing efficacy can vary significantly. Adjusted for 30 m electrofishing shots as presented in Table 4, approximately 35 fish may

be expected in a single 30 m electrofishing shot based on this mean density. Similarly, estimated catch rates from only samples from late March, April and early May in this period still yields approximately 30-35 fish per 30 m (Allan unpubl. data).

With a mean catch at Tantangara Creek Bottom flat of less than 1.5 fish per 30 m in April 2024, February 2025 and April 2025, when compared to the mean capture density of approximately 1.18 fish/m reported in 2016–2018 (Allan 2018), this represents a concerning decline. The catch rate at Top flat was consistently higher than Bottom flat in both 2024 and 2025, where caught or observed fish were approximately 7– 10 fish per 30 m shot.

The Stocky Galaxias catch rates at Sallys Flat Creek in 2025 varied between 3 and 35 individuals per 30 m, with a mean of 17.08 individuals per 30 m. In the Upper reach, which is dominated by Stocky Galaxias, catch rates in early February 2025 were higher than those recorded in April 2024 and late March 2025 and the 2025 catch rates are similar to those recorded in February 2023 (Table 4, Lintermans and Allan 2023, 2024, unpub. data, Figures 6 and 7)

In February 2023 an almost identical methodology was used in a mark recapture population estimate at Sallys Flat Creek. Single pass backpack electrofishing was used, with the start point for sampling being identical to that used in the current monitoring approach. Fish were identified to species and individuals < 40 mm LCF were assigned to *Galaxias* spp. The only difference was that shot lengths in February 2023 were 33 m rather than 30 m length, with 3 sequential shots completed (Table 4, Lintermans and Allan unpubl. data). Fish were sampled on 8/02/2023, finclipped on the caudal fin, and then released in the shot of capture, before being resampled on 16/02/2023 (Table 4). To assist comparison with the current monitoring, abundance data was adjusted for an equivalent 30 m sampling shot using the formula: $Adjusted\ abundance = \text{Number of fish caught in } 33 \text{ m x } \frac{30}{33}$, and is presented in Table 4. The numbers of Stocky Galaxias per 30 m recorded in February 2025 returned to the levels recorded in February 2023, notably higher than those from April 2024 (Lintermans and Allan 2024, Table 4). Between February and March 2025 there was a drop in Stocky Galaxias numbers recorded at Sallys Flat Creek, suggesting that the hypothesis of a seasonal sampling effect suggested in Lintermans and Allan (2024) was partially correct. As noted by Lintermans and Allan (2024), while the

application of the monitoring approach reported herein will provide information on trajectory and changes in relative abundance for the Stocky Galaxias populations at both sites, a periodic estimate of the population size at each site would be helpful. Such estimates will allow more robust consideration of the scale of any impact from future translocations from the two wild populations. A population estimate for the Sallys Flat Creek population was completed in 2023 (Lintermans and Allan 2023) and in mid-February 2025 sampling for a population estimate at Tantangara creek was conducted. While analysis of the 2025 Tantangara Creek data is yet to be completed, the catch rates were similar to that recorded for the 2025 Snowy Stocky Galaxias monitoring reported here (Lintermans and Allan unpublished data) (see Table 4 for Sallys Flat Creek data; Tantangara Creek data is unpublished).

Table 4: Comparison of fish abundance data (raw and adjusted) from Sallys Flat Creek (Upper reach) in February 2023 (Lintermans & Allan unpubl. data) and the Snowy 2.0 monitoring program in 2024 and 2025. Note abundance values for the 2023 sampling are calculated for a shot length of 30 m. Shot numbers indicate identical shots from 2023 across sampling dates, as do shot numbers from 2024 and 2025 (which are the same between years).

Date	Shot No.	Shot length (m)	Stocky Galaxiasa bund.	Mountain Galaxias abund.	*Galaxias* spp. abund.
8/02/2023	a	33	20.9	0.9	10.9
	b	33	21.8	2.7	4.5
	c	33	26.4	0.9	5.5
16/02/2023	a	33	15.5	2.7	6.4
	b	33	21.8	0.9	4.5
	c	33	25.5	0.9	6.4
2/04/2024	1	30	9	3	3
	2	30	6	1	1
	3	30	10	2	0
03/02/2025	4	30	30	4	17
	5	30	12	3	3
04/02/2025	6	30	25	1	3
31/03/2025	4	30	18	0	1
	5	30	3	0	1
	6	30	9	0	0

Reproduction

In Tantangara Creek, Stocky Galaxias larvae are first observed in December (after November spawning) and are approximately 9.8–10.6 mm in length (Allan et al. 2021), and by February young-of-year (YOY)

fish are readily observed (Lintermans and Allan 2024). In late March/April (the time of sampling in 2024 and in 2025) YOY fish can be expected to be slightly smaller than the 25 to 43 mm reported in May (Allan et al. 2021).

In 2025, YOY Stocky Galaxias were captured in both reaches of Sallys Flat Creek and captured or observed at Top flat of Tantangara Creek. Using a YOY length size range of 25–43 mm LCF for Tantangara Creek, YOY comprised 21/29 (72%) and 6/23 (26%) of the total catch in February and April 2025 respectively. There were no YOY detected at Bottom flat in Tantangara Creek in 2025. Considering *Galaxias* spp. below 40 mm LCF cannot be confidently identified to species in Sallys Flat Creek, the proportion of YOY Stocky Galaxias in the early February sample was not calculated, while in late March YOY comprised 8/40 (20%) and 6/30 (20%) of the total catch ≥ 40 mm LCF in the Lower and Upper reaches respectively (Figures 6 and 7).

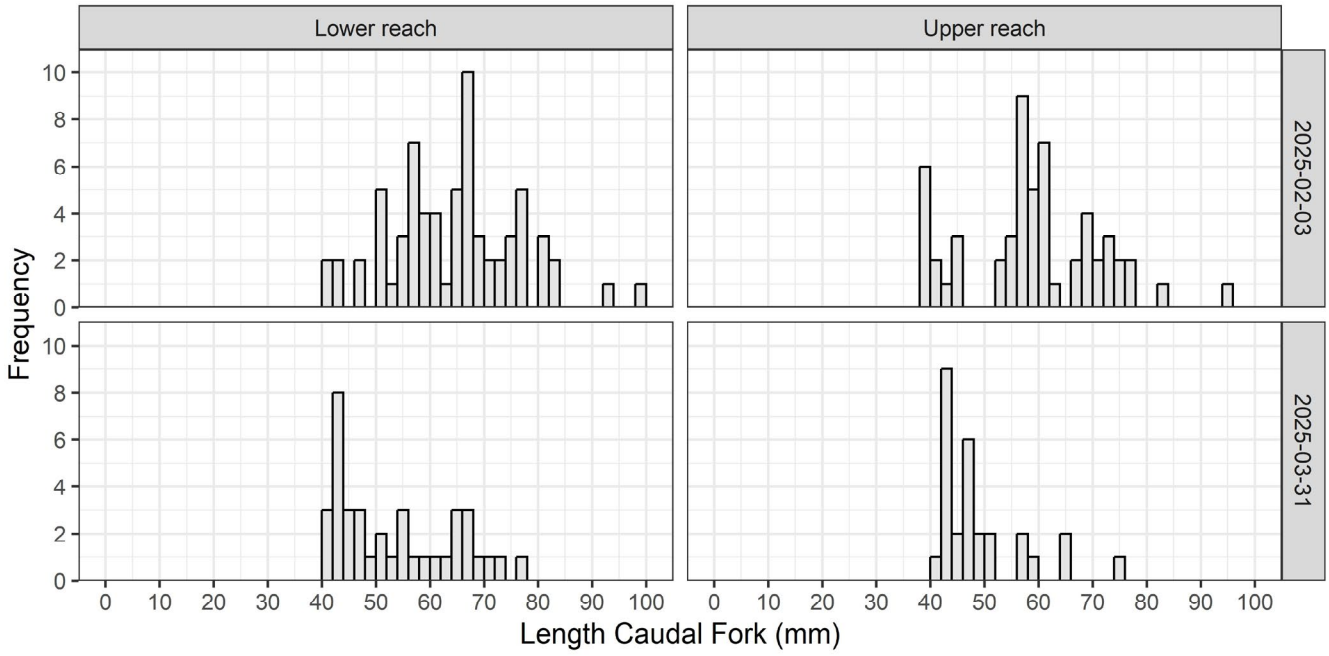

Figure 6: Length frequency of Stocky Galaxias captured from Sallys Flat Creek in February and March 2025.

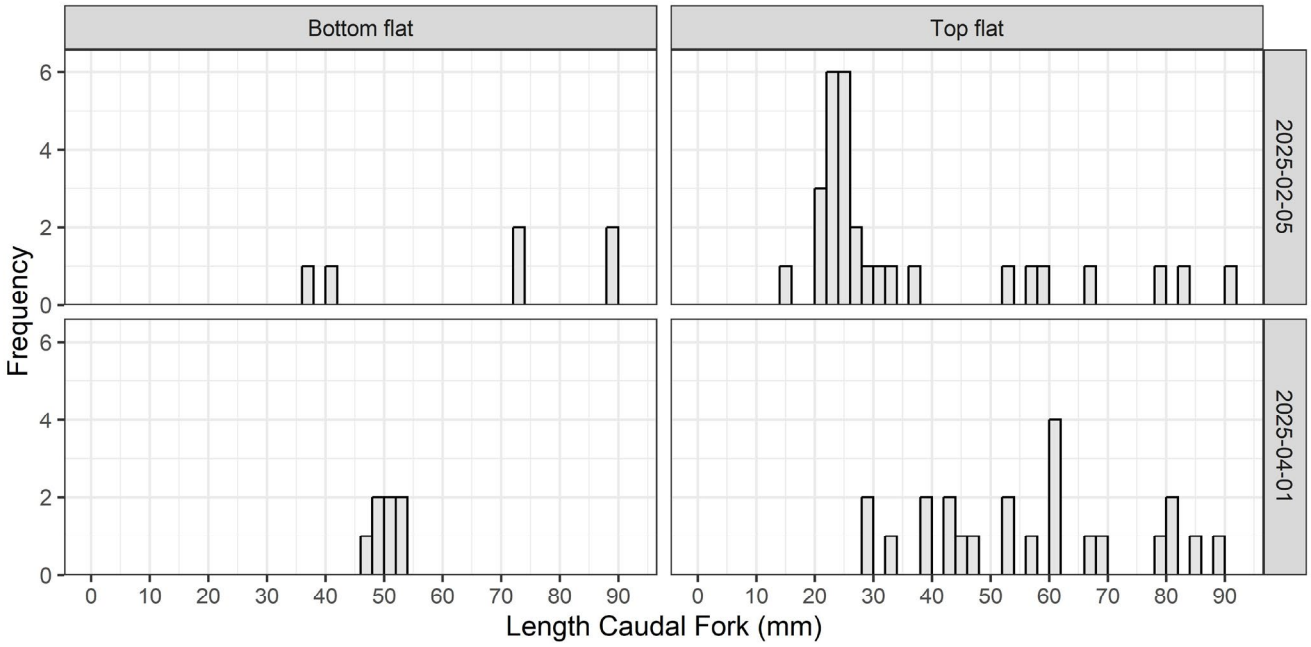

Figure 7: Length frequency of Stocky Galaxias captured from Tantangara Creek in February and April 2025.

Size at age for YOY Stocky Galaxias has only been estimated (via monthly sampling) in a single study and only where Mountain Galaxias was not present (so specific identification is possible, see Allan et al. 2021) with no otolith studies to verify age at length. Fish growth likely varies between years, and in small-bodied species the clear delineation of cohorts can be difficult with small length increments separating cohorts. As a consequence, the clear identification of the proportion of the Stocky Galaxias population that are YOY based solely on length is imprecise, but it is clear that recruitment has occurred at all reaches other than Tantangara Creek Bottom flat after successful spawning in late 2024. Given the very small home range of Stocky Galaxias and the lack of evidence to support large-scale spawning movements (Allan et al. 2021, 2022), the presence of YOY is believed to represent in-reach recruitment, although some downstream displacement of larvae is likely.

At Tantangara Creek 30 YOY individuals were observed and an additional 19 YOY were captured at Top flat in February 2025. The large number of observed (rather than captured) fish reflects the fact that small fish are not well sampled by electrofishing. By April 2025 these small YOY fish had grown to a

larger size (30–43 mm) and were more represented in the captured sample, rather than being observed. No YOY were observed at Bottom flat in either February or April in 2025 where the catch comprised fish of 47–54 mm individuals estimated to be at least 1 year old (Allan et al. 2021). Since the inception of the SGMP in 2024 only a single YOY fish has been recorded at Tantangara Creek Bottom flat, which occurred in April 2024 (Lintermans and Allan 2024).

Condition

Fulton's condition factor (K) for Stocky Galaxias in Tantangara Creek was 0.51–1.52 (mean 0.92, median 0.92, SD 0.24, SE 0.04, n = 32) in February 2025 and 0.37–1.45 (mean 0.85, median 0.84, SD 0.21, SE 0.04, n = 29) in April 2025 (Figure 9), with no significant difference in K between sampling dates (Mann-Whitney test, p = 0.1). At Sallys Flat Creek K was 0.34–1.18 (mean 0.80, median 0.80, SD 0.15, SE 0.01, n = 131) in February 2025 and 0.35–1.09 (mean 0.75, median 0.77, SD 0.17, SE 0.02, n = 68) in March 2025, with values from February significantly greater than those from March (Mann-Whitney test, p = 0.04). Additionally, Tantangara Creek had significantly higher values for K than Sallys Flat Creek in both February 2025 (Mann-Whitney test, p < 0.01) and March/April 2025 (Mann-Whitney test, p = 0.02).

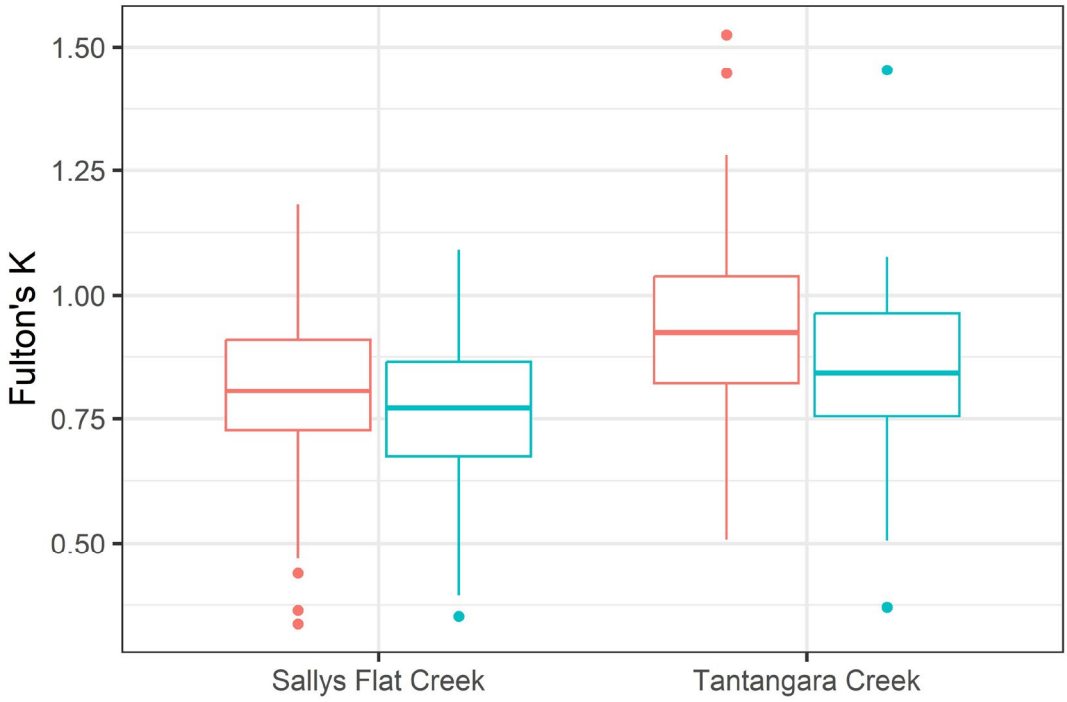

Figure 9: Boxplots of Fulton's condition factor (K) for Sallys Flat & Tantangara Creek in February (red) and March/April (blue) sampling events.

Fish health

There are three macroscopically externally visible parasites that have been previously recorded on *Galaxias* species in the Canberra region. These are the parasitic copepod *Lernaea cyprinacea*, the nematode *Eustrongylides* and digenean trematodes (Robinson 1982; Cowden 1988; Drayson 1989; Lintermans 2022b, 2023a, 2023c, unpub data; Shamsi et al. 2023,). *Lernaea* and *Eustrongylides* are rarely reported on *Galaxias* in the Canberra region, however digenean trematode cysts are routinely observed on *G. olidus* in southeastern Australia (Raadik 2014; Lintermans 2023a). Digenean trematode metacercaria were externally visible on both species at both reaches at Sallys Flat Ck, but none were observed at Tantangara Creek (Table 5). Although up to 20 cysts were observed on a single fish, the intensity of metacercarial infection was generally low with a median of only two cysts per fish (Table 6).

Metacercaria of digenean trematodes are commonly observed in many *Galaxias* species (Smith & Hickman 1983; Kelly et al. 2010; Raadik 2014; Tritt 2018; Lintermans 2023a; Thomas 2023) and other common small-bodied native fish in Australia such as carp gudgeons (*Hypseleotris spp.,* see Rochat et al. 2020; Shamsi et al 2021b). The prevalence and intensity of infection recorded in Stocky Galaxias in 2025 was lower than recorded in galaxiids in some other nearby locations (e.g. the Canberra region, see Lintermans 2018; unpubl. data).

Table 5: Prevalence (% fish infected) of digenean trematode metacercaria in fish caught during 2025 Stocky Galaxias monitoring.

Date	Site	Reach	Stocky Galaxias	Mountain Galaxias	*Galaxias* spp.
03/02/2025	Sallys Flat Ck	Lower	37% (25/68)	24% (17/70)	4% (1/24)
		Upper	36% (20/56)	38% (3/8)	9% (3/34)
05/02/2025	Tantangara Ck	Bottom flat	0% (0/6)	-	-
		Top flat	0% (0/29)	-	-
31/03/2025	Sallys Flat Ck	Lower	5% (2/38)	0% (0/14)	0% (0/3)
		Upper	21% (6/28)	-	33% (1/3)
01/04/2025	Tantangara Ck	Bottom flat	0% (0/7)	-	-
		Top flat	0% (0/23)	-	-

Table 6: Intensity of digenean trematode metacercaria in fish caught during 2025 Stocky Galaxias monitoring. Values are median number of metacercaria per fish, with minimum and maximum values in brackets (when n > 1).

Date	Site	Reach	Stocky Galaxias	Mountain Galaxias	*Galaxias* spp.
03/02/2025	Sallys Flat Ck	Lower	2 (1-20)	2 (1-8)	1 (1-1)
		Upper	2 (1-17)	1 (1-2)	1 (1-12)
05/02/2025	Tantangara Ck	Bottom flat	-	-	-
		Top flat	-	-	-
31/03/2025	Sallys Flat Ck	Lower	3.5 (3-4)	-	-
		Upper	1.5 (1-5)	-	1
01/04/2025	Tantangara Ck	Top flat	-	-	-
		Bottom flat	-	-	-

Objective 2 - Population trajectory & variability

As only a single sampling period (April 2024) of dedicated systematic monitoring is available for Stocky Galaxias, the evaluation of population trajectory is constrained whilst data is accumulated over successive years (Raadik and Lintermans 2022). Consequently, the first 2-3 years of population monitoring is largely descriptive until trajectory can be ascertained.

A number of previous studies and isolated sampling events provide indication on the variability of Stocky Galaxias abundance in electrofishing surveys, although sampling did not necessarily follow the same methodology as outlined in the SGMP and the current monitoring (Table 4, Lintermans and Allan 2024). Nonetheless, these sources may be useful in the first few years of the SGMP, before more data is collected (see earlier discussion under *SGMP Objectives 1 & 3 - Population persistence and status*). The hypothesis that the low abundance in April 2024 at both sites (Sallys Flat Creek and Tantangara Creek) might have been due to a seasonal sampling artefact (Lintermans and Allan 2024), is not fully supported across both sites by sampling in 2025. While catch rates at Sallys Flat Creek in late-March 2025 were lower compared to early-February 2025, this pattern is not evident for Tantangara Creek.

The small sample size of fish caught at Tantangara Creek Bottom flat in both 2024 and 2025 precludes robust statistical comparison between years (2024 vs. 2025) or months (Feb vs. April, 2025 only), but the consistently low abundance of fish in surveys for two consecutive years supports a hypothesised population decline from levels assumed in 2016-2018.

Objective 4 - Threat status

The rapid, visual assessment of potential threats did not reveal any critical new threats to Stocky Galaxias at either sample site. The major threats to the majority of Australian freshwater fish (habitat loss or modification, alien fish impacts; Lintermans et al. 2024) while largely responsible in defining the current relictual Stocky Galaxias distribution, have not intensified or penetrated past the barrier waterfalls that protect both populations. The impacts of feral horses at Tantangara Creek are being ameliorated by horse exclusion fencing (Lintermans 2023b; Lintermans and Allan unpubl. data). There has been no recent fire activity at any of the sampling reaches, and no apparent loss of riparian vegetation or instances of new erosion or sedimentation activity. On multiple visits across summer/autumn (i.e. early-Feb, mid-Feb, early-April, mid-April) there was no evidence of stream drying and cessation of flow. The instream and associated works associated with the construction of the Climbing Galaxias barrier are approximately 500 m downstream of the sampling location at Tantangara Creek Bottom flat and are not considered likely to have any impact on the monitored reaches.

Objective 6 - Pest fish incursion

No pest fish incursion was detected by the electrofishing sampling reported here. Additional pest fish incursion status information will be provided by the eDNA analysis of water samples, which is not part of this report.

Trigger Action Response Plan (TARP) criteria evaluation

Of the seven identified TARP criteria listed below, criteria 1–5 are triggered by a change from baseline data following the first year of monitoring (Raadik & Lintermans 2022), while criteria 6–7 (and a component of criterion 2) are triggered by specific events or observations (Raadik & Lintermans 2022).

1. Decline in relative population abundance.
2. Decline in fish condition.
3. Decline or loss of recruitment.
4. Genetic decline.
5. Water quality decline.
6. Fire or drought.
7. Predatory fish invasion.

Criterion 1 – Decline in relative population abundance

Criterion 1 is triggered by a decline in abundance of non-larval/early juvenile fish. To evaluate this, abundance of fish other than YOY were investigated across sampling from 2024 and 2025 (larval/juvenile fish are evaluated in *criterion 3 – Decline or loss of recruitment*).

Both reaches of Tantangara Creek and the Lower reach of Sallys Flat Creek recorded an increase in non-juvenile fish abundance between 17 and 70% from sampling in April 2024 and March/April 2025, and when evaluated at the site-scale Tantangara Creek showed an increase in Stocky Galaxias abundance by 50%. However, Sallys Flat Creek Lower recorded a 35% decline in March 2025 compared to sampling from April 2024, and when evaluated at the site scale Sallys Flat Creek showed an overall decline in Stocky Galaxias abundance by 15.2%; both of these declines trigger an Alert level 2 (Alert/investigate).

Although data from 2024 and 2025 only demonstrates decline at Sallys Flat Creek, it was hypothesised in 2024 that the abundance of Stocky Galaxias in Tantangara Creek has declined from levels observed during sampling in 2016–2018, based on coarse density data with slightly different sampling design to

SGMP monitoring (Lintermans & Allan 2024; see discussion in *SGMP Objectives 1 & 3*, *SGMP Objective 2*). Based on mean fish density reported during electrofishing surveys, approximately 30–35 fish may be expected in a 30 m electrofishing shot as prescribed in SGMP monitoring design (see discussion in *SGMP Objectives 1 & 3*). If "baseline data" for Tantangara Creek is to be coarsely inferred using this density (based on 30 fish per 30 m shot, with 5 shots at Bottom flat and 3 shots at Top flat), then the abundance of Stocky Galaxias in the reaches at Tantangara Creek reported in 2024 and 2025 represents a decline of between 81–96% since this 2016–2018 period, with a site-level decline of 93 and 90% for 2024 and 2025 respectively. This level of decline triggers an Alert level 3 (High alert/rectify) on both conditions: > 50% decline in 1 year, or > 15% decline in consecutive years.

Criterion 2 – Decline in fish condition

Triggers for criterion 2 detail the decline of individual fish condition (Fulton's K) and/or the observation of a high proportion of individuals with parasites or disease. See *SGMP Objectives 1 & 3* and *Table 5* for data pertaining to fish condition (K) and parasite loads. As this is only the second year of reporting on fish condition for Stocky Galaxias, and that no other values of Fulton's K have been reported for this or other Australian *Galaxias* species, we suggest that we are still in the baseline data collection phase of this metric. The SGMP trigger specifies ">30% of individuals declining in condition by >25%" but does not elaborate on how this 30% of individuals should be defined (i.e. combined across all age classes including YOY, or separating into age classes).

As no externally macroscopically visible parasites were recorded at Tantangara Creek, both reaches remain at Alert level 1 (Normal) based on only one year of previous parasite prevalence data (2024; Lintermans and Allan 2024). However, parasite loads on Stocky Galaxias at Sallys Flat Creek in February 2025 trigger an Alert level 3 (High alert/rectify), with 36 and 37% of fish infected at the Upper and Lower reach respectively. Parasite loads recorded in March 2025 were less than February with only 5% of individuals infected at the Lower reach and an Alert level 1 (Normal), although samples from the Upper reach still trigger an Alert level 2 (Alert/investigate) with 21% of fish infected. Trematode parasites usually complete their lifecycle in multiple hosts with fish eating birds such as cormorants, herons and pelicans a common adult host (Mathews and Cribbs 1998; Shamsi et al. 2021a). The interannual variation or "normal" levels of trematode infection is unknown for Stocky Galaxias. While

TARP trigger levels have been met for parasites at both reaches in Sallys Flat Creek, it is unknown whether the parasite trigger levels identified in the TARP realistically represent a ”threat” for all parasites (e.g. trematodes); the same levels of infestation with *Eustrongylides* and/or *Lernaea* at TARP trigger levels would be more concerning.

Criterion 3 – Decline or loss of recruitment

Criterion 3 is triggered by either a complete loss, or a > 30% decline in the abundance of 0+ (YOY) fish.

In March/April 2025 the abundance of YOY was between 24 and 50% of the abundance from the same site and reach in April 2024, representing declines of 50-76%. Note that this does not include Tantangara Creek Bottom flat, where no YOY fish were detected in 2025 and therefore decline was not calculated. Evaluating at the site level (by combining YOY catch from both reaches), the decline from 2024 to 2025 is 70 and 50% for Sallys Flat Creek and Tantangara Creek respectively.

February 2025 samples from Sallys Flat Creek were not used because YOY maximum length cutoff for February was 35 mm (derived from Allan et al. 2021) and fish were not identified to species when less than 40 mm in Sallys Flat Creek, and therefore no YOY were identified. The abundance of YOY in February 2025 surveys at Tantangara Creek Top flat was 21 individuals, which compared to the catch of 6 in April 2025 represents a ~71% decline, although comparing between samples from different times of year may be significantly influenced by seasonal differences; Allan et al. (2021) however does not report a decline in YOY between Feb and April for 2017 or 2018 (see Figure 7 in Allan et al. 2021).

Therefore, at both the site- and reach-scale, declines of greater than 30% have been observed in YOY abundance from April samples between 2024 and 2025 and a complete loss of YOY fish from Tantangara Creek Bottom flat in 2025, triggering an Alert level 2 (Alert/investigate).

No running-ripe males were detected in the early-April 2025 sampling at Tantangara Creek Bottom flat but the low number of fish captured (n = 5) precludes robust assessment about breeding condition at the reach or population scale. By contrast, in the early-April 2025 sampling at Tantangara Creek Top flat a total of three running-ripe males were caught (total catch = 23).

Criterion 4 – Genetic decline

As outlined by Raadik & Lintermans (2022), specific trigger levels for genetic diversity or decline cannot be defined as the genetic diversity of Stocky Galaxias is currently unknown. Analysis of population genetics is done every three years (or as per TARP) and is currently scheduled for the third year of monitoring and therefore is not evaluated this year or in this report.

Criterion 5 – Water quality decline

Water quality decline is triggered by consistently high air temperature, low dissolved oxygen levels or a pH change of 1.0. Water quality recorded in both sampling periods (early February and Late March/early April 2025 did not meet any of the TARP trigger levels. (Table 7). Only spot water temperature readings taken during the fish monitoring were collected and evaluated.

*Table 7: Water quality parameters (pH, conductivity, water temperature, turbidity and dissolved oxygen) at each site in February and late March/early April. * = conductivity meter faulty*

Site	Reach	Date	Time measured	pH	Cond. (uS/cm)	Water temp (˚C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
Sallys Flat Creek	Lower	3/02/2025	16:45	7.0	*	19.8	<9	5.0
Sallys Flat Creek	Upper	31/03/2025	16:40	7.0	50	17.0	<9	6.6
Tantangara Creek	Bottom flat	5/02/2025	14:30	6.5	*	20.0	<9	7.0
Tantangara Creek	Bottom flat	1/04/2025	11:20	7.0	30	12.0	<9	9.4

Criterion 6 – Fire or drought

Triggers for criterion 6 include a > 10% burn of the catchment area, or the cessation of streamflow at one or both monitoring sites. Fire has not occurred in the last 5 years at either site, with the 2019-20

fires affecting Tantangara Creek but not Sallys Flat Creek. Fire severity at Tantangara Creek varied between the Top and Bottom flats with Top flat burnt more severely causing loss of significant amounts of riparian vegetation and loss and death of streamside *Sphagnum* deposits. Bottom flat had some patchy riparian burning but was much less affected. Riparian vegetation is recovering slowly at Top flat, and ground cover has recovered well at both reaches (Lintermans and Allan 2024). Fencing to exclude feral horses from large portions of both flats in mid-2020 has been significant in protecting instream and riparian habitat (Lintermans and Allan 2022, unpubl. data; Lintermans 2023b).

At both sampling reaches of both Tantangara Creek and Sallys Flat Creek the stream was flowing during the two separate monitoring periods, although there is no stream gauging station or depth logger at either site to inform periods other than the isolated sampling dates.

Criterion 7 – Pest fish invasion

Criterion 7 is triggered by a large rainfall event or predator fish detection from eDNA or electrofishing.

See *SGMP Objective 6 – Pest fish incursion*; no predatory fish were detected from electrofishing as part of this monitoring, although eDNA sampling will provide further information for this criteria. Daily rainfall totals for the nearest Bureau of Meteorology rainfall station (Yarrangobilly Caves) did not exceed 33 mm for all but a single day in the period January to April 2025 with a daily rainfall of 74 mm on 10/02/2025 (Bureau of Meteorology 2025). Consequently, the rainfall trigger level of > 90 mm in 24 hours has not been met.

Conclusion and recommendations

The 2025 Stocky Galaxias monitoring has met trigger levels under a number of TARP criteria. Findings from both 2024 and 2025 suggest there has been a decline in the Stocky Galaxias population at Tantangara Creek, and lack of recruitment in 2025 at Tantangara Creek Bottom flat. Monitoring in 2025 did not find any threats requiring intervention around TARP criterion 5 (Water quality decline) 6 (Fire or drought), and 7 (Predatory fish invasion).

TARP responses

- Under **criterion 1** (Decline in relative population abundance) a 15% decline in non-larval/early juvenile phases in one year triggers two Alert level 2 responses: (i) undertake egg hatching monitoring in subsequent season to determine level of recruitment, and (ii) increased disease/parasite monitoring (samples to Veterinary clinic). As the decline has exceeded Alert level 3 (> 50% decline in non-larval/early juvenile phases in 1 year or > 15% decline in consecutive years) the response is to ”Notify NSW DPI and enact emergency intervention procedure”. This report fulfils Alert level 3 (notification), and it is recommended that the Alert level 2 responses should also occur.

- Under **criterion 2 (Decline in fish condition**) Trematode parasite loads on Stocky Galaxias at Sallys Flat Creek in February 2025 trigger an Alert level 2 (Alert/investigate) or Alert level 3 (High alert/rectify). The response to Alert level 2 is “increased disease/parasite monitoring (samples to Veterinary clinic)” and to Alert level 3 is “Notify NSW DPI and enact emergency intervention procedure” (see Raadik & Lintermans 2022 section 4.1.4). This report fulfils Alert level 3 (notification) and it is recommended that the Alert level 2 responses should also occur.

- Under **criterion 3 (Decline or loss of recruitment)** at both the site- and reach-scale, declines of greater than 30% have been observed in YOY abundance from April samples between 2024 and 2025 and a complete loss of YOY fish from Tantangara Creek Bottom flat in 2025, triggering an Alert level 2 (Alert/investigate). The recommended response to Alert level 2 is to “undertake spawning and egg hatching monitoring in subsequent season to establish the life stage where the failure may be occurring and seek to identify the cause”. Such spawning and egg monitoring would occur between October and December (the spawning and hatching season).

Refinement of TARP trigger levels

Under criterion 1 (Decline in relative population abundance), 2 (Decline in fish condition), 3 (Decline or loss of recruitment), 5 (Water quality decline) there are percentage changes or nominated levels which trigger responses under the TARP. However, it is not specified whether these levels apply to the overall population (i.e. all sites combined), site, or reach spatial scale, and how baseline variability is

incorporated. Given the disparity already observed for criterion 1 (population abundance) and criterion 3 (recruitment) in the first two years of monitoring (namely at Tantangara Creek), we suggest that it would be appropriately conservative to evaluate criteria for each sampling reach, at each site. The TARP trigger levels specified in Table 4 of Raadik and Lintermans (2022) also state that "All percentage changes are relative to mean baseline data following the first year of monitoring". In the current monitoring report we have expanded the baseline for criterion 1 (Decline in relative population abundance) to include the catch rates recorded from 2016–2018 (Allen 2018), as both the first year of monitoring (2024) and 2025 have shown much lower abundance of Stocky Galaxias than expected, and highlights a problem of applying trigger levels if declines have occurred prior to the establishment of the baseline monitoring program. This lack of certainty about how to apply the trigger levels needs to be clarified before the 2026 monitoring program.

Sampling effort

The monitoring approach developed and applied for the 2024 and 2025 monitoring at Sallys Flat Creek should be adopted and endorsed as the protocol for future monitoring years.

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Appendix 1(a). Habitat descriptors for Sallys Flat Creek (upper). *Scores: a = abundant, f=frequent, o=occasional, r=rare, -=absent*

Habitat sheet	
Date	3/02/2025
Reach name	Upper
Site name	Sallys Flat Creek

Site habitat	Score	**Site habitat**	
Substrate		**Cover**	
Bedrock	-	Rock	**r**
Boulder	**r**	Timber	-
Cobble	**o**	Undercuts	**a**
Pebble	**f**	Leaf litter	-
Gravel	**f**	Macrophytes	**a**
Sand	**r**		
Mud/silt	**a**		
Plants		**Mesohabitat**	
Native trees	-	Pool	**o**
Exotic trees	-	Run	**a**
Native shrubs	**r**	Riffle	**o**
Exotic shrubs	-	Rapid	-
Riparian grass	**a**	Backwater	-
Floating macrophytes	-	Velocity	**slow**
Emergent macrophytes	-	Avg depth (m)	**0.1**
Submerged macrophytes	**a**	Max depth (m)	**0.2**
Filamentous algae	**a**	Avg width (m)	**0.55**
Suspended algae	-	Water height on permanent marker	**285mm**
Biofilms	**a**		

Appendix 1(b). Habitat descriptors for Sallys Flat Creek (lower).

Habitat sheet	
Date	3/02/20254
Reach name	Lower
Stream name	Sallys Flat Creek

Site habitat	Score		Score
Substrate		**Cover**	
Bedrock	-	Rock	**o**
Boulder	**o**	Timber	-
Cobble	**o**	Undercuts	**f**
Pebble	**f**	Leaf litter	-
Gravel	**f**	Macrophytes	**a**
Sand	**o**		
Mud/silt	**f**		
Plants		**Mesohabitat**	
Native trees	-	Pool	**r**
Exotic trees	-	Run	**a**
Native shrubs	**r**	Riffle	**o**
Exotic shrubs	-	Rapid	-
Riparian grass	**a**	Backwater	-
Floating macrophytes	-	Velocity	**slow**
Emergent macrophytes	-	Avg depth (m)	**0.15**
Submerged macrophytes	**f (milfoil, ranunculus)**	Max depth (m)	**0.25**
Filamentous algae	**f**	Avg width (m)	**0.8**
Suspended algae	-	Water height on permanent marker	**85mm**
Biofilms	**a**		

Appendix 1(c).: Habitat descriptors for Tantangara Creek Bottom flat.

Habitat sheet	
Date	5/02/2025
Reach name	Bottom flat
Site name	Tantangara Creek

Site habitat	Score		Score
Substrate		**Cover**	
Bedrock	**-**	Rock	**a**
Boudler	**f**	Timber	**r**
Cobble	**a**	Undercuts	**a**
Pebble	**a**	Leaf litter	**r**
Gravel	**f**	Macrophytes	**-**
Sand	**o**		
Mud/silt	**o**		
Plants		**Mesohabitat**	
Native trees	**o**	Pool	**-**
Exotic trees	**-**	Run	**a**
Native shrubs	**r**	Riffle	**f**
Exotic shrubs	**-**	Rapid	**-**
Riparian grass	**a**	Backwater	**-**
Floating macrophytes	**-**	Velocity	**slow**
Emergent macrophytes	**-**	Avg depth (m)	**0.1**
Submerged macrophytes	**-**	Max depth (m)	**0.2**
Filamentous algae	**r**	Avg width (m)	**0.90**
Suspended algae	**-**	Water height on permanent marker	185mm
Biofilms	**o**		

Appendix 1(d): Habitat descriptors for Tantangara Creek Top flat.

Habitat sheet	
Date	5/02/2025
Reach name	Top flat
Site name	Tantangara Creek

Site habitat	Score		
Substrate		**Cover**	
Bedrock	-	Rock	**a**
Boudler	**o**	Timber	**f**
Cobble	**a**	Undercuts	**a**
Pebble	**a**	Leaf litter	-
Gravel	**a**	Macrophytes	-
Sand	**o**		
Mud/silt	**f**		
Plants		**Mesohabitat**	
Native trees	**r**	Pool	**r**
Exotic trees	-	Run	**a**
Native shrubs	**a**	Riffle	**a**
Exotic shrubs	-	Rapid	-
Riparian grass	**a**	Backwater	-
Floating macrophytes	-	Velocity	**slow**
Emergent macrophytes	-	Avg depth (m)	**0.10**
Submerged macrophytes	-	Max depth (m)	**0.19**
Filamentous algae	**r**	Avg width (m)	**1.0**
Suspended algae	-	Water heigh on permanent marker	95mm
Biofilms	**o**		

Appendix 2: site photos. Sallys Flat Creek (lower) Feb 2025.

Appendix 2 (cont): site photos. Sallys Flat Creek (upper) February 2025

Appendix 2 (cont): site photos. Tantangara Creek Bottom flat February 2025

Appendix 2 (cont): site photos. Tantangara Creek Top flat. February 2025

Appendix B

Macquarie Perch population monitoring in the upper Murrumbidgee Catchment

Snowy 2.0 Macquarie perch monitoring in the upper Murrumbidgee catchment 2025

Mark Lintermans

September 2025

Fish Fondler Pty Ltd
Research, Monitoring, Advice
for threatened freshwater fish

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Sampling was conducted under NSW Fisheries Scientific Collection Permit No. FP 23/108 and approval from the University of Canberra Animal Ethics Committee.

This research was conducted on Ngarigo and Ngambri country.

Cover photo: Sampling Site 5: 5/03/2025 (photo Mark Lintermans).

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Introduction

Macquarie perch *Macquaria australasica* is a moderately sized, deep-bodied, freshwater percichthyid fish, which is found in south-eastern Australia. It occurs in both the inland drainage of the Murray–Darling Basin (MDB) as well as the coastal drainages of the Shoalhaven and Hawkesbury-Nepean catchments in New South Wales (Lintermans 2023a, b; Faulks *et al*. 2010; Pavlova *et al*. 2017). It is now considered that the three morphologically distinct and geographically disjunct forms in inland and coastal drainages are likely to be separate taxa (Faulks *et al*. 2010; Pavlova *et al*. 2017; Lutz *et al*. 2022). In the MDB the maximum length is 550-mm total length (TL) and maximum weight is 3.5 kg, but individuals larger than 400 mm TL or 1 kg are uncommon (Harris and Rowland 1996; Lintermans 2023a). Length at maturity is variable with females generally mature at ~250 mm TL and males at 150–200 mm TL (Cadwallader and Rogan 1977; Appleford *et al*. 1998; Lintermans 2023a; Lintermans *et al*. 2019). The remaining coastal taxa (Hawkesbury-Nepean; Shoalhaven) are much smaller, generally not exceeding 180 mm length (Harris and Rowland 1996; Knight and Bruce 2010; Gilligan and Bruce 2019).

Macquarie perch (including all inland and coastal taxa) is currently listed as endangered both nationally and in all the States and Territories in which it occurs (Ingram *et al*. 2000; Lintermans *et al*. 2019; Lintermans 2023a). The most recent international listings under the IUCN Red List separate the three taxa and list the MDB taxon as endangered (Lintermans *et al*. 2019; 2024b) and the undescribed Hawkesbury-Nepean taxon as vulnerable (Gilligan and Bruce 2019). The undescribed Shoalhaven taxon, only previously known from the Kangaroo River, is now likely extinct.

Recovery plans are being drafted or implemented in several jurisdictions (ACT Government 2018; DSE 2009) with the first national recovery plan finalised in 2019 (Commonwealth of Australia 2018). The species complex (i.e. the 3 taxa) has declined significantly in both range and abundance since the 1940s, with the timing of decline varying with location. The upper Murrumbidgee River contains one of only a handful of remaining large, self-sustaining natural populations, with the species declining noticeably in the Murrumbidgee River in the ACT since the mid-1980s when catch rates dropped by ~95% (Lintermans 2002). Major threats to the species include habitat modification, (instream sedimentation, de-snagging and riparian degradation), barriers to fish passage, modification to river flows and temperatures), poor genetic diversity, interaction with alien species (competition, predation and disease transmission), and climate change induced episodic events such as extreme drought and fire (Ingram *et al*. 2000; Lintermans 2012, 2023a; Pavlova *et al*. 2017; Commonwealth of Australia 2018; Lintermans *et al*. 2019; Tonkin *et al*. 2022).

Recent research has demonstrated that the upper Murrumbidgee population regularly breeds and recruits along an approximately 95 km ‘recruitment reach’ from just downstream of Cooma to just below Yaouk (Lintermans 2023b, 2024a, 2024b). The reach extent and habitat quality, along with limited number, distribution and abundance of alien fish species present, and reliability of Macquarie perch recruitment in the recruitment reach makes it the best Macquarie perch population in NSW, and of national

significance (Lintermans 2023b). The recruitment reach provides a haven for the species from the impacts of some introduced fish (Woinarski *et al*. 2023). Macquarie perch is absent between Tantangara Dam and Yaouk, almost certainly as the result of instream barriers that prevent upstream fish movement, with insufficient flows downstream of the dam to drown out such barriers (Lintermans 2023b). The most recent genetic investigations into the upper Murrumbidgee population have shown that the effective population size (Ne) at all but the most downstream sites is low, and that it declines significantly from downstream to upstream sites. The pattern of genetic diversity also similarly declines in an upstream direction, and inbreeding is high (Pavlova *et al*. 2024).

Prior to the construction of Tantangara Dam the average annual flow (ANF) is estimated to have been approximately 270 to 301 Gl/year (Pendlebury et al 1997; ACTEW 2005). In 1998 the Snowy Water Inquiry concluded that flow diversions had contributed to the to the deteriorating ecological function of rivers downstream of the Snowy Scheme and in response to this the Snowy Water Inquiry Outcomes Implementation Deed (SWIOID) was agreed to by the participating Governments (Snowy Water Inquiry Outcomes Implementation Deed 2002). The SWIOID nominates a specific Montane Flows release target of 27 GL per year for the upper Murrumbidgee River, which the SWIOID estimated to be approximately 30% of ANF upstream of the dam. However publicly available reports indicate much higher estimates of ANF (see above) with these estimates widely used by Governments in assessing river health and setting environmental flow requirements (e.g. NSW DCCEEW 2024). Environmental flow releases from Tantangara Dam commenced in 2005 and ranged from 3.6 to 13.9 GL until 2009 with an annual average of 7.7 GL (Snowy Scientific Committee 2010). From 2009/10 onward the release strategy was reshaped for ecological objectives, notably the recovery of the endangered Macquarie Perch (NSW DPI Water (2016). A recent review of environmental flow releases between reported that the releases were below the 27 GL annual target in 10 of the 15 years from 2008 to 2022 (McGuire and Pittock 2025).

Tantangara Dam historically diverted around 99 percent of ANF from the upper reaches of the Murrumbidgee River to the adjacent Snowy River catchment, with the lack of flow downstream of Tantangara severely impacting the Macquarie perch population (Lintermans 2023b, 2024a, 2024b; Pavlova *et al.* 2024). While environmental water releases are provided from Tantangara as part of the Snowy Montane Rivers Increased Flows (SMRIF), they range from 3.1 to 44.7 GL since 2011-12, with an annual average of 21.35GL (Snowy Hydro data available in annual water reports at https://www.snowyhydro.com.au/about/reports/). These average annual environmental water releases since 2011-12 are around 7% of natural pre-impoundment flows (Pendlebury *et al.* 1997; ACTEW 2005; NSW DCCEEW 2024; Commonwealth of Australia DCCEEW 2025) and are considered insufficient to support natural values and threatened species (Snowy Scientific Committee 2010).

A critical knowledge-need for managing Macquarie perch in the upper Murrumbidgee recruitment reach is around the recruitment dynamics of where recruitment is occurring, and how it varies from year to year. (Lintermans 2023b). This knowledge is essential if important recruitment areas are to be protected, and to improve the timing and quantum of environmental water releases from Tantangara Dam. It is also essential if we are to adequately monitor, understand and manage population structure, status, and

threats to threatened species (Scheele *et al.* 2019). The recruitment dynamics of Macquarie perch have become better understood following 5 years of dedicated monitoring from 2019 to 2023 (Lintermans 2023b) but additional sampling was required to confirm the upstream extent of the species distribution below Yaouk, and to sample further downstream to examine how far the recruitment reach extends (Lintermans 2023b). Anecdotal information suggested that recruitment extends to approximately the junction of the Numeralla River with the Murrumbidgee River (Lintermans *et al*. 2022; D. Gilligan unpubl. data), but this area has been little sampled and was outside the resources available in the previous recruitment investigations (Lintermans 2023b). There is little published information available for the location or timing of Macquarie perch spawning in the upper Murrumbidgee River with a single study reporting spawning at and below Murrells Crossing in late October 2015 (sites UMR04 & UMR06 in Bylemans *et al*. 2017) and subsequent egg collection at some of these sites in mid-November 2020 (van der Muelen *et al.* 2023).

Snowy Hydro Limited received approval in 2020 to construct a new large-scale pumped hydro-electric storage and generation scheme (Snowy 2.0), to increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme. This will involve the connection of the existing Talbingo and Tantangara reservoirs via a series of underground pipes and an underground power generation station. Water will be transferred in both directions between the reservoirs, which are in separate river catchments. One of the threatened fish species potentially at risk from these water transfers is Macquarie perch (Cardno 2019; Snowy Hydro 2023). As part of the NSW and Commonwealth approvals for Snowy 2.0, the preparation of a Threatened Fish Management Plan including a series of monitoring requirements for threatened and alien fish was mandated (see Snowy Hydro 2023). As a component of this Threatened Fish Management Plan, a monitoring plan for Macquarie perch was developed (Lintermans *et al*. 2022). This report presents the implementation and results of the second year of the Macquarie perch Monitoring Plan (MPMP).

Hydrological conditions in 2024-25

Net-based sampling can only occur safely and provide representative catch rates when autumn flows in the upper Murrumbidgee River are <250ML/day at the Yaouk No 2 gauge at the upper end of the sampling reach. Mean daily flows during the March 2025 sampling period were approximately 53–148 ML/day (Figure 1).

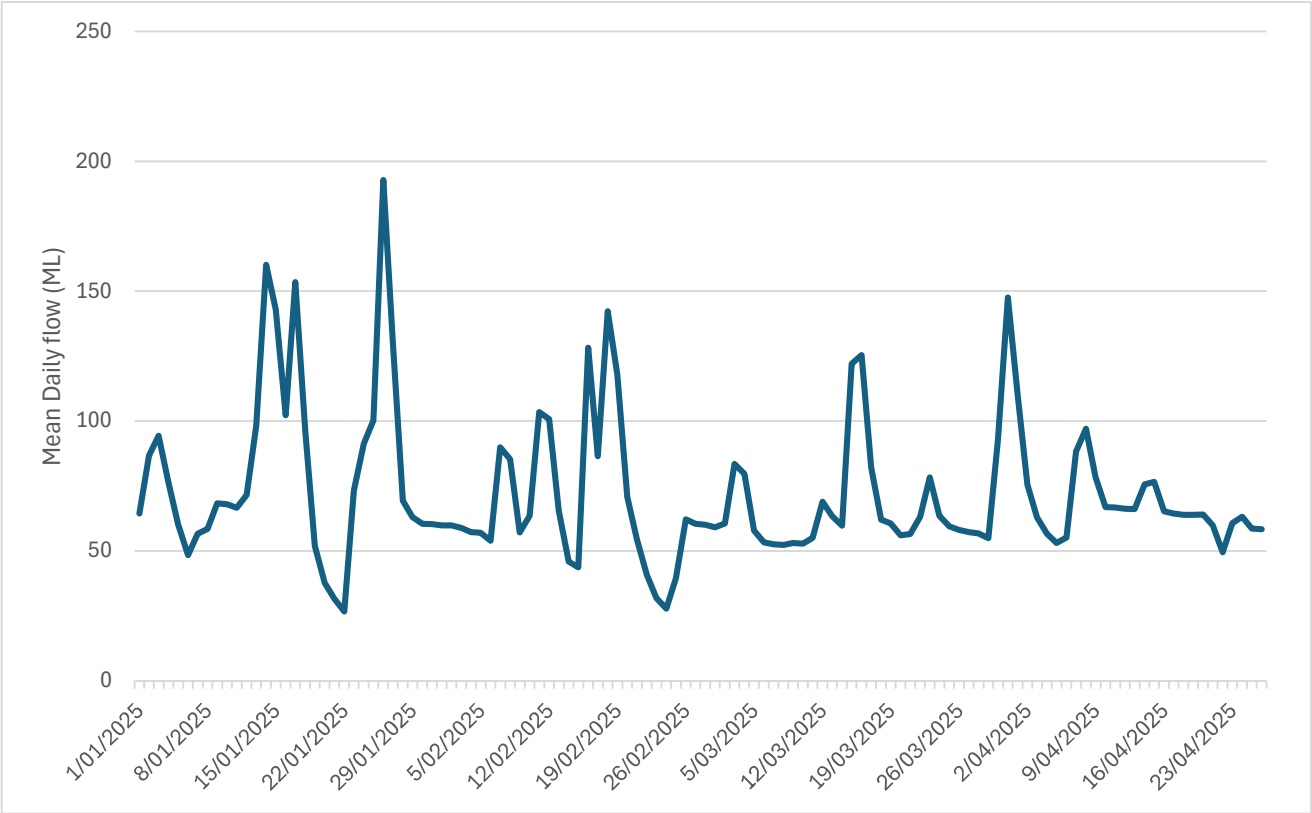

Figure 1. Mean daily discharge in the Murrumbidgee River at Yaouk No. 2 gauge during sampling season from 1/01/2025 to 26/04/2025. Flow data from Water NSW.

Methods

Site selection

Sampling was conducted at a total of nine sites on the Murrumbidgee River with all sites sampled between 03/03/2025 and 13/03/2025 (Figures 2 and 3) (Table 1) (Appendix 1). Eight sites were the same as sampled in the first year of monitoring (2024) but the upstream fringe site (Site 1, where Macquarie perch were known not to be present) changed to a location downstream of Yaouk. The previously sampled upstream fringe site did not have enough accessible pool habitat to allow full deployment of nets (Lintermans 2024a). The overarching aim of this monitoring project is *To provide baseline, comparable data on the Mid Murrumbidgee population, to inform decisions on management intervention for the long-term survival of the population* (Lintermans *et al*. 2022), consequently the core sites were selected to encompass the known range of the recruiting population along with an upstream and downstream fringe site (to detect future range expansion of the species). Following the construction of Tantangara dam in the early 1960s, the species had long been thought to have its upstream extent around Yaouk, with this limit a result of sedimentation of spawning habitat and the presence of natural instream barriers that no longer drown out as a result of the highly reduced and regulated flows released from Tantangara dam (Lintermans 2002; 2023b, 2024a, 2024b).

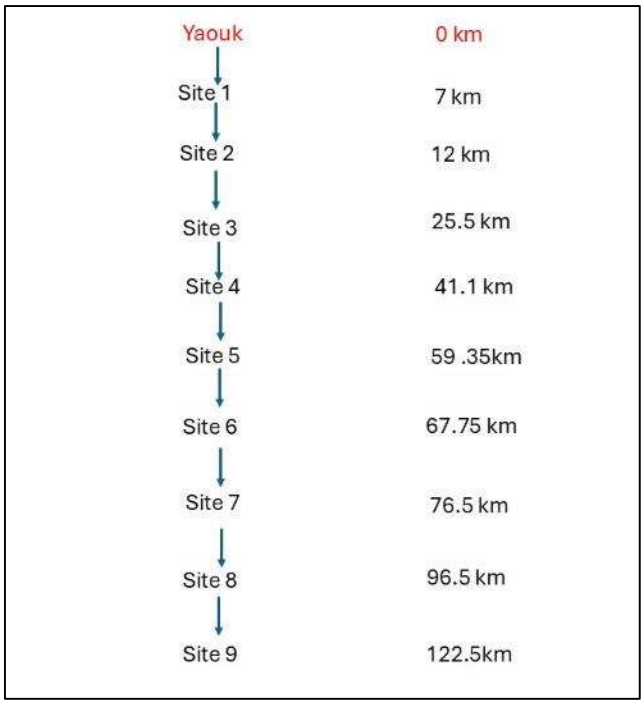

Figure 2. Conceptual diagram of the 2025 site layout and river lengths in the Murrumbidgee River. A reference point (Yaouk Bridge) is included (modified from Lintermans 2024a).

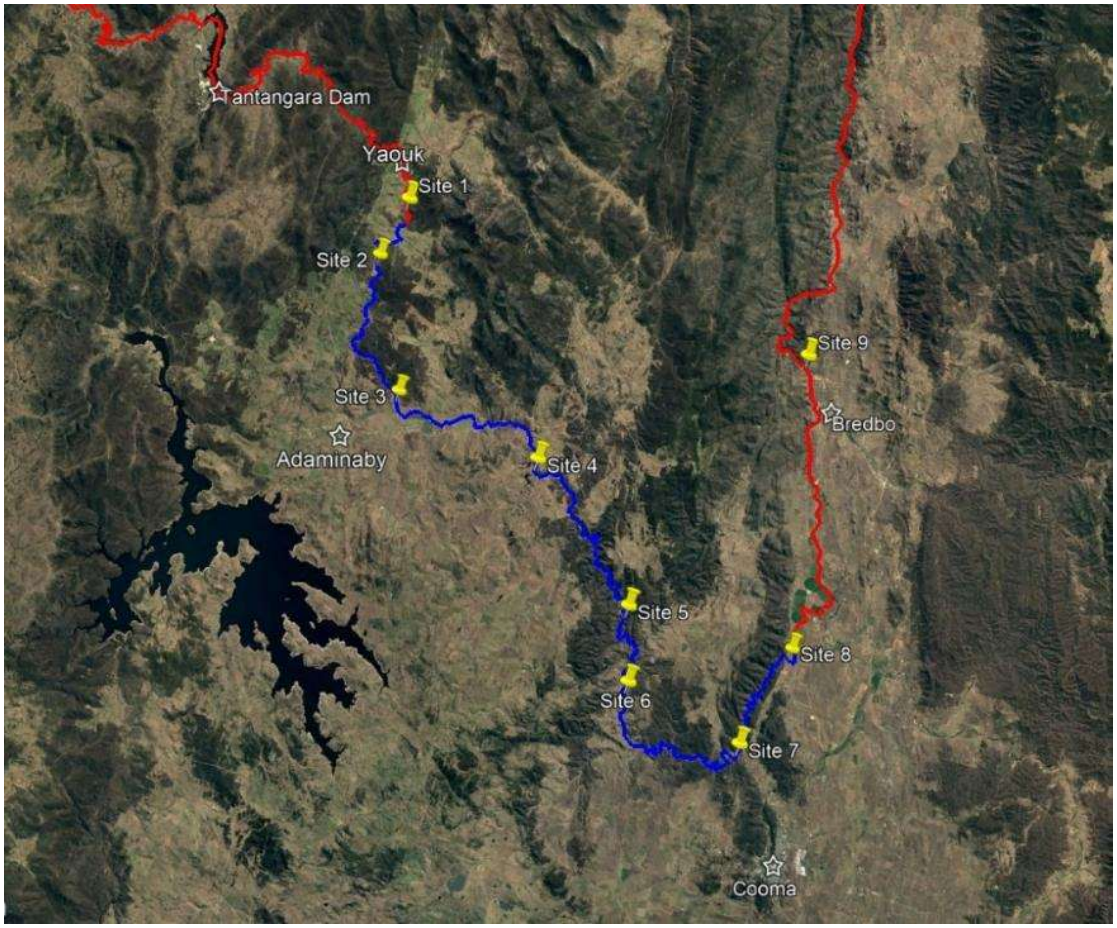

Figure 3. Location of sites sampled in 2025 on the Murrumbidgee River (Yellow pins indicate sampling sites; stars are locality names; blue line is the Macquarie perch Recruitment Reach).

Table 1. Reach names (from Lintermans et al. 2022), sampling site numbers, date sampled, site category (core or fringe) and site elevation of sites sampled in 2025.

Site/Reach name	Site No.	Core or fringe distribution	Date sampled	Elevation (m ASL)
Numeralla Junction to Bredbo Falls (reach)	9	Fringe	10/03/2025	700
Murrells Crossing	8	Core	13/03/2025	720
Mittagang Crossing	7	Core	11/03/2025	745
Kissops Flat	6	Core	12/03/2025	774
Middle Dry Plains (reach)	5	Core	4/03/2025	820
Alum Creek (reach)	4	Core	3/03/2025	940
Bolaro (reach)	3	Core	5/03/2025	986
Below Yaouk (reach)	2	Core	6/03/2025	1030
Below Yaouk Reach	1	Fringe	14/03/2025	1065

Previous sampling had identified the location of the most likely upstream limiting barrier (White 2022), with sampling in 2023 and 2024 failing to catch any Macquarie perch upstream of this barrier (Lintermans 2023b; 2024). The downstream boundary of the Macquarie perch recruitment reach had been previously determined to be between Murrells Crossing and the Murrumbidgee–Numeralla River junction (Lintermans 2023b, 2024). Consequently, seven of the proposed nine Murrumbidgee monitoring sites were selected within the recruitment reach between the Numeralla junction and downstream of Yaouk. The sampling sites comprise two reference sites (Sites 2 and 8) that have been previously recently sampled in every year from 2020 – 2024 (Site 2) and also in 2019 (Site 8) (Lintermans 2023b, 2024b) with another site (Site 6) for which long-term data exists (Lintermans 2016, 2024b). Two 'fringe' sites were also sampled, upstream and downstream of the known population distribution (Lintermans *et al*. 2022). Two reference sites originally proposed for monitoring in the Abercrombie River were not sampled as part of this sampling program, with sampling conducted separately by NSW DPIRD.

MPMP Objectives

A note on terminology. The Macquarie Perch Monitoring Plan (MPMP) was prepared using reach terminology as used in the Snowy 2.0 Environmental Impact Assessment (EIS) report (Cardno 2019). In the EIS, the Mid Murrumbidgee catchment is defined as being waters downstream of Tantangara Dam to the ACT/NSW border, with the Upper Murrumbidgee defined as tributaries of Tantangara Reservoir (including the Murrumbidgee River). As Macquarie perch no longer occur upstream of Tantangara, the MPMP refers to the waters of the Mid Murrumbidgee, which differs from virtually all other documents where the upper Murrumbidgee Catchment is considered to be the catchment upstream of Burrinjuck Dam (e.g. Lintermans 2002; Olley and Wasson 2003; ACT Government 2010; Snowy Scientific Committee 2010; Murrumbidgee Catchment Management Authority 2012; Commonwealth of Australia DCCEEW 2024b; Lintermans 2023b, 2024a, 2024b). Apart from direct quotes from the MPMP, the term 'Upper Murrumidgee'is used as the catchment descriptor for the area where sampling was conducted for this report (as was the case in the 2024 sampling report (Lintermans 2024a).

The overall aim of the Macquarie Perch Monitoring Plan is "*To provide baseline, comparable data on the Mid Murrumbidgee population, to inform decisions on management intervention for the long-term survival of the population*".

Specific monitoring objectives for Macquarie perch in the Mid Murrumbidgee catchment to meet the overall aim are to provide baseline, comparable data on:

1. The persistence of Macquarie perch (Is the species still present and breeding at sites where recorded since 1998).
2. The population trajectory (is the population increasing, stable or decreasing) and variability (significant change from normal).
3. The status of the Macquarie perch population (incorporating measures of abundance, distribution, reproduction and demographics).
4. The persistence and establishment of any new translocations of the species into the catchment.
5. Incursions of Redfin perch into the Mid Murrumbidgee catchment.
6. Triggers for further investigations and/or identified management interventions to mitigate potential sudden declines because of identified threats (e.g. Redfin perch fish invasion, drought, fire).

Trigger Action Response Plan (TARP)

Additional to the objectives outlined above, the Macquarie Perch Monitoring Plan details a decision-making framework for additional sampling in response to deviations from a 'normal' condition in Macquarie perch population metrics (Lintermans *et al*. 2022) or other threats identified in the routine surveillance monitoring. This framework is known as the Trigger Action Response Plan (TARP) and identifies the following triggers which when observed, justify additional sampling (Table 2):

A Redfin perch incursion

B Decline or loss of recruitment

C Decline in relative population abundance

D Decline in Fish condition or fish kill/mortality

E Genetic decline

F Occurrence of fire or drought

Note that as this is only the second year of sampling conducted under the MPMP plan, and not all sampling requirements of the MPMP or TARP are addressed or fulfilled in the current sampling (e.g. eDNA monitoring of predatory fish incursion; establishment of translocated populations), and not all of the MPMP Objectives or TARP triggers can be evaluated during the current monitoring. Consequently, MPMP Objective 4 (establishment of translocated populations), 5 (incursion of exotic fish species), and 6 (triggers and management actions) are not or only partially addressed. This report details the 2025 monitoring program for Macquarie perch in the upper Murrumbidgee in March 2025 and outlines the findings in line with their associated objectives and/or TARP triggers.

Table 2. Criteria, trigger levels, and suggested response activities, for each TARP alert level for Macquarie perch (reproduced from Lintermans *et al*. 2022).

Criteria / Alert level	Redfin Perch invasion	Decline or loss of recruitment	Decline in relative population abundance	Decline in fish condition or fish kill/morbidity	Genetic decline	Fire or drought (risk of sedimentation, water loss)
1 (Normal)	Continue monitoring.	Continue monitoring.	Continue monitoring.	Continue monitoring.	Continue monitoring.	Continue monitoring
2 (Alert / investigate)	*Trigger:* Redfin Perch reported or detected in annual monitoring. *Response:* immediate physical sampling (Section 4.1.2).	*Trigger:* Loss or > 30% decline of Young of Year life phases (in 2 consecutive years or 3 years out of 5) at > 2 sites *Response:* investigate spawning and egg hatching in subsequent season to establish the life stage where the failure may be occurring and seek to identify the cause (Section 4.1.1).	*Trigger:* > 20% decline in post-Young of Year life phases in 2 consecutive years. *Response:* investigate additional monitoring of recruitment, disease, survival (spring sampling run) (Section 4.1.1). - trigger levels to be reviewed following 3 years of data.	*Trigger:* > 30% of individuals declined in condition by > 25%; > 25% of individuals at 2 or more monitoring sites with externally visible parasites/disease, OR, fish kill observed or reported *Response:* investigate catchment (sedimentation, , riparian cover, food resources) and flow conditions (Section 4.1.3). - increased disease/parasite monitoring (samples to Veterinary clinic) and/or submission of samples from fish kill to veterinary clinic (Section 4.1.3).	*Trigger:* Loss of genetic diversity, increasing level of inbreeding. *Response:* additional annual analysis (2 years) of collected fin clips (Section 3.1.2) *Note* – specific trigger levels to be defined following first population genetic analysis.	Trigger: > 20% of catchment area burnt or streamflow ceases at nearest upstream flow gauge. Response: - additional monitoring of Macquarie Perch population for evidence of impact (spring sampling run) (Section 3.1.1).
3 (High alert)	*Trigger:* Redfin Perch detection in mid-Murrumbidgee confirmed by sampling (see Biosecurity Plan). *Response:* Immediately notify NSW DPI and enact emergency intervention procedure.	*Trigger:* Loss or > 30% decline in 3 consecutive years. *Response:* Notify NSW DPI and enact emergency intervention procedure to collect potential broodstock for incorporation into captive breeding program.	*Trigger:* > 30% decline in post Young of Year life phases in 2 consecutive years *Response:* Notify NSW DPI and enact emergency intervention procedure to assess need for supplementation of wild population in captive breeding program.	*Trigger:* > 50% of individuals declined in condition by > 25%; > 25% of individuals at 3 or more monitoring sites with externally visible parasites/disease. *Response:* Notify NSW DPI and enact emergency intervention procedure.	*Trigger:* Note – specific trigger levels to be defined following first population genetic analysis. *Response:* If captive breeding program operational, assess need for supplementation of wild population. Notify NSW DPI and enact any emergency intervention procedure to assess need for supplementation of wild population in captive breeding program.	Trigger: High risk of post-fire debris flow/instream sedimentation event, or pools drying. *Response:* Notify NSW DPI and enact emergency intervention procedure to collect potential broodstock for incorporation into captive breeding program. population when risks decline.

Sampling methods

As recommended by Lintermans *et al.* (2022), an assessment was conducted to determine appropriate sampling methods capable of fulfilling the objectives of the MPMP (i.e. sampling a range of age and size classes and detecting successful reproduction). Previous studies in the upper Murrumbidgee catchment have determined that fyke netting and gill netting were the most effective at detecting the presence of Macquarie perch at a site, with fyke nets being particularly effective at detecting recruitment (i.e. young-of-year or age 1+ individuals) and gill nets effectively capturing adults and subadults (Lintermans 2013, 2016; 2023b). In a multi-method survey across multiple sites and years, fyke nets captured Macquarie perch at 100% of sites where the species was detected and gill nets captured the species at 86% of sites (Lintermans 2016). Consequently, two sampling techniques were used in this project as was the case in the 2024 monitoring: fyke nets and unweighted gill nets (Table 3). Sampling was conducted in March 2025.

Table 3 Summary of recommended monitoring activities, methods and effort as grouped into either routine surveillance monitoring, or trigger-based monitoring (reproduced from Lintermans *et al*. 2022).

Sampling Type	Method	Duration/Level of Effort	Parameters measured	Frequency*	Location/Area
Routine Surveillance Monitoring					
Population monitoring	Gill net; Boat electrofishing; Fyke net; backpack electrofishing. Suite of methods site specific and to be determined upon initial site visit.	12 fyke nets (16 hr soak); 2 gill nets (6 hr soak); boat efish (min 12 x 90sec shots); bp efish (min 5 x 150 sec shots). Effort for each method site specific and to be determined upon initial site visit.	No. of fish; length; visual assessment for parasites; WQ* and stream characteristics; visual threat assessment.	Annually in Autumn (March/April); 1 day/night sampling per site.	Each monitoring site annually (Core and Fringe sites) Sampling to be conducted in Autumn (March/April).
Includes water temperature monitoring	Installed water temperature loggers, continuous recording.	Initial installation using punt, then data downloaded 6 monthly. 3.5 days required for two-person team for each download in addition to download during routine population monitoring.	Water temperature.	Continuous monitoring once installed	Installed at ~20–30 km intervals across the Macquarie Perch Murrumbidgee River monitoring reach, at the following sites: 1. Upstream Yaouk, 2. Bolaro, 3. Middle Dry Plains 4. Murrells Crossing, 5. Downstream Bredbo, 6. Lawler Road, 7. At one reference site.
Population genetics	Fin clipping.	Fin clips to be collected from up to 90 individuals per site. Up to 30 Young of Year and 30 age 1+ individuals to be sampled at each site; and all adults > 300 mm TL to be sampled each year. Samples collected as part of routine population monitoring.	Using SNP data: genetic diversity; effective population size; parentage analysis.	Collected each year, analysed every three years.	Each monitoring site in each sampling year in Autumn (March/April).

The characteristics and deployment of the fyke and gill nets used is the same as used in 5 years of Macquarie perch monitoring 2029 – 2023 and the Recovery Reach monitoring and Snowy 2.0 Macquarie perch monitoring in 2024 and is presented below.

Gill nets: Two braided multi-filament mono gillnets, 50 meshes deep, stretch mesh size of 75 and 100 mm, 33 m length when strung on a float line were set between 3:30 and 4:00 pm and retrieved between 9:30 and 10:00 pm, giving a ~6-hour soak time (Figure 4). The limited soak time was employed to reduce stress or possible mortality of threatened fish species or non-target species such as Platypus *Ornithorhynchus anatinus* and Eastern long-necked turtle *Chelodina longicollis*. Previous research had demonstrated that the 6-hr soak time captured 79 percent of the number of *M. australasica* captured using a 16-hr soak time, and that mortality of both target and non-target species was reduced (Lintermans 2013). One end of each gill net was attached to the bank and the other end was attached to an anchor mid-stream.

Fyke nets: Twelve single-winged fyke nets (12 mm stretch-mesh) were set at each site. Nets were attached to the bank at the cod-end and then set at an angle to the bank facing downstream (Figure 5), with a weight attached to the wing to hold the net securely. The single wing is attached to the centre of the front 'D' of the fyke net. Each fyke net had a 150 mm diameter polystyrene float inserted in the cod end to provide an airspace to prevent mortality of non-target animals such as Platypus and Eastern long-necked turtle. Nets were set between 15:30 and 16:30 hrs and left overnight. Nets were generally retrieved between 07:30 and ~08:30 hrs the following morning, giving a ~16-hour soak time, but at two sites where very large numbers of fish were caught (Sites 2 and 5) net retrieval was not completed until 10:30 and 10:50 hrs respectively.

Figure 4. A gill-net set at Site 1, Murrumbidgee River 2025. (photo Mark Lintermans).

Figure 5. Retrieving a single-winged fyke net set at Site 8, 2023. (From Lintermans 2023b).

Net inspection regime and processing captured animals.

Gill nets were patrolled at approximately hourly intervals after dusk with any captured animals (fish or non-target species) removed from the nets. Platypus *Ornithorhynchus anatinus* were retained in plastic 60 litre bins overnight to prevent recapture, with the bins containing a quantity of leaf litter/grass/tea tree 'nesting' material to allow animals to dry off and minimize stress. Fyke nets were not inspected once set, as they do not enmesh animals (so there is minimal stress to any captured animals) and were retrieved the following morning. Platypus were then released at the point of capture after removing fyke nets.

All fish were removed from the nets, identified, measured (Caudal Fork Length or Total Length, as appropriate) and released at the point of capture. Prior to release all fish were visually inspected for deformities, injuries (e.g. cormorant strike) and external parasites (e.g. *Lernaea cyprinacea*). *Lernaea* presence was scored based on the presence of adults (termed 'worms') or lesions (where *Lernaea* are invisible to the naked eye, have dropped off, or been rejected by the host). A small fin clip was collected from the lower distal edge of the caudal fin of Macquarie perch and preserved in 100% ethanol, and Macquarie perch were weighed to the nearest gram. Fish age/maturity was estimated for all Macquarie perch captured based on fish length and previous experience of Macquarie perch in the upper Murrumbidgee catchment (Lintermans 2013, 2016, 2023b, 2024a, 2024b). The first two age cohorts (young-of-year and age 1+) of Macquarie perch can be confidently estimated for this species (based on fish length), but age of subadults and adults can be problematic as sexes mature at different sizes and

individual growth rates vary. For example, a 190 mm TL fish could be a mature male or a sub-adult female.

Fish Condition

Fulton's condition factor (K) was estimated for each fish where $K = 100*W/L^3$, where W is the total weight of the fish in grams and L is its LCF in cm (Fulton, 1904; Nash *et al*. 2006).

Habitat details

At each sampling site the categorical abundance of a range of habitat measures was recorded (Appendix 2) covering substrate, depth, riparian vegetation types, available cover, mesohabitat type, and flow velocity. Each habitat metric was scored categorically on abundance (abundant, frequent, occasional, rare) with flow recorded as either slow, moderate, or fast. River width was measured with a laser rangefinder (Nikon Forestry Pro II) and depth was measured with a Hondex PS-7 handheld depth sounder.

Water quality

Routine water quality measurements were taken at each site. pH was measured with Machery-Nagel test strips, conductivity and surface water temperature was measured with a Eutech Expert CTS meter; dissolved oxygen was measured with an EcoSense ODO200 meter; turbidity was measured with a turbidity tube. Water quality was unremarkable at all sites (Appendix 3).

Site suitability

Eight of the nine sites sampled are established fish monitoring sites that have been previously sampled. As noted earlier, the previous Site 1 (which was a new site established in 2024) proved challenging to access a suitable length of contiguous stream to allow adequate separation of nets. Consequently Site 1 (the upstream fringe site) has been moved downstream and is a new location for this monitoring program but has been previously sampled in previous projects (Lintermans 2023b, 2024b).

Results and Discussion

As noted earlier, not all SGMP Objectives are evaluated as part of this monitoring report.

Overall sampling results

A total of 648 individuals of eight species of finfish were sampled or observed with the native Macquarie perch the most abundant species followed by the alien Carp *Cyprinus carpio*, then Mountain galaxias *Galaxias olidus* (Table 4). No other species recorded had an abundance >6 individuals. The only other native species captured was Murray cod *Maccullochella peeli* (Figure 6). Murray Cod have been stocked into the upper Murrumbidgee since 2010 (Lintermans 2020, 2023b). It is unknown whether this Murray Cod is slow growing stocked fish or an offspring of the fish previously stocked. This species had not previously been recorded upstream of the ACT until the stocking program commenced (Lintermans 2020, 2023b).

Figure 6. A 389 mm Murray cod from site 8 (photo Dale Campbell).

Table 4. Snowy 2.0 Macquarie perch Monitoring: Fish captured (or observed) in 2025.

Common name	Macq. perch	Mount. galax.	Murray cod	Rainbow trout	Brown trout	Carp	Gold fish	***Gambusia***	Total fish
Sites									
1	-	3	-	-*	-	-	-	-	3
2	183	6	-	-	-	-	-	-	189
3	22	5	-	1	2	-	-		30
4	15	1	-	-	-	-	-	obs	16
5	125	-	-	-	2	45	2		172
6	53	-	-	-	-	63	-		116
7	4	-	-	-	-	45	1	obs	50
8	31		1	-	-	22	1		55
9	1	-	-	-	-	14	2	obs	17
TOTAL	**434**	**15**	**1**	**1**	**5**	**187**	**6**		**648**

*Trout of unknown species observed

In addition to Carp and Goldfish *Carassius auratus*, another two alien species were captured, Rainbow trout *Oncorhyncus mykiss,* and Brown trout *Salmo trutta*, with Brown trout being more abundant than Rainbow trout. An additional alien species Eastern gambusia *Gambusia holbrooki* was observed at three sites (Table 4) but has previously been observed at all sites downstream of Site 2. Macquarie perch were by far the most abundant fish species recorded in 2025 (Figures 7-8) with more than twice as many captured than Carp. Macquarie perch were captured at eight of the nine sites, only being absent from the upstream 'fringe' site 1. Of the other native species, Mountain Galaxias was recorded at four sites, and Murray cod at one. The alien species Carp was recorded at five sites and Goldfish at four sites, with both of these species recorded only in the mid and lower sites. Neither species has ever been recorded upstream of Site 2 (Lintermans 2023b). relatively few trout of either species was captured in 2025 (Table 4).

Seven non-fish, non-target species were captured during the sampling comprising 2 mammals, 2 birds, 1 reptile and 2 crustaceans. Freshwater prawn *Macrobrachium australiense* was by far the most numerous non-fish non target species collected and were collected at all but the three most upstream sites (Table 5). The other crustacean Yabby *Cherax destructor* was collected at all sites. Platypus *Ornithorhynchus anatinus* were commonly observed or collected, with Rakali/Water rat *Hydromys chrysogaster* infrequently observed and not captured. The Eastern long necked turtle *Chelodina longicollis*, recently proposed for listing under the Environment and Biodiversity Conservation Act 1999 was caught at four sites, all in the lower portion of the sampled reach.

Table 5. Non-target non-fish species captured or observed during the 2025 Macquarie perch monitoring.

Common name	Eastern Long neck turtle	Freshwater prawn	Yabby	Platypus	Rakali/ Water rat	Little Black cormorant	Australasian Coot
Sites							
1	-	-	3	2 + 2 obs	-	-	-
2	-	-	6	3	-	-	-
3	-	-	7	4 +	-	1	1
4	-	1	5	2 obs	-	-	-
5	-	1	14	3	-	-	-
6	5	51	17	-	-	-	-
7	1	151	1	-	obs	-	-
8	5	84	13	1	obs	-	-
9	1	359	13	1	obs	-	-
Total	**12**	**647**	**79**	**15 +**		**1**	**1**

MPMP Objectives 1, 2 & 3 - Population persistence, trajectory and status

Abundance and distribution

Macquarie perch were in exceptionally high abundance with 434 individuals captured, and were recorded at eight of the nine sites on the Murrumbidgee River, including all of the core sites and the lower fringe site. The only fringe site where the species was absent was at the most upstream site approximately 7 km downstream of Yaouk (Table 4) where the species is known to be absent (Lintermans 2023b, 2024). 2025 was the second sampling of Site 4 and site 5 in the middle of the Recruitment Reach, with these sites not part of the 2019–23 recruitment monitoring (Lintermans 2023b). Site 5 recorded record numbers of Macquarie perch, more than double that recorded in 2024 (Lintermans 2024a). Site 2 also returned record numbers of Macquarie perch in 2025 with the abundance being more than double the previous record. At Site 4, downstream of Bolaro, the numbers recorded in 2025 were similar to that of 2024 and were in relatively low abundance. Similarly, Site 3 also returned relatively low to moderate numbers of Macquarie perch, with 22 individuals captured. Macquarie perch abundance at Site 3 is variable between years with previous samplings of this site in

2021, 2022, and 2024 returning 32, 7, and 4 individuals respectively (Lintermans 2023b, 2024a). Abundance in the downstream end of the recruitment reach was relatively low in 2025, with Site 7 recording only 4 Macquarie perch compared to 0, 3, and 4 in previous sampling in 2019, 2023, and 2024 respectively (Lintermans 2023b, 2024a). Site 8 recorded 31 Macquarie perch in 2025 which is close to the previous long-term average of 27 individuals in annual sampling at this site in 2029-2023 (Lintermans 2023b). The catch was up on the 2024 result of 14 individuals (Lintermans 2024a). Good abundances of Macquarie perch have previously been recorded at this site in in years of higher or average flow and low abundances during drought years (2019, 2020) (Lintermans 2023b) — 2025 was not a drought year in the upper Murrumbidgee but flows were low.

A large number of young-of-year (age 0+) individuals was the highlight of the sampling in 2025 (Figure 7) with record numbers of this age class captured at sites 2, and 5. Unusually large numbers of age 1+ individuals were also captured at some sites.

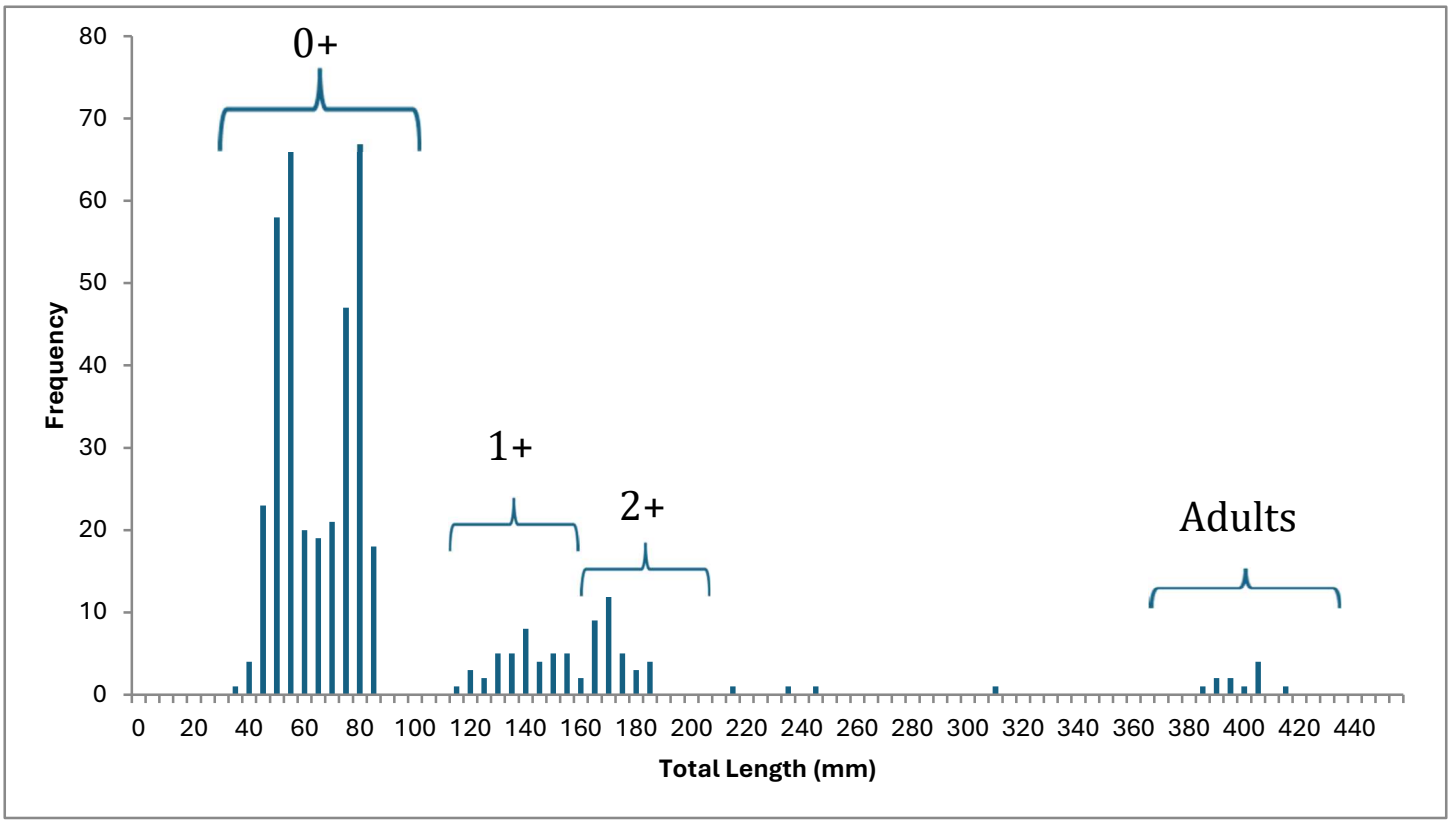

Figure 7. Captures by year of Macquarie perch from the Murrumbidgee River in 2025. Annotations above bars indicate age classes (years of age) of fish.

The abundance of age 1+ individuals in 2025 was low at many sites, as has been regularly found in past sampling (Lintermans 2023b, 2024a, 2024b). While Age 1+ individuals were detected at all sites within the Recruitment Reach, numbers were low at all but three sites (Sites 2, 5, and 6: the sites that had reasonable production of Age 0+ fish in 2024)(Lintermans 2024b)). Even following reasonable production of young-of-year, the abundance of age 1+ individuals is often low (Lintermans 2013, 2023b, 2024). The reason for poor survival from young-of-year to age 1+ is unknown. The capture of 29 Age 1+ individuals at Site 2 was surprising given that only 39 Age 0+ fish were caught at this site the previous year (Lintermans 2024b). This suggests that either the sampling in 2024 was not particularly efficient, or that survival of the age 0+ fish has been above average.

The capture of a single Macquarie perch at the most downstream site in the study (Numeralla Junction to Bredbo Falls reach: Site 9) repeats the detection of this species at this site in 2024 (Lintermans 2024b). Individuals have been occasionally collected between Angle Crossing (the ACT/NSW southern border) and the Numeralla River junction, (Lintermans 2016; Beitzel *et al*. 2019; Lintermans 2023b, unpubl. data; ACT Government unpubl.data), the collection of YOY at this site in consecutive years indicates that there is a small breeding population present, even though the site and adjacent reaches are significantly impacted by sand.

One of the individuals captured at Site 3 was pit-tagged fish that had originally been collected between Site 7 and Site 8 in late 2024 and then subsequently released at Site 3 (Luke Pearce pers. comm.).

Figure 7. A group of Macquarie perch young-of-year from Site 2 from a fyke net (Photo Mark Lintermans).

Figure 8. A large Macquarie perch (386 mm TL) captured in a 75 mm mesh gill net at Site 2. (photo Dale Campbell).

Population trajectory

As different sites have been sampled each year since 2019, a standard comparison of trajectory is difficult until multiple years of results from the same sites is available. It has also been shown that many of the individual sampling sites within the upper Murrumbidgee Recruitment Reach are fragmented with little or no genetic interchange between sites (Pavlova et al. 2024). Such fragmentation means that individual site trajectories are likely as important than the population trajectory as a whole. However, the combined abundance of Macquarie perch sampled in 2025 was by far the highest on record for the Murrumbidgee River, with the previous highest tally of 197 caught in 2021 (from a sampling of five sites) (Lintermans 2021, 2023b). The record Macquarie perch abundance was driven by results from Site 2 and Site 5 which both recorded >100 Macquarie perch and contributed 71 percent of the survey total. No site has recorded >120 individuals in any previous sampling by the author in ~ 30 years of sampling the upper Murrumbidgee River (Lintermans 2016, 2023b, 2024a, 2024b). Abundance at Site 2 was much higher than the previous high (109 individuals in 2021) for this site in sampling since 2020 (Lintermans 2023b, 2024a, 2024b). These record catches at Site 2 and Site 5 in March 2025 were followed by even larger catches of 299 and 208 Macquarie perch at Site 2 and Site 5 respectively in April 2025 (Lintermans and Campbell 2025), highlighting what was obviously an amazing year for the species in 2025.

Site 6 also had high abundance, approaching the 66 recorded in 2024, and notably higher than long-term average of 30 Macquarie perch per night, (University of Canberra unpublished data, see Broadhurst *et al*. 2023). Gill nets are not used in the University of Canberra sampling.

A comparison in the abundance of Macquarie perch at Sites 2 and 8 using just the fyke net data collected with the identical sampling methodology and effort since 2019 demonstrates year-to-year fluctuation in raw abundance by age class, with the majority of this fluctuation driven by the abundance of young-of-year and age 1+ cohorts (Figure 9) with the first 2 cohorts only shown in Figure 10. (Lintermans 2023b, 2024b). The high totals at both Sites 2 and 5 were driven by exceptional abundance of age 0+ individuals in 2025 (Figures 9 and 10).

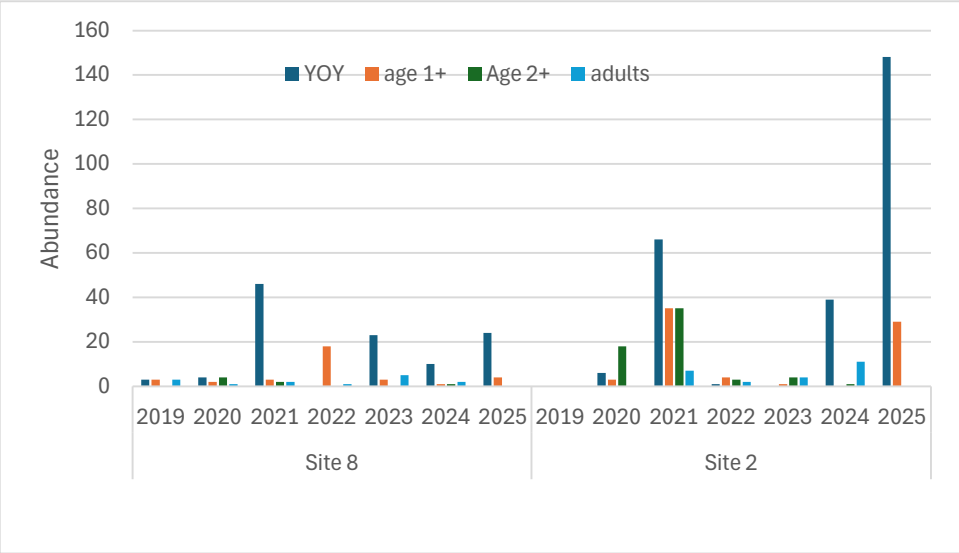

Figure 9. Captures by year of Macquarie perch (all age classes) in fyke nets at sites 8 and 2 between 2019 and 2025.

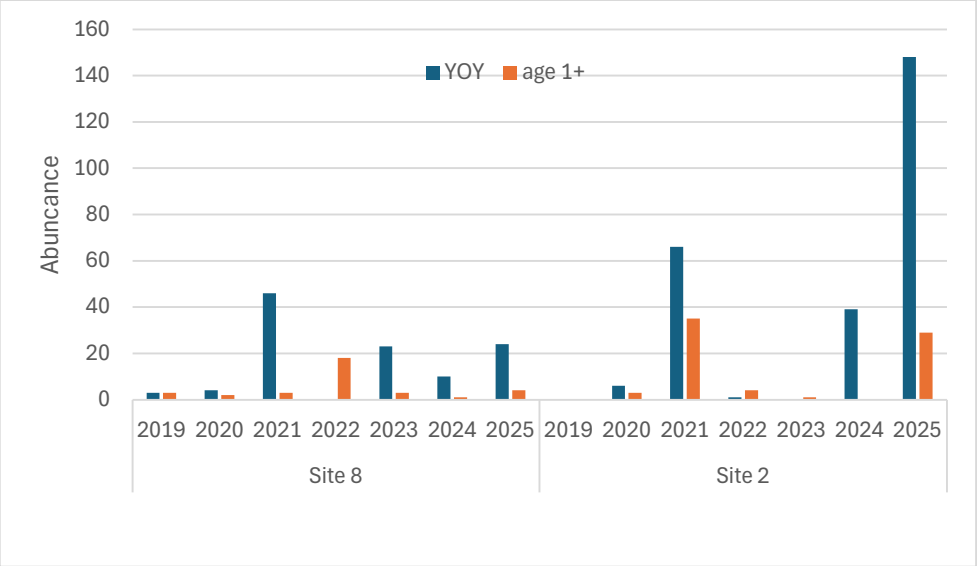

Figure 10. Captures by year of Macquarie perch young-of-year (YOY) and age 1+ in fyke nets at sites 8 and 2 between 2019 and 2025.

Population abundance and site trajectory is highly influenced by recruitment dynamics, which has been variable at a site and sub-reach level since 2019. Total recruitment failure (i.e. absence of young-of-year) has been documented twice (in 2022 and 2023) over the last 5 years at Site 2 (Figure 10), with sampling at two other sites in the upper end of the recruitment reach also demonstrating a failure to produce YOY in 2023 (Lintermans 2023b). Failure to produce young-of-year subsequently results in an absence of age 1+ individuals the following year (Figure 10), with this then flowing on to the adult population in subsequent years (a 'recruitment shadow'). A similar situation occurred in the enlarged Cotter Reservoir in the ACT when a recruitment failure for 3 consecutive years (2014–2016) led to a subsequent substantial decline in the adult population (Broadhurst *et al*. 2018. 2023). The recruitment failure in the Cotter resulted from inundation by a rising reservoir of previous spawning sites, and an inability to pass additional upstream barriers until the reservoir reached full supply level. The Macquarie perch recruitment failure in the most upstream sites within the upper Murrumbidgee recruitment reach was likely a result of high flows washing out eggs or damaging larvae (Tonkin *et al*. 2017; Lintermans 2023b), but it is too early to see how this repeated recruitment failure has affected adult abundance at Site 2. Adults are predominantly captured in gill nets rather than fyke nets (Lintermans 2013, 2016). Estimates of effective population size (the number of breeding adults) derived from genetic investigations are likely to give a better indication of the number of adults at individual sites (see Pavlova et al. 2024), with genetic analysis of collected finclips scheduled for after the 2026 sampling (i.e. 3 years of monitoring, Lintermans et al. 2022). The high abundance of young-of-year at Site 2 in 2024 suggested that high age 1+ abundance would occur in 2025 (Lintermans 2024b) and this was the case, with higher abundance of age 1+ fish recorded in 2025. Similarly, the high abundance of Age 0+ fish at Sites 2 and 5 in 2025 is expected to result in high abundance of the Age 1+ cohort at these sites in 2026.

The species continues to be recorded at sites where it has regularly been recorded in the past, but there are sites with patchy records of occurrence (Site 7), however a newly established site just upstream of Site 7 (not part of the Snowy 2.0 monitoring program) and the reference site downstream (Site 8) recorded reasonable abundance of most age classes in 2023 and 2024 (Lintermans 2023b, 2024) suggesting that the patchy occurrence at Site 7 is a local, rather than sub-reach issue.

Recent genetic characterisation of the upper Murrumbidgee population in the recruitment reach gives cause for considerable concern with effective population size (N_e) at upstream sites being alarmingly low (Pavlova *et al.* 2024). With N_e of <10 in some years in several upstream sites, low genetic diversity, high inbreeding, and an apparent lack of connectivity to downstream sites, the local site populations in this upstream sub-reach appear to be on a knife edge. With recreational fishing still capturing adults at these sites, and a potential 'recruitment shadow' from 2022 and 2023 in play, the future of the upstream sub-reach is insecure. The downstream sub-reach is more secure with higher N_e, greater (though still impoverished) genetic diversity, and some connectivity apparent (Pavlova *et al*. 2024). Genetic rescue of the upper sub-reach commenced in 2020 with fish introduced to a limited number of sites from Cataract Reservoir (Pavlova et al. 2024). In 2025 further within-population genetic rescue commenced with a total of 52 individuals moved between upper Murrumbidgee sites including releases at Site 2, Site 3 and a site immediately upstream of Site 2 (Lintermans and Campbell 2025).

Reproduction

Macquarie perch generally breed in in October to November in the upper Murrumbidgee and so sampling in February to April is expected to return a good representative sample of young-of-year fish aged approximately 3–5 months of age and between 50–100 mm total length (Bylemans *et al*. 2017; Broadhurst *et al*. 2018, 2019, 2023; Lintermans 2016, 2023a,b, 2024; Lintermans *et al*. 2013).

Young-of-year (Age 0+) Macquarie perch were captured in all core sites as well as in the downstream fringe site (Site 9) (Figure 11; Table 6). Young-of-year comprised 79% of all Macquarie perch captured in 2025, with Age 1+ comprising 14 % and small, medium and large adults 7% (Table 6).

Compared to 2024, Age 0+ has remained at essentially the same percentage (80% in 2024) with Age 1+ increasing (7% in 2024) and subadults and adults decreasing (17% in 2024).

Table 6. Estimated age composition (based on total length) of Macquarie perch captured (with both fyke and Gill net) from upper Murrumbidgee River in 2025.

Site	Age 0+ (<100 mm)	Age 1+ (100-~170 mm)	Subadults/ small adults (195-~260 mm)	Medium adults (261-350 mm)	Large adults (>350 mm)
2	148	29	1	1	4
3	10	1	7	-	3
4	8	1	6	-	-
5	116	8	1	-	-
6	37	15	-	-	1
7	2	1	1	-	-
8	24	4	-	-	3
9	1	-	-	-	-
TOTAL	**345**	**60**	**17**	**1**	**11**

Total length as an age surrogate for the young-of-year and age 1+ cohorts is readily determined and widely applied for Macquarie perch (Ebner and Lintermans 2007; Broadhurst et al. 2013, 2023; Lintermans 2013, 2016, 2023b, 2024; Pavlova et al. 2024) with otolith ageing confirming the validity of these length-based age estimates (Tonkin et al. 2014, 2017; Todd and Lintermans 2015). It is clear that recruitment has occurred at all eight sites where Macquarie perch were caught in 2025 after successful spawning in 2024. Home range or movement of young-of-year is not known but could reasonably be assumed to be relatively limited. Consequently, the presence of young-of-year at sites could be assumed to represent local site recruitment, although some downstream displacement of larvae is likely. Length at age for older cohorts is more variable and varies with annual flow and other factors (Tonkin et al. 2014, 2017) and so the estimated ages of fish > 170 mm total length is more problematic. However, as a broad indicator of coarse population structure (i.e. the presence of a range of adult and subadult sizes) such length-based population structure estimates are useful.

Condition

Fulton's condition factor (K) for Macquarie perch varied from 0.739– 2.560 (mean = 1.295, sd = 0.165, n = 425) (Figure 12).

Age classes older than 0+ (young-of-year (YOY)) tended to have higher K values (Figure 12) but in contrast to 2024 results, the lowest values of K were not always associated with YOY individuals (Figure 13). This has occurred because of a large disparity in the size of YOY at two sites. At site 2 the YOY were notably longer than at other sites and at Site 5 YOY were notably shorter. Whether this size discrepancy represents different times of spawning or different growth rates is unknown.

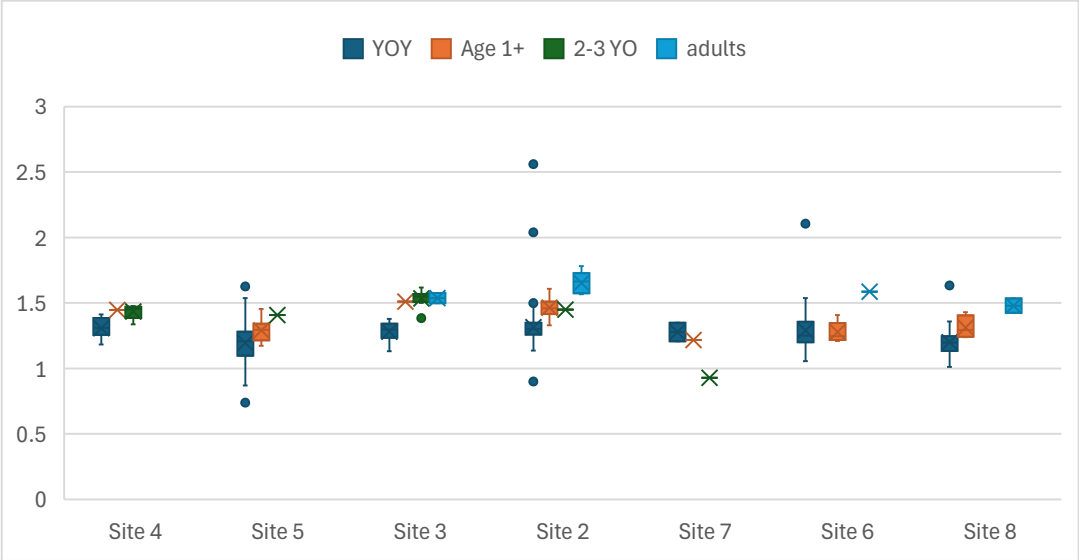

Figure 12. Range, median, and upper and lower quartiles for Fulton's condition factor (K) of Macquarie perch (all sites combined) for young-of-year, age 1+, age 2+, and adults (large and small combined) captured in 2025.

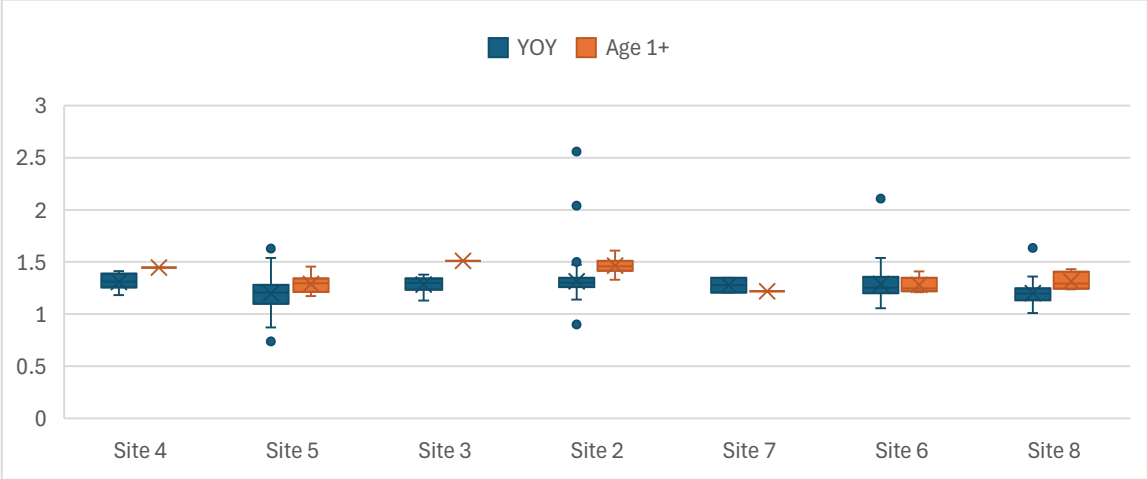

Figure 13. Range, median, and upper and lower quartiles for Fulton's condition factor (K) of age 0+ and Age 1+ Macquarie perch captured in 2025.

As noted in the 2024 Macquarie perch monitoring report (Lintermans 2024a), to meaningfully compare the condition of individuals of different sizes, the condition index used must remove the effects of growth on the weight-length relationship, with such standardization leading to equal mean values for different age classes (i.e. growth effects have been accounted for) (Peig and Green 2010). Fulton's K is known to vary with fish length and relies on a cubic relationship of fish length to weight, with most species known to have the exponent of the weight-length relation deviating from 3 (Cone 1989; Froese 2006; Wuenschel *et al*. 2018). The measure of central tendency in the box plots of Fulton's K (Figure 13) clearly shows that young-of-year have different values to other age classes. Fulton's K is not commonly used to evaluate body condition across the size range of Macquarie perch, but is sometimes used for adults (Broadhurst *et al*. 2023) and as with many fish species, would be expected to vary across the reproductive season (as gonads enlarge, and then empty with spawning) and vary between sexes (with females allocating higher investment to gonad weight than males at certain times of the year (Appleford *et al.* 1998). The trend for clearly lower values in Fulton's K for young-of-year Macquarie perch from most sites (Figures 12 and 13) suggests Fulton's K is potentially of limited value for very small individuals and cannot be directly compared with larger fish. However, it may be useful for comparing body condition of young-of-year between sites or across years.

Fish health

Although fish 'health' is not specifically mentioned in any of the 6 MPMP objectives, the collection of information from a 'visual inspection for parasites' is specified in the population monitoring requirements and so is reported here. The external parasite *Lernaea* was not detected on the Macquarie perch at Site 4 but was present on Macquarie perch from all other sites where mor than a single fish was caught (i.e. excluding sites 1 and 9) (Table 7). Recent research has confirmed that the *Lernaea* present in the mid to lower Murrumbidgee River is *Lernaea cyprinacea* (Zhu *et al*. 2021) and it is assumed that this is the species recorded in the current project. Carp and Goldfish are major hosts for *Lernaea* in the upper Murrumbidgee catchment (Robinson 1982, Lintermans 2022, 2023b, 2024b). *Lernaea* prevalence was low or absent on the most upstream and some middle reach sites (Sites 2–4) and highest at the lower-mid and lower sites (Sites 5–8). The mean *Lernaea* intensity on Macquarie perch in the Murrumbidgee River was ≤2 at all but two sites (Sites 3 and 8), with most fish having a single lesion or worm (Table 7). However, at Site 8 approximately one third of individuals had more than 2 lesions or worms with one fish having 9 (Table 7). At sites 7 and 8 approximately half the Macquarie perch captured had evidence of *Lernaea* infection. Lernaea prevalence was lower in 2025 than in 2024 (Lintermans 2024b). Note that *Lernaea* prevalence and intensity may be higher than reported here as gill openings are not inspected for the parasite in the current study, and this location is a known common point of *Lernaea* attachment.

Other species that had *Lernaea* present were Mountain galaxias, Murray cod, Carp, Goldfish, Rainbow trout and Brown trout (Table 8) with the majority of affected individuals found in mid to downstream sites (Sites 5–9). All fish species caught had some presence of *Lernaea* in the current 2025 which is a rare occurrence ((Lintermans 2022, 2023b; 2024a, 2024b).

The pattern of greatest *Lernaea* prevalence and intensity at downstream sites repeats that found in previous sampling since 2019 and other Macquarie perch sampling in the Upper Murrumbidgee in 2024 (Lintermans 2022, 2023b, 2024a, 2024b).

Table 7. Prevalence (number and percentage) and intensity of *Lernaea* infection on Macquarie perch by sampling site where Macquarie perch were captured in 2025.

Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Total No. Macquarie perch captured	*0*	183	22	15	125	53	4	31	1
Prevalence (*No. fish with lesions/worms*)		8 (4%)	2 (9%)	0	31 (25%)	25 (47%)	2 (50%)	17 (55%)	0
Mean load (*No. lesions/ worms per affected fish*)		1	4	0	1.1	1.2	1	2.2	0
Max load (*lesions/worms per fish*)		1	6	0	2	3	1	9	0
Individual Load (Lesion/worm count on individuals)		1, 1, 1, 1, 1, 1, 1, 1	6, 2		1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 1, 1	3, 1, 1, 1, 1, 2, 1, 2, 1, 1, 1, 1, 1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1	5, 9, 1, 1, 1, 3, 1, 1, 2, 1, 3, 1, 1, 3, 1, 3, 1	

Table 8. Prevalence (number and percentage) and intensity of *Lernaea* infection on other fish species by sampling site in 2024. Only species which recorded *Lernaea* are included.

Site	**1**	**2**	**3**	**3**	**5**	**6**	**7**	**8**	**9**
Mountain galaxias (total no. caught)	3	6	5	1	0	0	0	0	0
No. Mountain galax with lesions/worms	0	0	1 (20%)	0					
Mean No. lesions/worms per affected Mountain Galax	0	0	1	0					
Murray cod (total no. caught)	0	0	0	0	0	0	0	1	0
No. Murray cod with lesions/worms								1 (100%)	
Mean No. lesions/worms per affected Murray cod								5	
Carp (total no. caught)	0	0	0	0	45	63	45	22	14
No. Carp with lesions/worms					5 (11%)	8 (13%)	6 (13%)	1 (5%)	0
Mean No. lesions/worms per affected Carp					1	1	1.3	1	0
Goldfish (total no. caught)	0	0	0	0	2	0	1	1	2
No. Goldfish with lesions/worms					0	0	1 (100%)	1 (100%)	0
Mean No. lesions/worms per affected Goldfish					0	0	2	1	0
Brown trout (total no. caught)	0	0	2	0	2	0	0	0	0
No. Brown trout with lesions/worms			2 (100%)		2 (100%)				
Mean No. lesions/worms per affected Brown trout			4		4.5				
Rainbow trout (total no. caught)	0	0	1	0	0	0	0	0	0
No. Rainbow trout with lesions/worms			1 (100%)						
Mean No. lesions/worms per affected Rainbow trout			3						

MPMP Objective 6 - Threat status

The greatest threat to the Macquarie perch population is the lack of adequate flows in the river following the construction of Tantangara Dam in 1961. The current flow regime has long been recognized as inadequate (Pendlebury et al. 1997; Lintermans 1998, 2002, 2023b; Snowy Scientific Committee 2010) with fish (a major biotic value) severely impacted. One fish species has become locally extinct in the Murrumbidgee upstream of the ACT (Lintermans 2023c) and Macquarie perch is on a knife-edge, with the population fragmented, genetically compromised, and with few breeding individuals remaining in upstream sites (Pavlova et al. 2017, 2024). The critical threat that is driving the genetic problems is fragmentation by instream barriers which do not drown out as a result of insufficient river flow resulting from flow diversion at Tantangara Dam. Currently Tantangara Dam diverts approximately 93% of the pre-impoundment river flow (Commonwealth of Australia DCCEEW 2024a, NSW DCCEEW 2024). The maximum flow releases delivered since 2012 to the Murrumbidgee River from Tantangara are 1500 ML/day, which is insufficient to facilitate Macquarie perch movement between sites (The genetics show this: Pavlova et al. 2024). Flows are governed by the Snowy Water Inquiry Outcomes Implementation Deed (SWIOID) with the Commonwealth Government recently announcing a review of the SWIOID to be completed by mid-2027. Unless more flows are provided from Tantangara to the upper Murrumbidgee river following this review, the future for the Macquarie perch population is grim.

The rapid, visual assessment of potential threats did not reveal any critical new threats to Macquarie perch at any site, but the existing and continuing threats identified in 2024 still relevant. Uncontrolled stock access are feral goat access to the river or immediately adjacent tributaries at a number of sites in in the upper Murrumbidgee is resulting in streambank and fringing reedbed degradation. Feral goat grazing has almost totally denuded fringing reedbeds at Site 6 (Figure 14) and goat control is urgently needed at this site. Fringing reedbeds provide shade, habitat complexity, and cover for both juvenile and adult Macquarie perch (Lintermans 2012). Bank degradation results in sedimentation of the stream which has impacts on stream depth and spawning site integrity. Controlling stock and feral animal access facilitates the establishment and retention of macrophyte beds (both submerged and emergent) While some landholders have recently completed riparian fencing to control stock access, many properties haven't. Further management actions to control stock access to the river; the erection of riparian fencing; and feral animal control along the Murrumbidgee mainstem would be of benefit.

Figure 14. Bank degradation and uncontrolled grazing of reedbeds at Site 5 in March 2025. (photos Mark Lintermans).

The habitat in river reaches upstream and downstream of Site 9 was significantly impacted during and following the 2019-20 fires, with parts of the Murrumbidgee and tributary Numeralla catchment severely burnt. Subsequent rainfall then delivered significant sediment loads to the Murrumbidgee, with sand accumulation continuing to smother habitat. The presence in both 2024 and 2025 of an isolated subpopulation of Macquarie perch with recruitment at Site 9 highlights the need for active habitat protection and rehabilitation measures in upstream reaches. There has been no recent fire activity at any of the sites, and no apparent loss of native riparian vegetation or instances of significant new erosion activity at the sites. It should be noted that the significant reduction of alien riparian species at several

sites within the recruitment reach as a result of coordinated willow control in recent years (Lintermans 2023b) has been of significant value, but follow-up control to remove individuals that were not successfully controlled is required.

As noted in 2024, the development of the rural residential subdivision immediately adjoining the river on the eastern side of Site 9 downstream of Bredbo will add further recreational pressure to the Murrumbidgee River but also provides an opportunity to build awareness of the threats facing the river and its fauna. A focus on recreational fishing rules and regulations, and signage about Macquarie perch and other threatened fauna would be beneficial, along with signage or information about the threat posed by Redfin perch.

No new pest fish incursion (Redfin) or range expansion (Carp, Goldfish, Eastern gambusia) was detected by the sampling reported here. The confirmed reports of Redfin perch *Perca fluviatilis* in 2019 further downstream in the reach between Angle Crossing and approximately Michelago (Beitzel *et al*. 2019) are still of concern as the origin of the individuals caught in 2019 remain unknown (i.e. whether they were from illegal releases directly into the Murrumbidgee River or are they the result of downstream displacement from farm dam populations). Additional pest fish incursion status information will be provided by the ongoing Snowy 2.0 eDNA sampling, which is not part of this monitoring program, but this program does not sample farm dams. The capture of a Murray cod at Site 8 is the most upstream verified record of this species in the upper Murrumbidgee and now documents the presence of this species within the recruitment reach. The addition of this large predatory species to the Recruitment Reach is unwelcome, and should the species become established in the Recruitment Reach it will all size classes undoubtedly result in predation of a range of Age classes of Macquarie perch (particularly Age 0+ and Age 1+).

Trigger Action Response Plan (TARP) trigger evaluation

There are six identified TARP triggers in the Macquarie Perch Monitoring Plan:

A Redfin perch incursion

B Decline or loss of recruitment

C Decline in relative population abundance

D Decline in Fish condition or fish kill/mortality

E Genetic decline

F Occurrence of fire or drought

Of the six identified TARP triggers, items B, C, D, and E require baseline or trend data to determine if 'decline' has occurred. As this is the second monitoring year completed for Macquarie perch at several sites it is too early to robustly ascertain whether such declines have occurred, or triggers are met.

Trigger A (Redfin perch incursion) has not been detected since the isolated individuals were captured in 2019 well downstream of the Monitoring reach. No Redfin perch have been detected since 2019, and there are no records from the monitoring reach. Hence, Trigger A has not been met. However, the first detection of predatory Murray cod within the Recruitment Reach is of concern.

Trigger B (Decline or loss of recruitment) has been addressed earlier in this report and there is no evidence of a recruitment decline, in fact recruitment was at record levels in 2025.

One issue that will seriously hamper future TARP investigations for Trigger B is the knowledge gap around the location of spawning sites in the recruitment reach. One of the required activities under TARP Trigger B is to 'investigate spawning and egg hatching' to establish the life stage where the recruitment failure may be occurring (Lintermans *et al.* 2022). Spawning sites are only known from one sub reach (downstream of Sites 7 and 8 (Bylemans *et al.* 2017; van der Muelen *et al.* 2023) with a broader search for spawning locations in 2023 (at Sites 2, 3, 6 and 8) failing to locate spawning riffles (Lintermans *et al*. 2024) with a similar but higher intensity search in 2024 yet to be reported on (Campbell unpub. data). Locating spawning locations across the recruitment reach is a priority if future TARP investigations into recruitment failure are to be focused and deliver timely results.

Trigger C (Decline in relative population abundance) has also been addressed earlier in this report and there is no evidence of a whole of population decline. Site abundance tend to fluctuate significantly between years and so detecting a statistical decline will take further years of monitoring.

Trigger D (Decline in Fish condition or fish kill/mortality) has not been met as no fish kills have been reported or observed. Fish condition measures are still in the baseline phase of data collection and so detecting a statistical decline will take further years of monitoring.

Trigger E (Genetic decline) has already been met based on the genetic analysis of samples collected between 2019 and 2023 with low connectivity between sites, low effective population size, low genetic diversity, and high inbreeding detected, particularly at Sites 2, 3, and 6 (Pavlova et al. 2024). Sites 4 and 5 were not sampled in this genetic study, so their genetic status is unknown but can be readily inferred from results at adjacent sites. Initial results from genetic rescue of the upper Murrumbidgee Macquarie perch population by introducing individuals from the highly genetically diverse Cataract Reservoir population commenced in 2020 with promising initial results detected (Pavlova et al. 2024). As a consequence of the poor genetic diagnosis and lack of instream connectivity by Pavlova et al. (2024), a pilot project to manually mix fish between sites commenced in 2025 (Lintermans and Campbell 2025) and is expected to be extended for another 2 or 3 years.

Trigger F (Occurrence of fire or drought) has not been met in 2024 or 2025 and there has been no significant fire since 2019-20, and similarly no drought since that of 2017–2019.

Conclusion and recommendations

The 2025 Snowy 2.0 Macquarie perch monitoring found there were no new or exacerbated threats or other triggers to require TARP intervention. However, the inadequate flow releases from Tantangara Dam are a clear long-term threat to the population. The abundance of Macquarie perch in the sampling program is at a record high. The high Macquarie perch abundance in 2025 is almost totally driven by an exceptional recruitment of Age 0+ fish at two sites. Good numbers of Age 1+ fish at two sites reflects an above average number of Age 0+ fish caught in 2024. This high recruitment of Age 0+ fish in 2025 will hopefully translate into abundant Age 1+ fish in 2026.

Recommendations

- The Snowy 2.0 monitoring program for Macquarie perch should be repeated in 2026 using the same sites and methodology as used in 2025.
- To focus future TARP investigations into future potential recruitment failures, locating spawning locations across the recruitment reach is a priority if future TARP investigations are to be focused and deliver timely results.
- The impacts of the current inadequate environmental flow releases from Tantangara Dam on the Macquarie perch population in the upper Murrumbidgee need to be addressed in the upcoming review of the Snowy Water Inquiry Outcomes Implementation Deed (SWIOID).

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Appendix 1. Photos of field sampling sites in 2025.

Site 1

Appendix 1 (continued).

Site 2

Appendix 1 (continued).

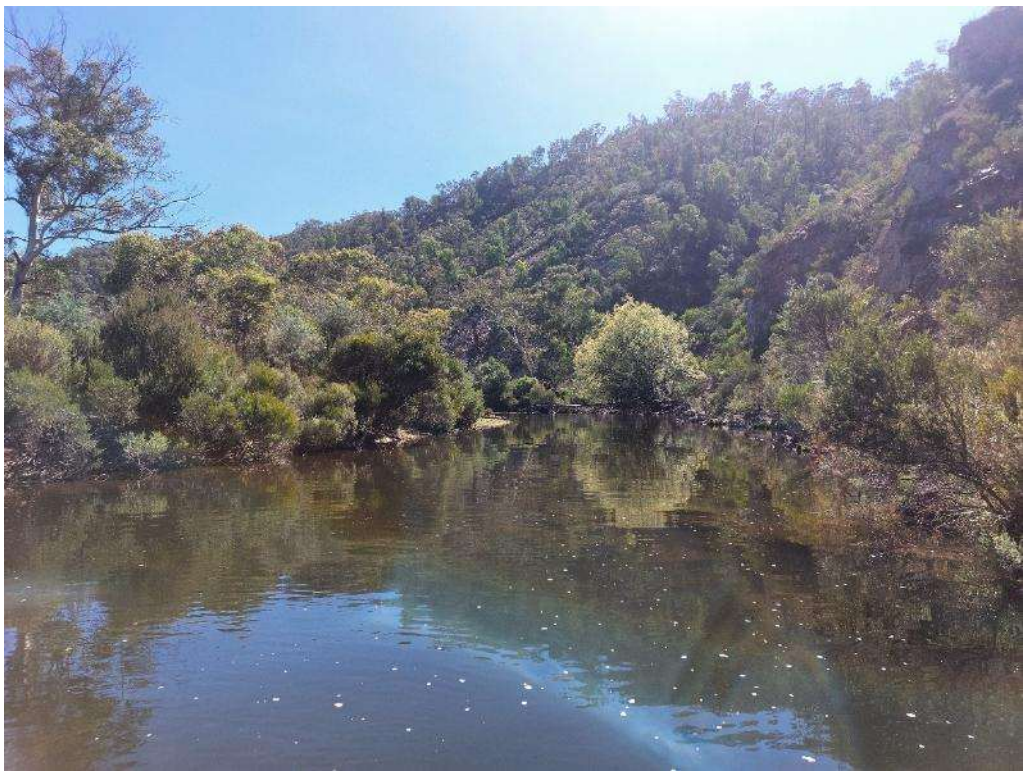
Site 3

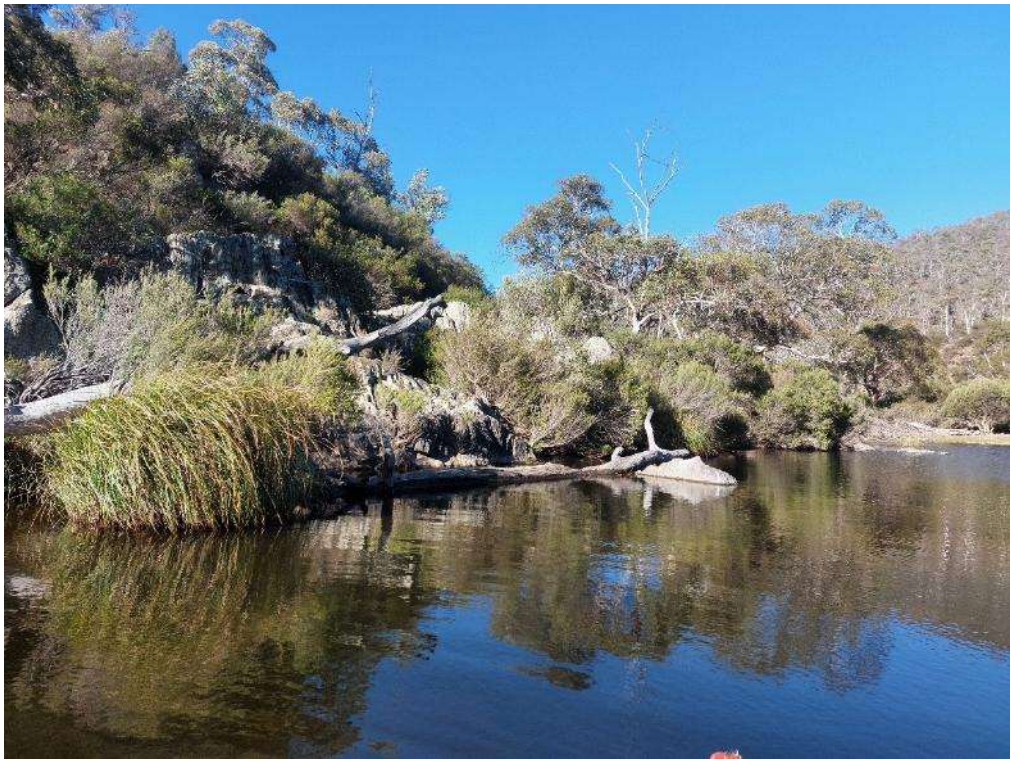
Appendix 1 (continued).

Site 4

Appendix 1 (continued).

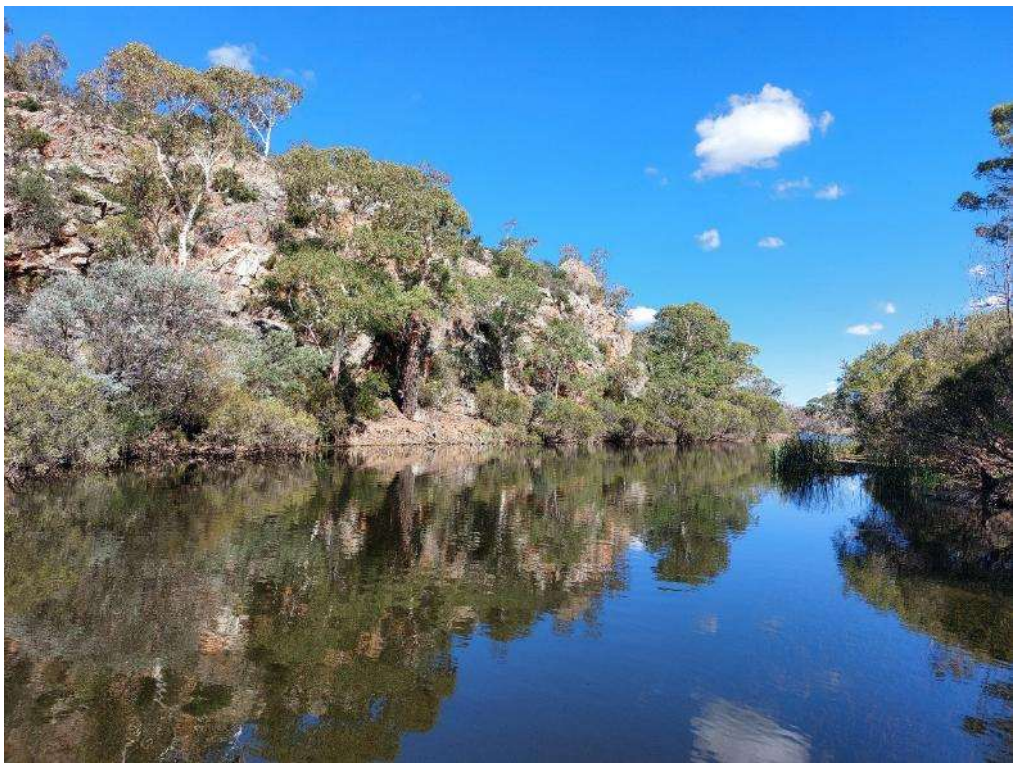
Site 5





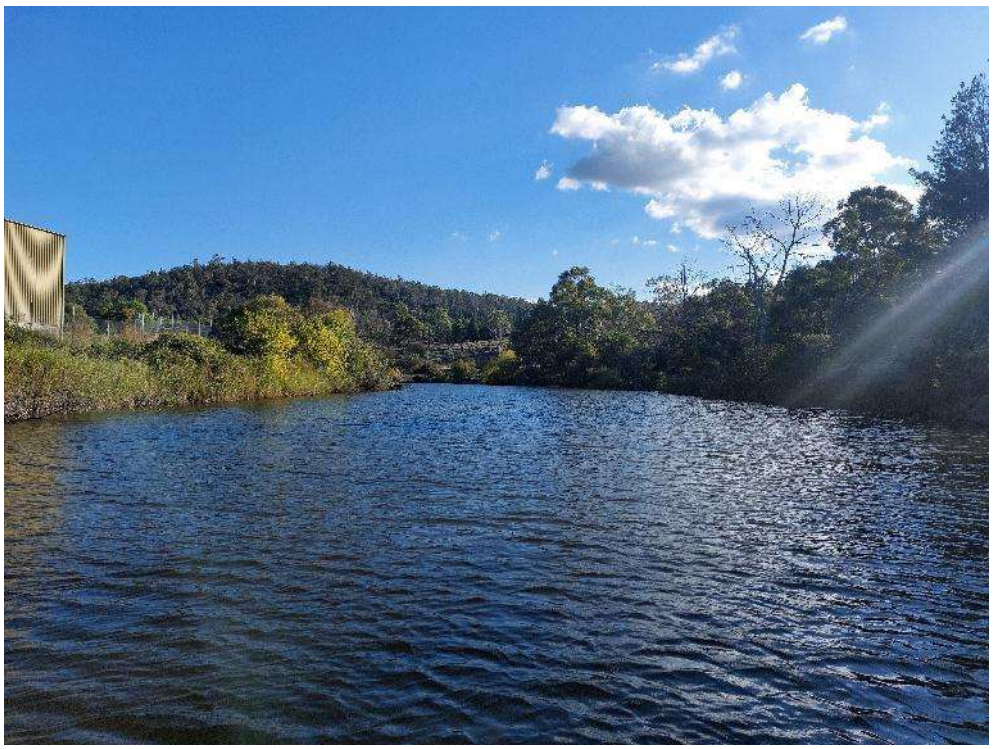
Appendix 1 (continued).

Site 6



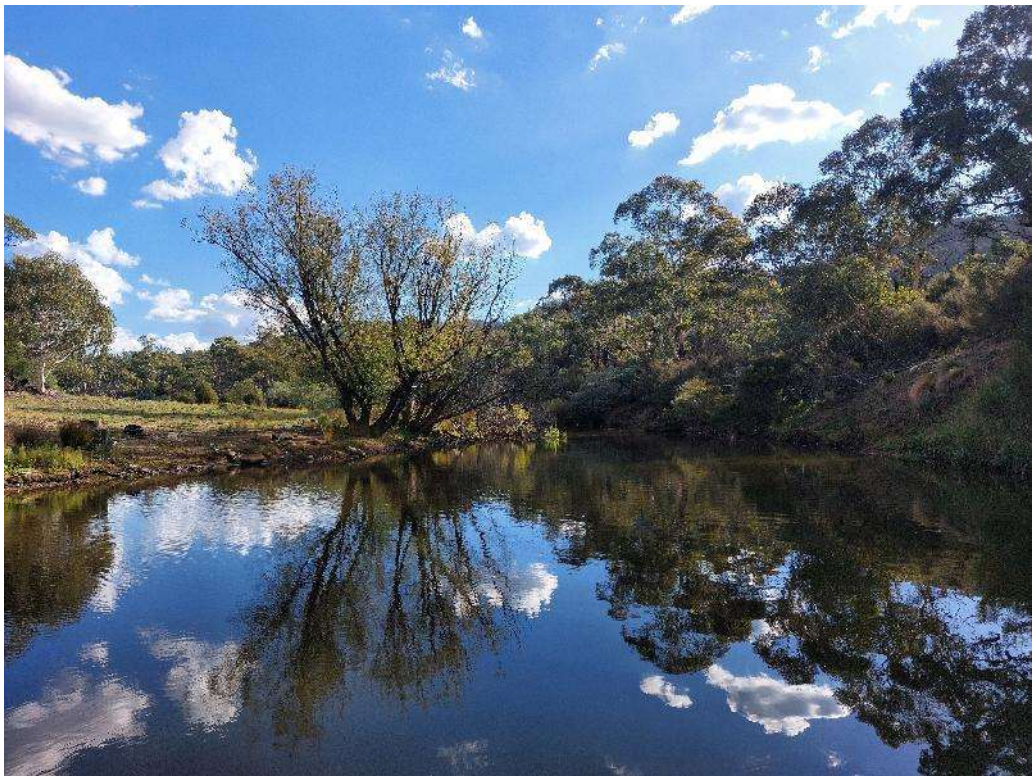
Appendix 1 (continued).

Site 7



Appendix 1 (continued).

Site 8



Appendix 1 (continued).

Site 9

Appendix 2. Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	14/03/2025
Site name	Site 1

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	F	Rock	F
Boulder	F	Timber	O
Cobble	O	Undercuts	-
Pebble	O	Leaf litter	R
Gravel	R	Macrophytes	A
Sand	F		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	-	Run	O
Native shrubs	A	Riffle	O
Exotic shrubs	-	Rapid	O
Riparian grass	O	Backwater	F
Floating macrophytes	F	Velocity (still, slow. mod, fast)	slow
Emergent macrophytes	F	Avg depth (m)	1.5
Submerged macrophytes	O	Max depth (m)	2.7
Filamentous algae	R	Avg width (m)	40
Suspended algae	A		
Biofilms	F		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	6/03/2025
Site name	Site 2

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	O	Rock	F
Boulder	F	Timber	O
Cobble	F	Undercuts	-
Pebble	F	Leaf litter	O
Gravel	O	Macrophytes	A
Sand	O		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	R	Run	O
Native shrubs	F	Riffle	O
Exotic shrubs	O	Rapid	-
Riparian grass	A	Backwater	-
Floating macrophytes	O	Velocity (still, slow. mod, fast)	slow
Emergent macrophytes	F	Avg depth (m)	1.4
Submerged macrophytes	F	Max depth (m)	2.6
Filamentous algae	O	Avg width (m)	23.5
Suspended algae	F		
Biofilms	F		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	5/03/2025
Site name	Site 3

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	A	Rock	F
Boulder	A	Timber	O
Cobble	A	Undercuts	-
Pebble	A	Leaf litter	A
Gravel	F	Macrophytes	F
Sand	F		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	R	Run	A
Native shrubs	A	Riffle	-
Exotic shrubs	-	Rapid	-
Riparian grass	A	Backwater	-
Floating macrophytes	O	Velocity (still, slow. mod, fast)	Slow
Emergent macrophytes	F	Avg depth (m)	1.0
Submerged macrophytes	F	Max depth (m)	1.4
Filamentous algae	A	Avg width (m)	25
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	*3/03/2025*
Site name	*Site 4*

Habitat element	*Score*	***Habitat element***	*Score*
Substrate		***Cover***	
Bedrock	***A***	*Rock*	***A***
Boulder	***A***	*Timber*	***A***
Cobble	***F***	*Undercuts*	***O***
Pebble	***F***	*Leaf litter*	***O***
Gravel	***O***	*Macrophytes*	***O***
Sand	***O***		
Mud/silt	***A***		
Plants		***Mesohabitat***	
Native trees	***F***	*Pool*	***A***
Exotic trees	***O***	*Run*	***F***
Native shrubs	***A***	*Riffle*	***R***
Exotic shrubs	***O***	*Rapid*	***R***
Riparian grass	***A***	*Backwater*	***-***
Floating macrophytes	***R***	*Velocity (still, slow. mod, fast)*	***Slow-mod***
Emergent macrophytes	***O***	*Avg depth (m)*	***1.8***
Submerged macrophytes	***O***	*Max depth (m)*	***5.1***
Filamentous algae	***-***	*Avg width (m)*	***22.5***
Suspended algae	***-***		
Biofilms	***A***		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	*4/03/2025*
Site name	*Site 5*

Habitat element	*Score*	***Habitat element***	*Score*
Substrate		***Cover***	
Bedrock	***A***	*Rock*	***A***
Boulder	***A***	*Timber*	***O***
Cobble	***A***	*Undercuts*	***-***
Pebble	***A***	*Leaf litter*	***F***
Gravel	***O***	*Macrophytes*	***A***
Sand	***O***		
Mud/silt	***A***		
Plants		***Mesohabitat***	
Native trees	***F***	*Pool*	***A***
Exotic trees	***O***	*Run*	***O***
Native shrubs	***A***	*Riffle*	***R***
Exotic shrubs	***-***	*Rapid*	***-***
Riparian grass	***-***	*Backwater*	***-***
Floating macrophytes	***-***	*Velocity (still, slow. mod, fast)*	***Slow***
Emergent macrophytes	***-***	*Avg depth (m)*	***1.4***
Submerged macrophytes	***A***	*Max depth (m)*	***1.9***
Filamentous algae	***-***	*Avg width (m)*	***19***
Suspended algae	***O***		
Biofilms	***A***		

Appendix 2 (cont). Site habitat descriptors

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	12/03/2025
Site name	Site 6

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	O	Rock	F
Boulder	F	Timber	F
Cobble	F	Undercuts	R
Pebble	F	Leaf litter	O
Gravel	F	Macrophytes	A
Sand	O		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	R	Run	R
Native shrubs	A	Riffle	-
Exotic shrubs	O	Rapid	-
Riparian grass	F	Backwater	-
Floating macrophytes	-	Velocity (still, slow. mod, fast)	Slow
Emergent macrophytes	A	Avg depth (m)	2
Submerged macrophytes	F	Max depth (m)	6.1
Filamentous algae	R	Avg width (m)	35
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	11/03/2025
Site name	Site 7

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	O	Rock	A
Boulder	A	Timber	F
Cobble	A	Undercuts	R
Pebble	F	Leaf litter	-
Gravel	O	Macrophytes	A
Sand	O		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	A	Run	R
Native shrubs	F	Riffle	-
Exotic shrubs	F	Rapid	-
Riparian grass	F	Backwater	-
Floating macrophytes	-	Velocity (still, slow. mod, fast)	Slow
Emergent macrophytes	A	Avg depth (m)	2.4
Submerged macrophytes	A	Max depth (m)	2.7
Filamentous algae	R	Avg width (m)	32
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	13/03/2025
Site name	Site 8

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	O	Rock	O
Boulder	O	Timber	A
Cobble	F	Undercuts	R
Pebble	F	Leaf litter	F
Gravel	A	Macrophytes	A
Sand	A		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	F	Run	R
Native shrubs	A	Riffle	R
Exotic shrubs	O	Rapid	-
Riparian grass	F	Backwater	-
Floating macrophytes	-	Velocity (still, slow. mod, fast)	Slow
Emergent macrophytes	A	Avg depth (m)	1.5
Submerged macrophytes	F	Max depth (m)	3.1
Filamentous algae	R	Avg width (m)	23
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

Scores: A = abundant, F=frequent, O=occasional, R=rare, -=absent

Habitat sheet	
Date	10/03/2025
Site name	Site 9

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	A	Rock	F
Boulder	F	Timber	O
Cobble	F	Undercuts	-
Pebble	F	Leaf litter	O
Gravel	F	Macrophytes	O
Sand	A		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	-	Run	A
Native shrubs	A	Riffle	O
Exotic shrubs	O	Rapid	O
Riparian grass	A	Backwater	-
Floating macrophytes	F	Velocity (still, slow. mod, fast)	slow
Emergent macrophytes	O	Avg depth (m)	0.8
Submerged macrophytes	F	Max depth (m)	1.7
Filamentous algae	O	Avg width (m)	39
Suspended algae	A		
Biofilms	A		

Appendix 3: Water quality parameters at each site

(pH, conductivity, water temperature, turbidity and dissolved oxygen).

Site	Date sampled	Time measured	pH	Cond. (uS/cm)	Water temp (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
Site 1	14/03/2025	09:10	6.5	30	18.3	<9	8.08
Site 2	6/03/2025	12:25	7	30	19.4	<9	7.75
Site 3	5/03/2025	11:40	7	30	19.1	<9	8.3
Site 4	3/03/2025	11:25	7	40	21.1	<9	8.11
Site 5	4/03/2025	13:00	7	40	21.2	<9	7.4
Site 6	12/03/2025	12:15	6.5	40	22.5	10	7.51
Site 7	11/03/2025	11:30	7	60	21.5	<9	7.07
Site 8	13/03/2025	?	7	60	22.6	<9	7.46
Site 9	10/03/2025	10:00	7	130	21.8	10	7.26

Appendix C

Abercrombie River reference site monitoring length frequency, length-weight relationship and site photos.

Appendix C – Abercrombie River reference site monitoring length frequency, length-weight relationship and site photos.

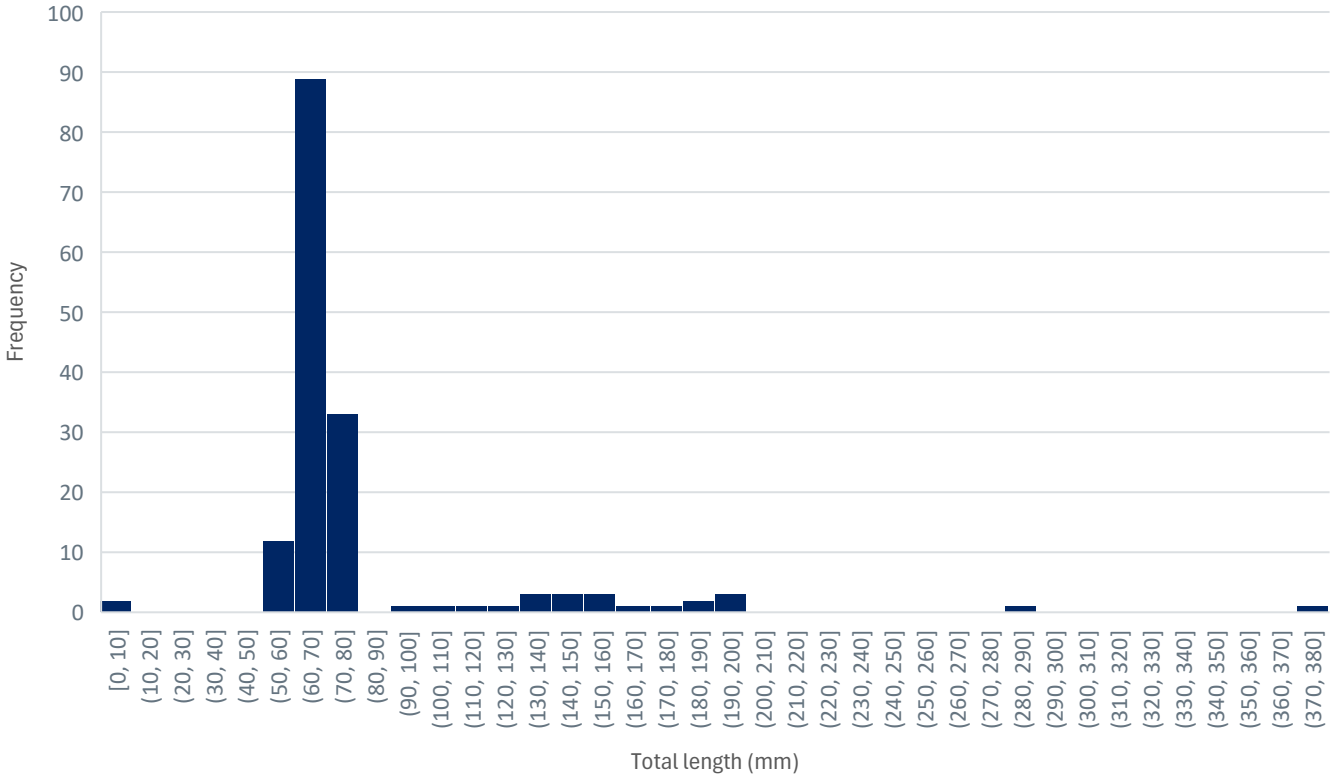


Figure C1. Length frequency of Macquarie Perch captured at the Abercrombie River reference sites in 2025

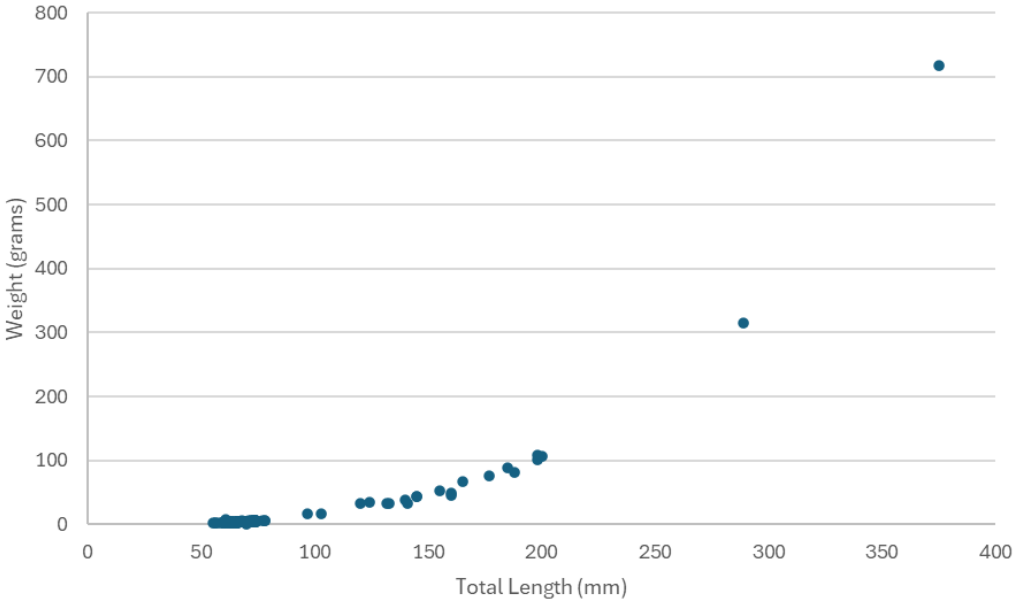


Figure C2. Length-weight relationship of Macquarie Perch captured at the Abercrombie River reference sites in 2025.

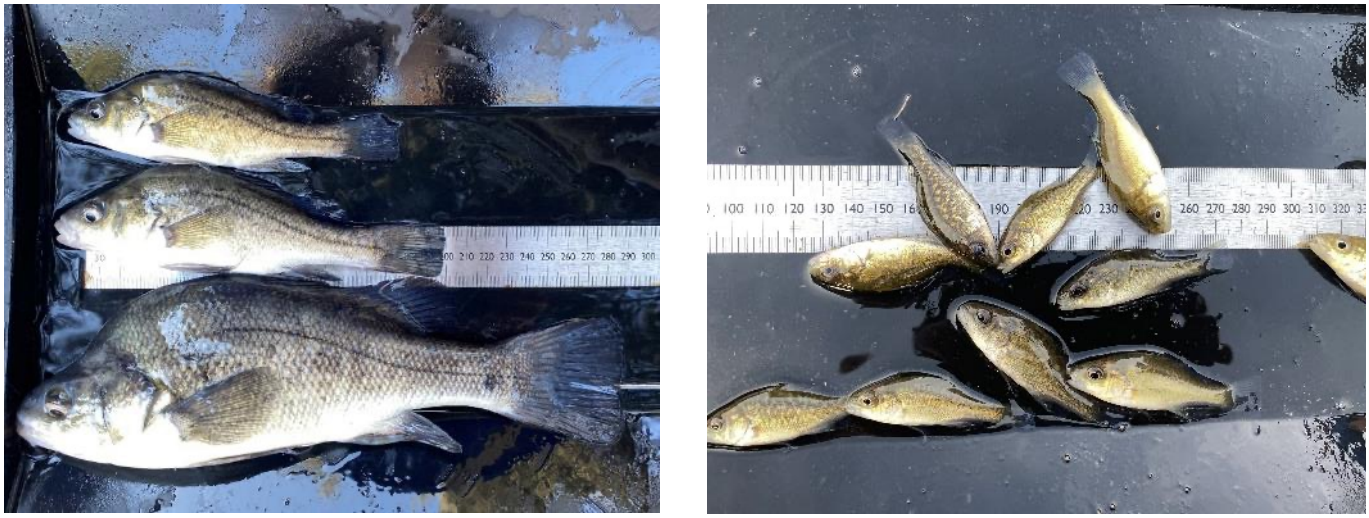


Figure C3. Various sizes classes of Macquarie Perch captured during sampling in the Abercrombie River in 2025

Figure C4. Large adult Macquarie Perch, captured during sampling in the Abercrombie River in 2025

Figure C5. Smiths Crossing Abercrombie River in 2025

Figure C6. Tween Cabin Abercrombie River in 2025

Appendix D

Eucumbene Borrows water temperature monitoring

Appendix D – Eucumbene Borrows water temperature monitoring.

In November 2024, five additional temperature loggers were deployed at the borrows (Table D1), two in the bottom pond (surface and bottom), one in the middle pond, and two in the top pond (surface and bottom). Previously deployed temperature loggers were also retrieved, and data was analysed.

Table D1. Temperature Logger Details

Location	Number	Updated number if replaced
Lower Stream (1)	20863230 – replaced Nov 24	21702381
Lower Stream (2)	20863218	
Upper Stream	20863247 – replaced May 25	22038071
Bottom Pond (Bottom)	21702382	
Bottom Pond (Surface)	21700697	
Middle Pond	21702379	
Upper Pond (Bottom)	21702365	
Upper Pond (Surface)	21702378	

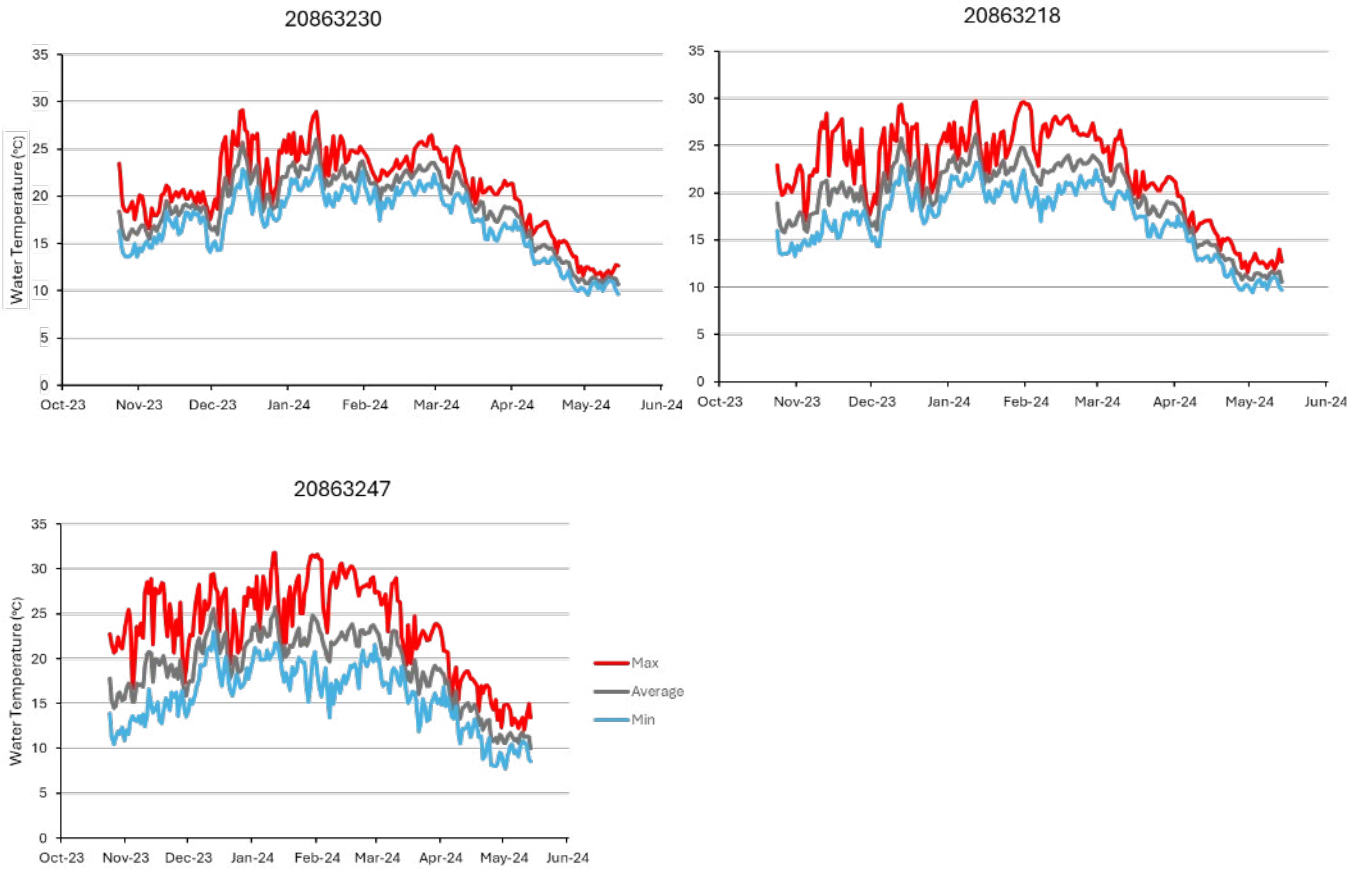


Figure D1. Water temperature for Lower and Upper Streams between Oct 23 and May 24

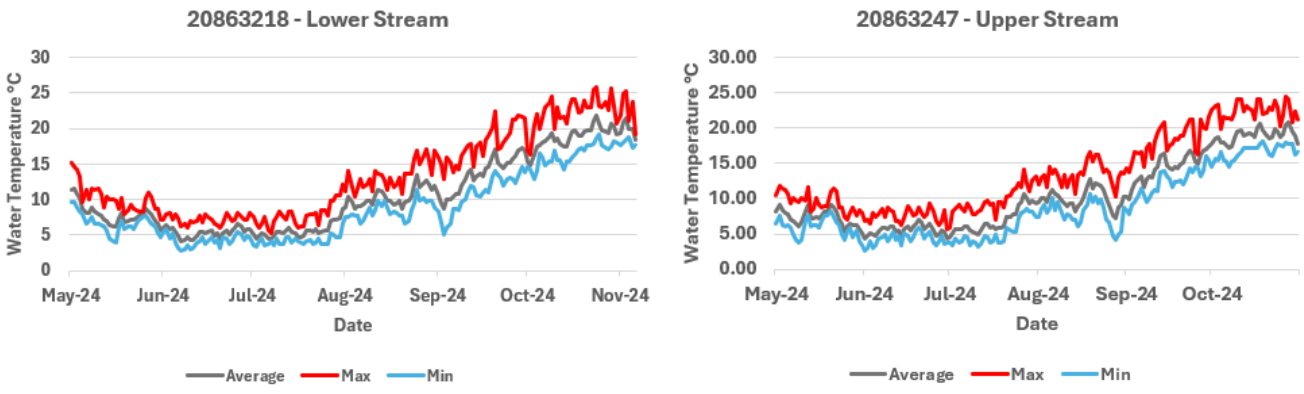


Figure D2. Water temperature for Lower and Upper streams between May 24 and Nov 24

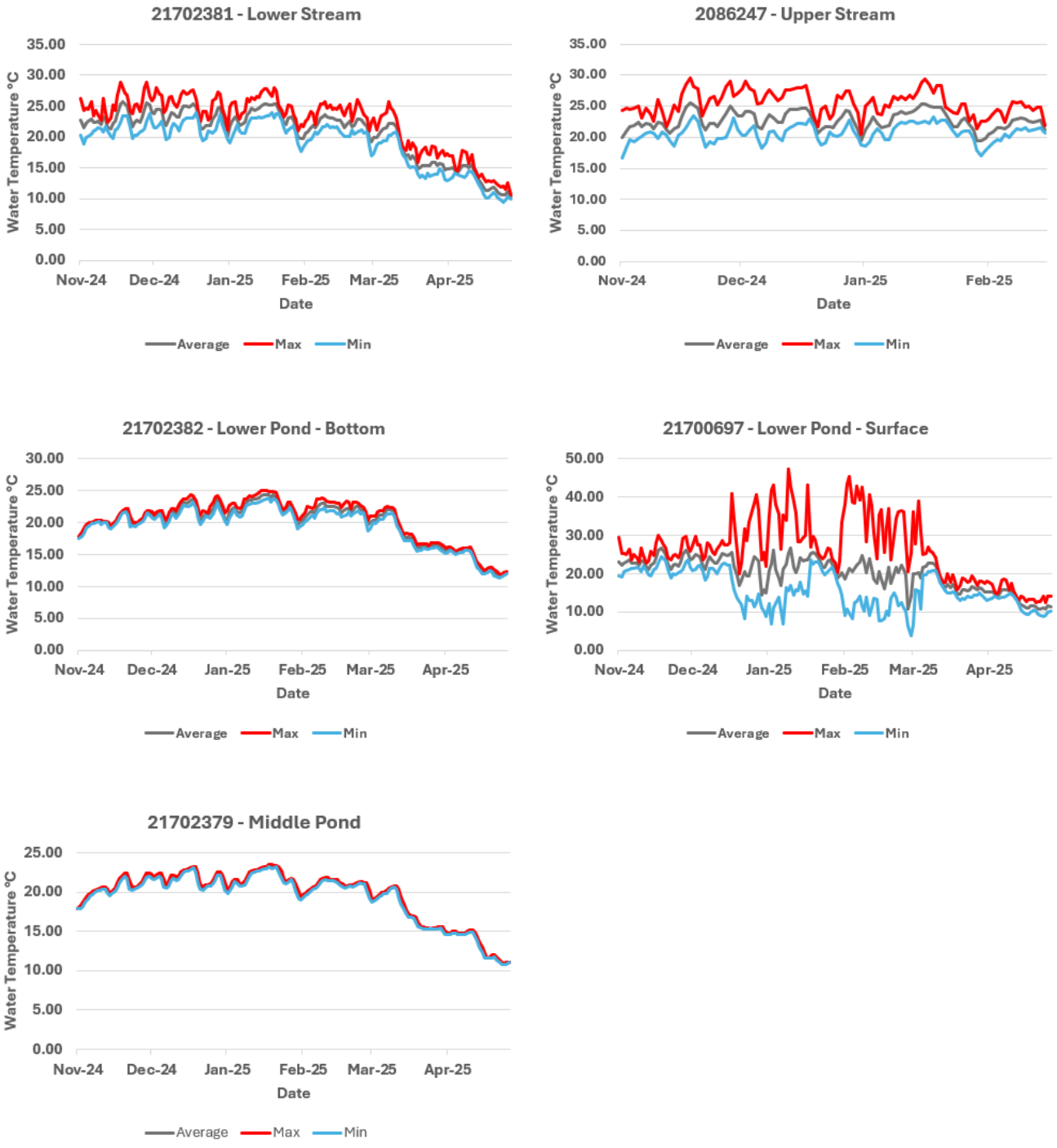


Figure D3. Water temperature for the Streams and ponds between Nov 24 and May 25

Appendix E

Stocky Galaxias Captive Breeding Manual

Charles Sturt University

Hatchery Manual: *Galaxias tantangara*

Amina Price, Zac Rolfe, Katie Doyle, An Vu, Jarrod McPherson, Lee Baumgartner

Charles Sturt University - TEQSA Provider Identification: PRV12018 (Australian University). CRICOS Provider: 00005F.

Hatchery Manual: *Galaxias tantangara*

Amina Price, Zac Rolfe, Katie Doyle, An Vu, Jarrod McPherson, Lee Baumgartner

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Introduction/Preface

The Stocky Galaxias (*Galaxias tantangara*) is a newly described endemic species of fish, known only to occur in two locations, the headwaters of Tantangara Creek and Sallys Flat Creek, both of which are in Kosciusko National Park in NSW (Lintermans *et al*., 2021). The Stocky Galaxias is considered to be one of Australia's most threatened freshwater fishes (Lintermans *et al*., 2020) and is listed as critically endangered in NSW and federally under the EPBC Act. The species faces a range of threats, with one of the most significant threats being predation and competition from alien salmonids (Brown Trout – *Salmo trutta* and Rainbow Trout – *Oncorhynchus mykiss*) (Lintermans *et al*., 2021). Current information indicates that the species only persists in locations where trout are absent. In both locations where Stocky Galaxias has been found, they are restricted to relatively short reaches upstream from waterfalls or cascades that create barriers to trout invasion (Lintermans *et al*., 2021). Another introduced species, Oriental Weatherloach (*Misgurnus anguillicaudatus*), currently spreading throughout the upper Murrumbidgee catchment represents another potential threat to the Stocky Galaxias via egg predation (FSC, 2016). The Stocky Galaxias is also at risk from the introduction of non-endemic native species, such as Climbing Galaxias (*Galaxias brevipinnis*), which has increased its range due to inter-basin water transfers (Lintermans *et al*., 2021). There is a risk that this species may be transferred into the upper Murrumbidgee Catchment as a result of the Snowy Hydro 2 pumped hydropower scheme (Lintermans *et al*., 2021).

Being restricted to two small, isolated populations, the Stocky Galaxias is also at significant risk of extinction from natural disturbances such as storms and bushfires which have the potential to impact both water quality and habitat (Lyon and O'Connor 2008; Lintermans *et al*., 2021). Feral horses exacerbate these threats causing loss of riparian vegetation, bank erosion, stream widening and siltation due to feral horses has already been observed in sections of Tantangara Creek (FSC, 2016, Lintermans and Allan, 2019). Finally, climate change may impact the species via both direct effects (e.g. increases in stream temperature, changes to flows) and indirect effects (e.g. increased frequency and severity of bushfires) (Lintermans *et al*., 2021).

Given the range of threats that the species is facing and the restricted and fragmented distribution of the species, the Stocky Galaxias is considered to be at risk of extinction in the next 20 years (Lintermans *et al*., 2020). It has been recommended that additional populations be established to mitigate this risk (Lintermans and Allan, 2019; Lintermans *et al*., 2020). Due to the estimated small size of the two existing populations, wild to wild translocations are not believed to be sustainable and as such, captive breeding has been recommended to produce offspring for translocations (Raadik and Stoessel 2022; Stoessel and Raadik, 2022). In addition, to ensure that Stocky Galaxias populations are protected from the threats from Snowy 2.0, the establishment of a viable captive population is required (Raadik and Stoessel 2022).

During the summer of 2019/20, prior to discovery of the Sallys Flat population, Tantangara Creek was impacted by bushfire. Post-fire impacts, in particular sediment and ash being washed into the creek posed a significant risk to the Stocky Galaxias population and there was concern for the future of the population and indeed the species (Lintermans *et al*., 2021). In light of these concerns, 142 fish were removed from the creek and transferred to a NSW Department of Primary Industries (DPI) trout hatchery in Jindabyne (Lintermans *et al*., 2021). The removal of these fish presented an opportunity to develop a captive breeding program for the species, with the goal of releasing captive bred fish back into the wild to establish new populations and thereby reduce the risk of extinction. Of the 142 fish that were collected from Tantangara Creek in 2020, 16 were later transported to the aquatic research facilities at Charles Sturt University and a further 23, that were collected in January 2021 as juveniles to bolster the captive population, are now also housed at this facility. Attempts at captive

breeding were unsuccessful in 2020 and 2021, but fish were successfully bred in 2022 and 2023.

The purpose of this hatchery manual is to describe the transport, acclimation, quarantine, housing and maintenance and captive breeding of the rescue population at CSU between 2020 and 2024.

1. Taxonomy, biology, distribution and life-history

Taxonomy

The Stocky Galaxias (*Galaxias tantangara* Raadik, 2014) is part of the Galaxiidae family, which is made up of 66 extant species from 7 genera (Alo *et al*., 2013; Raadick, 2014; Coleman *et al*., 2015). The family Galaxiidae is restricted to the southern hemisphere and is predominantly comprised of small-bodied species that are found in temperate water (Raadik, 2011). Many species are found in high altitude, upland and alpine environments (Raadik, 2011). All species require freshwater; however, a number of species are diadromous, migrating to estuarine and marine environments to spawn, with juveniles then migrating back into freshwater environments (Raadik, 2011). The greatest species diversity is found in Australia where 37 species are currently recognised, and of these, 95% are endemic (Raadik, 2014; Coleman *et al*., 2015). This makes the Galaxiids one of the largest families of freshwater fishes in Australia. Galaxias is the largest and most widespread genus within the family Galaxiidae, with 47 recognised extant species (Raadik, 2014; Coleman *et al*., 2015).

The Stocky Galaxias forms part of a cryptic complex of 15 closely related species that until recently, were all considered to be Mountain Galaxias (*Galaxias olidus*) (Raadik, 2014). Of these, nine species are listed as threatened (Lintermans *et al*., 2020). Stocky Galaxias were first collected from Tantangara Creek in 2002 but weren't formally identified until 2014 (Raadik, 2014).

Distribution, biology and life-history

Tantangara Creek is a small alpine stream in the headwaters of the Murrumbidgee River in Kosciuszko National Park, NSW. A single population occurs there within a small reach (approximately 4km) above a 3.5m waterwall (Raadik, 2014; refs). Trout are present below the waterfall but are not able to ascend above the waterfall (Raadik, 2014; Lintermans, 2021). Within this reach, Stocky Galaxias are present at elevations between 1360 and approximately 1500m (Lintermans *et al*., 2021). No other species of fish have been recorded within this stream reach. The only other known population of Stocky Galaxias, which was only discovered in late 2020, is in Sallys Flat Creek (Lintermans *et al*., 2021). Sally Flat Creek is approximately 30km from the Tantangara Creek reach as the crow flies but approximately 350 river kilometres away from the Tantangara Creek population (Lintermans *et al*., 2021). However, it's possible that during very wet conditions, the two streams may be connected via a small tributary (Lintermans *et al*., 2021). Like Tantangara Creek, Sally Flat Creek is a small headwater stream (elevation ~ 1325m that is currently trout-free due to a series of cascades and waterfalls at the base of the stream (Allan and Lintermans, 2021; Lintermans *et al*, 2021). Mountain Galaxias have also been recorded in Sallys Flat Creek and genetic analyses showed that there are no signs of hybridisation having occurred (Lintermans *et al*., 2021)

It's likely that prior to the widespread invasion of trout, Stocky Galaxias occurred across a much broader geographic range across the upper Murrumbidgee catchment and potentially beyond (Raadik, 2014; Lintermans *et al*., 2021). The discovery of the Sallys Flat Creek population suggests that there may be other remnant populations in upland streams where trout are unable to invade (Lintermans, 2021).

Both Tantangara Creek and Sally Flat Creek are cool, clear, alpine headwater streams that are relatively small and shallow (Lintermans *et al*., 2021). Between November 2021 and June 2018, data loggers in Tantangara Creek showed that the water temperature ranged between 0°C and ~20°C, although average daily temperatures never exceeded ~15.5°C (Allan *et al*., 2020). Between May and October, maximum daily water temperatures did not exceed 6°C (Allan *et al*., 2020). The upper section of Tantangara Creek where Stocky galaxias occur is fast flowing and consists predominantly of riffles and runs with some small cascades and a small number of pools (Raadik, 2014; Lintermans *et al*., 2021). The substrate is mainly

comprised of bedrock, boulder and cobble with some pebble, gravel and silt (Raadik, 2014; Lintermans *et al*., 2021). Riparian vegetation consists of fringing Eucalypts, small shrubs and tussock grasses (Raadik, 2014; Lintermans *et al*., 2021). Instream habitat consists of overhanging banks and vegetation and rocks (Raadik, 2014).

To date, there has only been one study that has investigated the reproductive ecology of the Stocky Galaxias. Allan *et al*. (2020), undertook monthly monitoring over an 18-month period in Tantangara Creek and this study has indicated that Stocky Galaxiids spawn during spring. Males appear to reach sexual maturity up to 1-2 years before females and ripe males were observed in all months of year except for January (noting that sampling was not undertaken in August and September). Ripe females were observed in November 2016 and 2017, February 2017 and March 2018, however, spent females were only observed in November and December 2017. Fecundity appears to be relatively low (mean relative fecundity reported for the Tantangara Creek population is 73 oocytes g^{-1}).

Eggs are relatively large (mature oocyte range: 1.192–2.200 mm, mean 1.671 mm), transparent, spherical and adhesive and contain a visible oil droplet. Females may use multiple spawning sites, however, as no partially spent females were recorded, spawning appears to take place over a short period of time. Only one spawning site was found during the study. This was at the upstream end of a riffle, upstream of a slow run. Approximately 50 eggs were adhered to the underside of a cobble which was slight raised off the stream bed. There were multiple clusters of 2-25 eggs, most eggs were in a single layer but in some cases, there were up to four eggs that were layered in top of each other. The egg cluster was partially covered by coarse gravel and small twigs. No adult fish were observed near the spawning site indicating that there is no parental care for this species. Based on the data from Tantangara Creek, duration of egg incubation is at least 13 days but is likely to be between 26-47 days depending on water temperature, spawning site and riffle microhydraulics. Schools of up to 20 larvae were observed in mid-late December in slow sections of the creek.

There is no information regarding the diet of Stocky Galaxias, however it's likely that it is similar to that of Mountain galaxias, which consists mainly of aquatic insect larvae as well as terrestrial insects that fall into the water from overhanging vegetation (Lintermans, 2007).

2. Collection and transportation of captive broodstock

Collection and transportation of broodstock

To date, Stocky galaxias have been successfully collected from Tantangara Creek and Sally's Flat Creek using backpack electrofishing (Allen *et al*., 2021; Lintermans *et al*, 2021). Once collected, fish should be immediately placed in transport containers pre-filled with water from the collection site, filled to just below the brim to minimise water movement and potential damage of fish during transport. Transport containers should be insulated to prevent rapid changes in water temperature and continuous aeration must be provided within each barrel. During transport, water temperatures should be regularly monitored.

Anaesthetics and other water treatments (e.g. addition of salt or calcium, stress reducing products such as Aqua Plus) may be added to the water to reduce stress and prevent infection (Dunn and O'Brien, 2018). Depending on the duration of transport, it may be necessary to add an ammonia detoxification product to the water to ensure that ammonia levels don't build up due to excretion during transport. The stocking density of fish within the barrels must be relatively low, and fish should be separated based on size classes.

Quarantine and acclimation

On arrival, fish must be immediately acclimated to hatchery conditions by gradually adding hatchery water to the transportation containers over a period of 1 to 2 hours to minimise stress and physiological shock. Once the temperature, pH and salinity of the water in the transport containers match the hatchery water, fish can be transferred into isolated quarantine tanks. Dissolved oxygen levels in both the transport and quarantine tanks should be maintained as close to 100% as possible (Stoessel and Raadik, 2022).

During the first 12-24 hours, low light levels should be maintained to reduce stress and fish should not be fed. Following the initial acclimation period, fish should continue to be held in a separate quarantine culture system for at least two weeks as outlined in NSW DPI's 'A Guide to Acceptable Procedures and Practices for Aquaculture and Fisheries Research' (4th Edition, 2015). Dedicated equipment must be used within the quarantine system to prevent cross-contamination. During the quarantine period, salt concentrations can be raised to 5g/L (at a rate of <1 g/L per day) as a prophylactic treatment for protozoan, bacterial, fungal, and parasitic infections. Fish should be monitored daily for any signs of injury, disease, infection or abnormal behaviour. In the absence of any signs of disease, fish can be transferred to the broodstock culture system. Any fish that show signs of disease or infection must be immediately isolated in a separate treatment tank and if appropriate (e.g. in the instance of a fungal infection), treatment should be applied to all fish in quarantine. If the cause of the disease or infection, or the appropriate treatment, is unknown, it is necessary to consult a qualified veterinarian.

3. Broodstock management

Broodstock holding and conditioning facilities

Set-up and design

Fish must be housed within a temperature-controlled environment where maximum temperatures can be kept below 16 °C in summer, and low winter temperatures can be achieved (see 'Overwintering conditions and sexual maturation' below). It is recommended that a back-up system/generator be available in case of system failures or power outages. In addition, it is recommended that there is an automated alarm system to notify staff if temperatures fall outside a specified maximum or minimum temperature, or if there is a power outage. Lighting in the facility must be able to be set and adjusted to mimic natural photoperiod. Good airflow is required to prevent excess humidity, which can lead to bacterial and/or fungal growth (Stoessel and Raadik, 2022).

As outlined by Stoessel and Raadik (2022), fish may be housed within a flow-through, recirculating or closed freshwater system, however a recirculating system is recommended. In the current system at Charles Sturt University, the fish are housed within recirculating aquaria systems with moving bed biological reactor filter sumps (Figure 2). A 150-Watt Single Lamp UV Treatment System is plumbed into the filtration system, ensuring all water passes through it, providing filtration at an estimated dose of 150 mJ/cm^2. Aged and conditioned tap water is used.

Each aquarium has a gravel substrate with some larger rocks and a PVC pipe as added structural habitat. The fish appear to be adept climbers, capable of moving heavy objects relative to their bodyweight and can squeeze through gaps thinner that the width of their bodies. They appear to be largely rheotactic and are attracted to the inlet pipes, even attempting to swim 'up the flow' of the inlet pipes. Consequently, all aquaria are fitted with lids that prevent fish from escaping through any gaps between the lid of the aquarium and the inlet pipe (Figure 3). In addition, the inlet pipes are extended further into the aquarium to remove this cue and minimise escape risk.

The fish appear to be photosensitive and prefer darker conditions. They become erratic when light levels are high or when there are sudden changes in lighting. Shading may be required to reduce light intensity.

Figure 1. The refrigerated shipping container that the Stocky galaxiids are housed within at Charles Sturt University. The ambient air temperature within the container can be controlled via two sources, the internal refrigeration unit and an external cooler, and can be maintained at temperatures between 2-30° C. The container is also equipped with a backup generator that can run the external cooler and run air into the container.

Figure 2. Rack system comprised of 28 x 30L aquaria.

Figure 3. Inlet pipes are extended into the aquaria and the lids have no gaps through which the fish can escape.

Stocking density (sizes, ages and sex ratios)

Despite initial reports of aggressive behaviour at the Gaden Trout Hatchery, Stocky galaxias do not need to be housed individually. Both juvenile and adult fish have been successfully housed in groups of 2-15 fish per tank. However, size groupings are recommended as larger fish display aggression (chasing and attacking) smaller fish. To date adult fish have been kept at a maximum density of approximately 1 fish per 10 litres of water. Each aquarium is numbered and labelled with the number of fish, the source of the fish (stream and stream section) and the collection date.

Water quality

Water quality (temperature, dissolved oxygen, turbidity, salinity, electrical conductivity) must be checked daily, and nitrates, nitrites, ammonia and alkalinity must be checked at least twice weekly (see Stoessel and Raadik (2022) for a full description of the nitrogen cycle and management of nitrogenous waste). All aquaria need to be vacuumed/siphoned to remove excess food and waste twice weekly, and water changes must also be undertaken twice weekly. The range of water quality conditions within the aquaria, as well as the recommended range for key water quality parameters, are shown in Table 1.

Table 1. Actual water quality ranges that the Stocky galaxiids have been exposed to between July 2020-July 2022 and recommended water quality ranges.

Water quality parameter	Range	Average	Recommended range
Temperature ° C	2-19*	10.55	2-15
pH	5.67-7.99	7.27	7.5 to slightly acidic
SPC (mS/cm^3)	0.05-5.83	0.67	>1.5
Salinity (ppt)	0.04-3.09	0.34	<3ppt
Turb (NTU	0-5	2.08	<20
DO (mg/L)	8.11-17.79	11.15	>7.5
DO (%)	81.4-145	99.64	>80
NH3/NH4+ (mg/L)	0-3**	0.12**	0
NO2- (mg/L)	0-2**	0.11**	0
NO3- (mg/L)	0-40**	6.22**	<60
Alk/KH (mg/L)	15-116	39.52	60-80

* Prior to being moved to the refrigerated container, water temperatures reached up to 19° C in late January and February 2021 during the late afternoon/early evening. While these temperatures appear to have been tolerated by the fish, there may be an increased risk of fungal infections if temperatures are higher than 15° C (T. Raadik pers comm).

** Ammonia (NH3/NH4+), nitrates (NO3-) and nitrites (NO2-) were initially high, but this only lasted for a short period of time and was managed with water changes.

Feeding

Broodstock should be fed a varied diet to ensure they receive the necessary nutrients for optimal health and reproduction. The primary foods include white worms, blackworms, bloodworms, and artemia, which can be provided in live, frozen, or freeze-dried forms. However, ensuring that at least some of the diet consists of live food is important if there is a possibility of releasing the broodstock back into the wild. Additionally, broodstock have been successfully fed a manufactured insectivore gel. To date, attempts to transition broodstock to artificial pelleted food, specifically Otohime pellets, have been unsuccessful. Despite veterinarian recommendations to use Otohime pellets as a supplemental feed to enhance nutrition, the adult fish did not consume them. Various methods of presenting the pellets, such as wet/dry, crushed dry/wet, and soaked with algal or nutrient enrichment solutions, were tried without success. It was instead recommended to feed crushed pellets to white worms, which may absorb the essential fatty acids, indirectly benefiting the broodstock.

Feeding frequency should be adjusted based on water temperature. When water temperatures are above approximately 6°C, broodstock should be fed daily. In colder conditions, feeding should be reduced to once every two days.

Health monitoring and disease control

Infectious diseases can be a common challenge in aquaculture and hatchery environments and can lead to significant mortalities (NSW Department of Primary Industries, 2015). Effective disease control relies on regular monitoring and appropriate management to maintain good fish health. When disease events occur, especially when the cause is unclear, it is crucial to investigate promptly, seek veterinary advice and/or submit samples to a diagnostic laboratory for further investigation.

All fish must be monitored daily for:

- Changes in feeding.
- Changes in behaviour (e.g. reduced activity; unusual swimming behaviour; 'flashing' or repeated rubbing against hard surfaces)
- Changes in respiration (rapid gill movement or gasping at the surface)
- Physical abnormalities (e.g. protruding scales, clamped fins, bulging or cloudy eyes, fin erosion, emaciated appearance, lesions, blotches, spots, lumps, ulcers or other growths on the body or fins).
- Long, stringy faeces.

As recommended by Stoessel and Raadik (2022), in the case of an outbreak of ill-health in individuals housed in either broodstock, larval or grow-out aquaria, the following should be immediately investigated:

- Water parameters, including the functioning of aerators, chillers/heaters and filters.
- Possibility of poisoning, e.g. from iron, copper or fungal toxins, or contamination by detergents, soaps, perfumes, paints, glues, solvents, or insecticides (Huntley and Langton 1994).
- Possibility of physical damage because of antagonistic and territorially related aggression by other animals.
- Potential nutritional deficiencies, e.g. manifesting as spinal deformities, cloudy eyes, and skin haemorrhaging (Huntley and Langton 1994).
- Pathogens (parasites, bacteria, viruses, fungi) (e.g. DPI VIC 2005, 2008; NSW Department of Primary Industries, 2015).

Any fish displaying signs of injury, infection or disease should be promptly moved to an isolated 'hospital' tank located in dark, quiet location. If the fish is showing signs of fungus, it should be treated with fungicide and all other broodstock within the same system should also be treated with fungicide. Salinity should be increased (up to 3.0g/L) in all tanks. Salinity should also be increased in cases of injury, and fish should be monitored until they have fully recovered. If the cause of illness or infection is unknown, prompt advice should be sought from an appropriately qualified Veterinarian.

To date, there has only been one instance of illness in the captive population. Some of the fish that first arrived in mid-2020 were showing signs of illness and other individuals developed signs of illness over the first two weeks that the fish were at CSU. The fish already had, or later developed, black banding around their bodies, as well as body lesions. These fish were isolated in separate 'hospital' aquaria that were covered with black plastic to create a dark environment. These was no filtration, water quality was regularly monitored and managed using water changes and by having no gravel substrate within the aquaria in which waste material could accumulate. Air stones were used to provide aeration. This occurred over winter and prior to the fish being moved into the refrigerated container, so water temperatures were not actively managed.

To treat the fish, SPC was raised to 3.0 g/L within the 'hospital' aquaria as well as within the recirculating aquaria system. The water in the 'hospital' aquaria was dosed for 3-7 days with an antifungal treatment, Pimafix, at a dosage of 0.125 ml per L aquarium water. A single fish was euthanised and sent to a veterinary pathobiologist who found that the fish was infected with parasitic cysts (*Myxobolus* sp) and also had a bacterial infection (columnaris disease). Veterinary advice suggested that diet (frozen blood worms only) could have been a contributing factor. Based on veterinary recommendations, the sick fish were further treated using antibiotic immersion baths for up to 14 consecutive days. Fish were dosed with high purity oxytetracycline (CCD Oxytet HCL; oxytetracycline

hydrochloride; >95% concentration) at 20 mg/L for 6-8 hours daily followed by a 100% water change.

Overwintering conditions and sexual maturation

Sexual maturation does not occur unless water temperatures and photoperiod are manipulated to mimic natural conditions. Broodstock have been successfully brought to sexual maturity by gradually reducing temperatures to 2°C and daylength to ~9.5 hours of daylight over winter, and then gradually increasing temperature and daylength to mimic the onset on spring and then summer (up to 15 °C and ~14.5 hours of daylight). It is important to adjust temperatures slowly (maximum change of 1°C per week) to avoid negatively impacting biofilters and to monitor ammonia, nitrates and nitrites to ensure that biofilters continue to operate effectively.

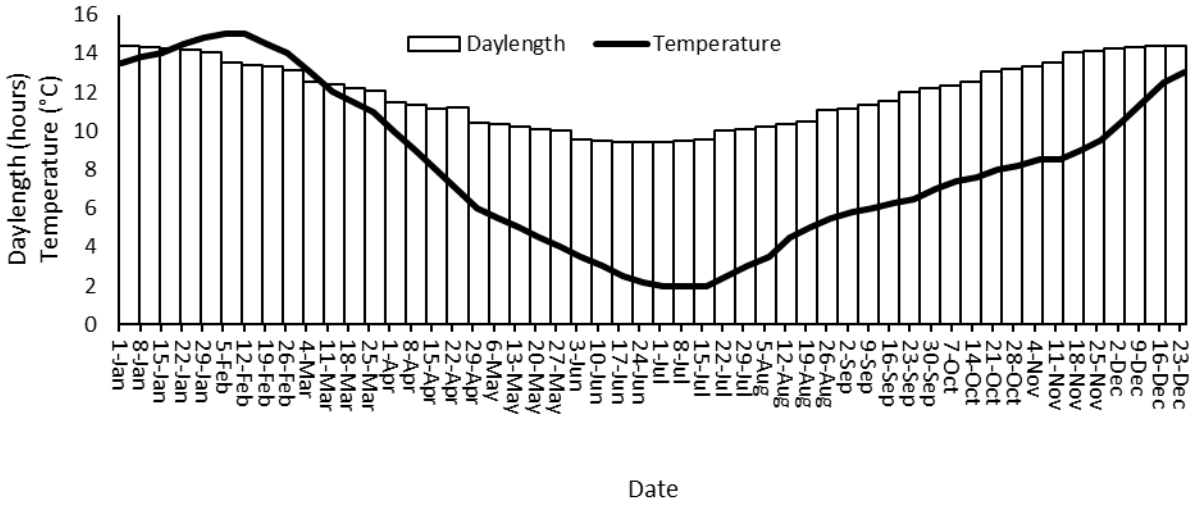

Figure 4. Average weekly temperature and daylength data in the aquaria at the CSU facilities. Solid black line = average weekly water temperatures, bars = daylength.

Gonad maturity status and sex determination

Reproductive maturity and the sex of the fish can be determined by visual examination of the abdominal wall as per Allan *et al*., (2020). Stage of reproductive maturity can be determined according to criteria adapted from Pollard (1972) (Table 2).

Table 2. Gonad developmental stages

Stage	Description
1 – Immature/resting	Gonads not visible, sexes are indistinguishable
2 – Developing	Gonads enlarged and visible, small eggs present (female)
3 – Mature	Gonads fill most of the body cavity
4 – Ripe	Gonads fill all the body cavity, eggs/sperm may be extruded with mild abdominal pressure
5 – Spent	Gonads flaccid, testes may be grey with white areas (indicating residual sperm), whereas ovaries may be colourless/pale yellow, possibly with residual eggs.

Note: Adapted from Pollard (1972).

4. Egg extraction and fertilisation

Stocky galaxias have not successfully bred naturally in captivity. In 2021 when natural spawning was attempted, the adult fish became gravid throughout November and began to deposit eggs in early December. This matched the timing of spawning that has been observed in Tantangara Creek (Allan *et al*., 2020) but occurred when water temperatures were only at 10°C, indicating that spawning can occur at lower temperatures (fish in Tantangara Creek spawned when water temperatures were between approximately 11-13.5° C). While some female fish appeared to actively deposit eggs around a rock, others dropped their eggs across the gravel. However, no eggs were successfully fertilised, and females were observed eating the deposited eggs.

In 2022 and 2023, fish were successfully hand stripped and fertilised. Suitability for hand stripping is examined by applying pressure with the thumb and forefinger and compressing anteriorly-posteriorly toward the vent. Fish are considered ripe when milt or oocytes can be extracted with gentle pressure. In addition, the papilla is extruded on female fish that are ripe. There is some variability in when the females become ripe (1-3 weeks). Males are ripe throughout November and December, and some males can be stripped twice.

Prior to stripping, all equipment that the fish will come into contact with should be sterilised. Broodstock should be sedated (e.g. with an isoeugenol aquatic anaesthetic (AQUI-S) as per manufacturers guidelines). Following this, the fish is rinsed in freshwater and then its abdomen is gently dried. The fish are held gently in a wet, soft cloth for stripping. Milt should be collected from male fish prior to oocytes being extracted (Figure 6). Milt can be extruded by applying gentle pressure anteriorly-posteriorly. As milt exits the vent, it should be directly drawn into 1ml syringe with tubing attached at the end. The milt from 3 males is used per 2 females to maximise the chances of viable and compatible sperm fertilising the eggs. Oocytes should then be stripped from females by applying gentle pressure toward the vent and stripping the eggs directly into a Petrie dish (Figure 6). Care should be taken to strip the eggs as a single layer.

Water should be added to the Petrie dishes with a syringe (at a ratio of 1g eggs: 1g water) and agitated. Milt is then added within 10 minutes (Figure 7). Approximately 0.05ml of milt is added per gram of oocytes. The oocyte and milt mixture is agitated for a further minute before being rinsed for three minutes with clean water to remove protein from the egg. Eggs are then rinsed by immersing the Petrie dish in a beaker of dechlorinated water.

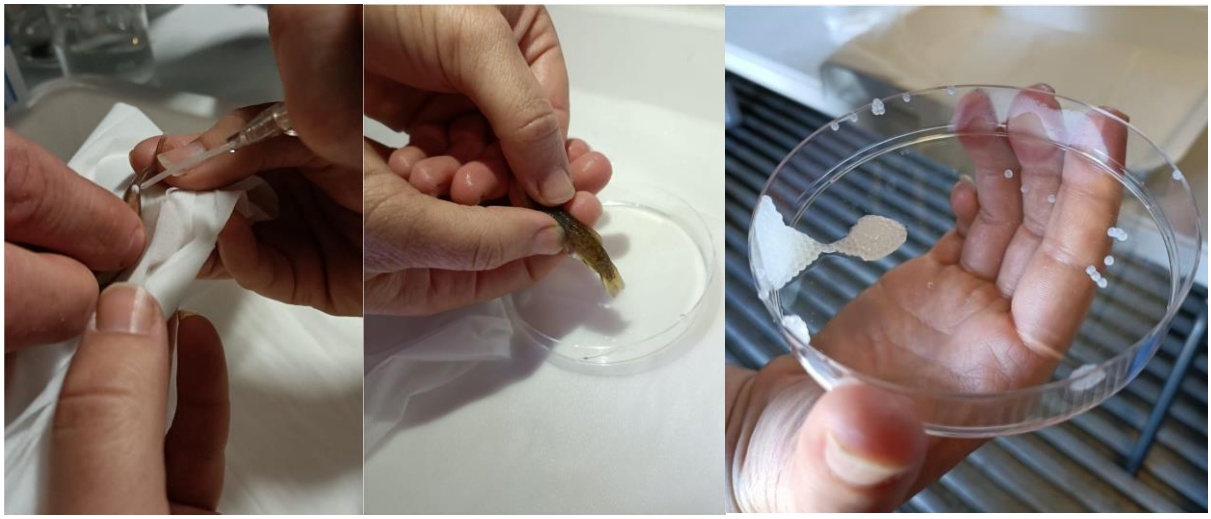

Figure 6. Collection of a) milt from a male fish; b) oocytes from a female fish and c) unfertilised oocytes immediately after being stripped into a Petrie dish.

Figure 7. Milt and water being added to oocytes simultaneously in Petrie dish prior to mixing.

Not all eggs have been observed to be immediately adhesive. Eggs that are adhesive should be left attached to Petrie dishes. Eggs that are not immediately adhesive or that become dislodged from the Petri dish should be placed in incubators. The incubators used at CSU are based on those described by Stoessel *et al*. (2020). They are made from 90mm PVC pipe cut at lengths of approximately 150mm. Hose-clamps are used to attach mesh (500 microns) to one end of the pipe to prevent eggs from becoming loose in tanks.

After stripping, fish should be treated in a prophylactic treatment at 5ppt salt (NaCl) for 20 minutes before being returned to regular broodstock holding tanks. Care should be taken to ensure that water temperature is similar between the salt bath and the broodstock holding tanks. Stoessel and Raadik (2022) recommend that fish are also treated with fungicide prior to returning them to the broodstock holding tanks and that ProTech (Aquasonic Pty Ltd) be added to the tanks to counter the loss of protective mucus on the skin of fish due to handling.

5. Egg incubation

The harvested eggs should be immediately placed into aquaria or a larval rearing system that has the same water temperature as the broodstock housing system. Eggs should then be incubated under the same temperature and photoperiod regime as the broodstock.

Eggs should be observed daily to monitor for fungus and to remove unviable or infected eggs and placed in aerated formalin baths at a dosage rate of 1ml/L for 15 minutes per day to prevent fungal growth. Care should be taken during this process to minimize temperature variation and exposure to air. Formalin baths should be discontinued once eggs are eyed, as there is some evidence that the formalin baths may induce premature hatching (see ‘Hatching of larvae’ below).

Eggs were observed to be relatively large (around 2.91mm diameter before fertilisation), transparent, and containing visible, fragmented oil droplets (Figure 8). After fertilisation, eggs swelled to an average of 3.03mm (SD-0.10) at 3 days post fertilization. There was little change in the size of the eggs after this point. Eyes were observed developing at approximately 12

days post fertilisation (Figure 8) and were fully eyed at 17 days, with fish starting to also show pigmentation (Figure 8). From approximately 17 days post fertilisation movement was visible within eggs. Changes from this stage until hatching consisted of pigmentation becoming heavier, with yolk sacks clearly visible before hatching (Figure 8).

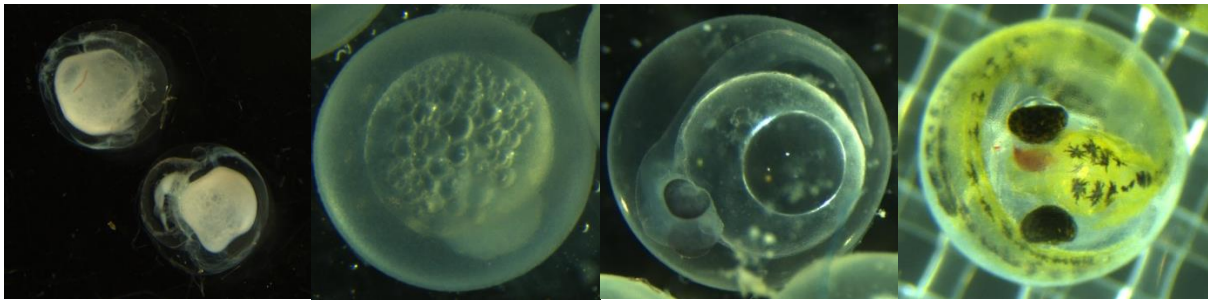

Figure 8. Egg development, a) unfertilised eggs immediately after being stripped; b) Eggs after successful fertilisation; c) 6-day old eggs showing characteristics of being 'eyed'; d) Eggs 33 days post fertilisation, just prior to hatching, showing developed eyes and strong pigmentation.

5. Rearing of larvae and juveniles

Hatching of larvae

In 2022, at temperatures between 10-12°C, the duration of embryogenesis ranged between 20 and 37 days (mean 29 days). In 2023, at temperatures between 9-11.5°C, the duration of embryogenesis ranged between 34 and 44 days (mean 38 days). The larvae that hatched earlier (between 20-29 days) in 2022 appeared to have hatched in response to increased light and/or the formalin baths. Eggs were exposed to increased light during the formalin baths so it is unclear whether light or the formalin baths were responsible. Consequently, the formalin baths were discontinued as soon as larvae began to hatch in 2022 and in 2023, were discontinued earlier to avoid early hatching (see above).

Newly hatched larvae spend a short amount of time immobile on the bottom of the tank and should not be disturbed until they become mobile. Once mobile, larvae are active and make use of the entire water column. At this stage, they may be transferred from incubation tanks to larval rearing tanks if required, ensuring that all water quality parameters match those of the incubation tanks. Larvae are best moved using a pipette or beaker.

Rearing of larvae and juveniles

Larvae and juveniles should be kept under the same temperature and photoperiod regime as the broodstock. Salinity should be gradually raised to approximately 1.5ppt until fish are approximately four months post hatch, as low levels of salinity have been shown to aid in fish development and growth. All water quality parameters should be kept as stable as possible, particularly while larvae are young. Daily checks of all water quality parameters, including ammonia, nitrite, and nitrate, are essential to maintain optimal conditions.

Ideally, the sides of the tanks should be dark to help larvae see their prey against a dark background, and tank bases should be white to allow easy viewing of the larvae and to make detritus more visible as it accumulates on the bottom.

Daily removal of excess food and waste is necessary to maintain water quality. This can be done by siphoning the bottom of the tanks using thin tubing (e.g. 4-8 mm in diameter) to avoid sucking in the larvae. As the fish grow, the diameter of the tubing can be increased. If larvae cannot be screened off or separated from the bottom, extreme care must be taken to avoid siphoning them up. During cleaning, water must be siphoned into a bucket, and this should be

carefully checked for larvae. Any larvae accidentally sucked through the tubing should be gently transferred back into the holding tank.

Stocking density

Stocking density is a critical factor in the rearing process. Larval rearing tanks can be stocked directly with newly fertilized eggs or newly hatched larvae. At the CSU facilities, stocking densities have varied from 1-3 larvae per litre for newly hatched larvae. As the larvae grow, it is important to regularly monitor and adjust tank density. This ensures they have adequate space, reduces feeding competition, and promotes healthy growth and development."

Feeding protocols

Larvae have been observed consuming newly hatched Artemia nauplii at approximately 10 days post-hatch. However, it is recommended to offer liquid fry starter and smaller prey items (such as vinegar eels and rotifers) from 6 days post-hatch, as it is not certain when they begin consuming these food items. Once it is clear that all larvae are consuming Artemia, the provision of liquid fry starter and smaller prey items can be discontinued.

Larvae should be fed live Artemia nauplii hatched daily, a minimum of 4-5 times per day at intervals of approximately 2.5 hours for the first 15-20 days of exogenous feeding. After this period, the frequency of feeding can be reduced to 3-4 times daily. At around 60 days post-hatch, larger live food items, such as finely chopped white worms (*Enchytraeus albidus*), may be introduced to supplement the diet and increase protein intake. The volume of feed should be increased to match the growth of the juvenile fish, ensuring they receive adequate nutrition for healthy development.

6. Remaining knowledge gaps

While we have successfully bred Stocky galaxias for two years in succession, there are several areas where the program could be further developed or refined. These include:

- To date, no attempts have been made to breed the fish out of season or to investigate whether multiple annual breeding events are possible. If large numbers of captively-bred fish are required, multiple annual breeding events would facilitate this.
- Given the success of hand-stripping following natural maturation, we have not investigated the utility of hormone induction. However, given that there is some variation in when individual female fish are ready for stripping (1-3 weeks), hormone induction would enable synchronicity in maturation. In addition, given that the exact timing of ovulation can't be visually determined, and the eggs of some female fish have been over-ripe when they've been stripped, there may be benefit in investigating whether hormone induction would enable a better estimation of the optimal time for hand stripping the female fish. Investigating timing of ovulation following hormone induction could potentially be achieved using Mountain galaxias (*Galaxias olidus*) as a surrogate species.
- Stoessel & Raadik (2022) have highlighted the importance of genetics in underpinning conservation-based captive breeding. To-date the primary aim of the program has been to develop successful methods for captive breeding. However, with this now in place, it would be beneficial for genetics to be incorporated into the program.

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Appendix F

2024/2025 CSU Stocky Galaxias optimal growth and upper thermal limit study

Appendix F – 2024/2025 CSU Stocky Galaxias optimal growth and upper thermal limit study.

(Provided by Amina Price, Research Fellow, Charles Sturt University)

Optimal growth experiments

Optimal growth experiments began on the 2/1/2025 when the fish were 13 days post hatch and concluded on the 20/03/2025 when the fish were 90 days post hatch. 50 × 13-day old fish were placed into one of five temperature treatments: 12°C, 17°C, 22°C, 27°C and 32°C. All fish commenced the optimal growth experiments at 12°C and were acclimated to the required temperature at a rate of 2°C per day. Fish were successfully acclimated up to 28°C but died when the temperature was increased to 30°C. Following this, the decision was made to lower the temperature for the next highest treatment to 26°C. Prior to the temperature increase to 30°C, the fish were observed to be more active and were consuming more food at the higher temperatures but there were no indications of thermal stress.

Initial growth measurements (24 days post-hatch) showed that fish in the 12°C treatment were smaller and lighter than fish in the other treatments and that fish in the 17°C treatment were lighter than fish in the 22°C and 26°C treatments (Figure F1).

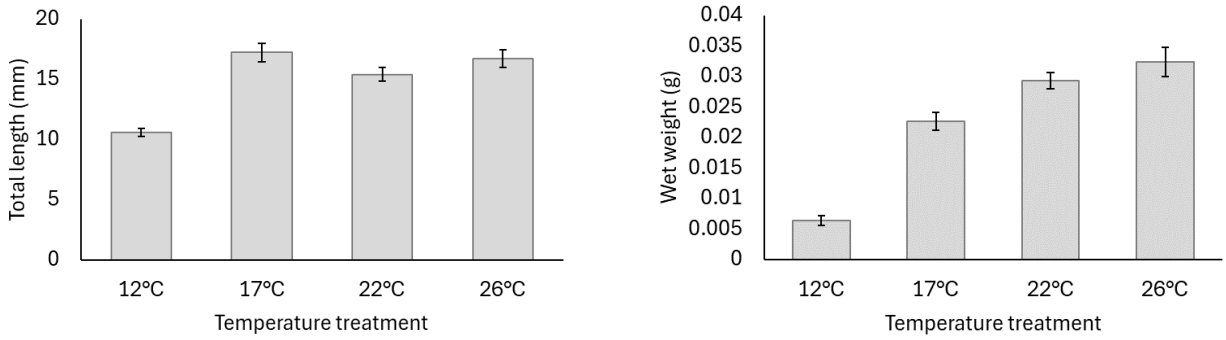

Figure F1. Mean (±1 standard error) for total length and wet weight of 24-day post-hatch Stocky Galaxias

The 26°C treatment was terminated on January 24, 2025 (35 days post-hatch), due to spinal abnormalities being evident in approximately 50% of the fish. Temperature-related spinal abnormalities have been observed in various other species. In exogenously feeding larvae and juveniles, these deformities are believed to arise from accelerated muscle development, which puts pressure on the developing spine.

The 22°C treatment was terminated on February 20, 2025 (62 days post-hatch), due to a high number of mortalities observed during the preceding two weeks. No mortalities were observed in the other temperature treatments during this period. Six fish (three that had died and three that were euthanised) from the 22°C treatment were sent for histopathology and parasitology, and the water temperature was reduced to 14°C for the remaining fish in this treatment. There was no evidence of illness or parasites, and no further mortalities occurred once the temperature was reduced, indicating that the mortalities were associated with water temperature.

The final growth measurements (90 days post hatch) showed that the fish in the 17°C treatment were longer and heavier than the fish in the 12°C treatment (Figure F2).

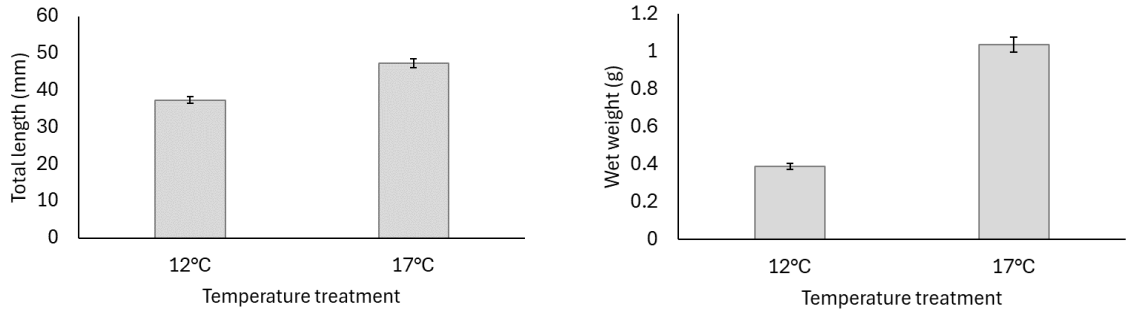

Figure F2. Mean (±1 standard error) for total length and wet weight of 90-day post-hatch Stocky Galaxias

Key findings

- → Daily average temperatures must be below 26°C during the larval growth period.
- → Daily average temperature must be below 22°C during the juvenile growth period.
- → Optimal survival and growth of larvae and juveniles occurred at 17°C.

Upper thermal limit (CTmax) experiments

CTmax experiments were undertaken for the following groups:

- → 60 days post-hatch from the 12°C treatment,
- → 60 days post-hatch from the 17°C treatment,
- → 90 days post-hatch from the 12°C treatment,
- → 90 days post-hatch from the 17°C treatment,
- → Adult fish kept at 13°C.

For each CTmax experiment, a total of 15 fish were used. Of these, five were control fish that were placed in a separate water bath that wasn't heated. The 10 CTmax experimental fish were individually placed in containers with mesh sides or bottoms that were sitting within an aerated and mixed water bath that was at the same temperature as the water in their holding tanks.

The fish were acclimated to the holding containers and the temperature of the water within the bath was then increased at a rate of 1°C every 3 minutes. The fish were continuously monitored and the temperature at which loss of equilibrium (CTmax) occurred was recorded. All fish recovered well, and no mortalities were recorded.

Key findings

- → All fish that were held at 12-13°C, lost equilibrium at between 26-27°C. This was consistent among all age groups.
- → All fish that were held at 17°C lost equilibrium at between 30-31°C. This was for both 60 and 90-day-old fish.
- → Across all age groups and both acclimation temperatures, fish were able to cope with a rapid temperature increases of about 13-15°C.

Appendix G

Macquarie Perch captive breeding progress report

MILESTONE PROGRESS REPORT

FRDC PROJECT NUMBER: 2022-116

DATE DUE: 03 February 2025

PRINCIPAL INVESTIGATORS: Abigail Elizur, Josephine Nocillado, Tomer Ventura, Luke Pearce and Stewart Fielder

OVERALL PROJECT PROGRESS:

During the October 2024 spawning season, the University of the Sunshine Coast and NSW Fisheries focused on spawning induction of the Macquarie Perch using slow-release GnRHa implants and determining whether the source of water (bore and river) and water temperature (20°C and 23°C) influenced the spawning response of Macquarie perch. Broodstock comprised of both captive-held F1 and wild-caught Macquarie perch at Narrandera Fisheries Centre (NFC), and based on results of 2023 studies, groups of 4-5 females and 3-4 males were combined in individual spawning tanks to secure optimal spawning response. Slow-release GnRHa implants were effective, as observed in the preceding 4 spawning seasons. Neither water source nor temperature affected spawning levels or latency period from hormone induction. A total of 21 spawning events were harvested successfully in the recirculating tank system and external egg collector. Approximately 80% of viable females spawned, and there was no difference between F1 and wild female spawners.

A total of approximately 315,684 eggs (with fertilisation rates ranging from 0-96%) were collected, which equated to a mean of 15,033 eggs/spawn. However, there were major problems with egg development, and most batches of eggs failed to develop, with only 3 spawns resulting in hatched larvae, representing approximately 0.5% survival of eggs spawned. This was especially pronounced in eggs spawned in bore water, where embryos failed to develop within several days of spawning. Possible reasons include (1) the initial poor condition of female and male fish (suggesting inadequate nutrition during gonad maturation) that resulted in poor quality gametes, (2) the new external egg harvest method was not suitable, although it was used successfully in 2023, (3) unknown seasonal effects in ponds where the fish had been held prior to spawning induction, and (4) unknown water quality issues.

A study was designed to evaluate whether small F2 broodfish (spawned in 2020) and wild-collected fish from the Cataract Dam were mature and able to spawn. Although the female fish had oocytes that we considered were mature and most males were spermiating, no fish from those groups spawned after hormone induction. This could have potentially reflected the poor initial fish condition but also could reflect observations in wild populations where the spawning of young mature fish is not evident. The captive F2 and Cataract fish may simply require more time in captivity before they become viable spawners.

One challenge was the rapid occurrence of fungal infections, which led to a study designed to evaluate potential treatments of eggs to prevent such aquatic fungus infection. A range of concentrations and exposure times of Boric acid and sodium chloride (NaCl) were compared with formalin treatment, considering their safety for Macquarie perch eggs post water hardening (24-48h post spawn). We showed that Boric acid and NaCl was safe to Macquarie perch eggs at all tested concentrations and exposure times

and we now have safe (hatchery operator and fish eggs), cheap and effective alternatives to formalin for aquatic fungus control.

During the October 2024 season, we identified that the management of Macquarie perch broodfish in small ponds is potentially different to that in the large pond as in previous years. Attention to pond productivity and live feed production, as well as an understanding of feeding artificial diets/supplements is necessary to ensure fish are in optimal condition prior to spawning in Spring each year. This will be a focus of the research team leading up to 2025 spawning.

In line with the aim to understand the reproductive biology of Macquarie perch, we are developing assays that will help characterise the hormonal profile of the species throughout its reproductive cycle. We have produced a Macquarie perch recombinant single chain follicle stimulating hormone (Fsh), and its beta subunit (Fshβ), from which polyclonal antibodies were generated. The Fsh enzyme-linked immunosorbent assay (ELISA) is currently being developed. We are also developing an ELISA for vitellogenin, which is a marker of ovarian development. In this regard, we are using the golden perch as vitellogenin source of plasma, which we have collected from NFC in October 2024. These assays are expected to help refine the breeding techniques of captive Macquarie perch.

Milestones within the first progress report (as per agreement):
(1). Project Steering Committee Meeting 1 - **Achieved**
(2). Attend and present progress report at Project Steering Committee Meeting 2 - **Achieved**
(3). Provide second progress report to VFA - **Achieved**

Milestone Status

Has this milestone been achieved (Yes/No)	**Yes, to all 3 milestones above.**
Will the project be completed according to the current milestone schedule (Yes/No)	**Yes.**

PROJECT PROGRESS AGAINST PROJECT OBJECTIVES

The overall aim of the activities for the University of The Sunshine Coast and NSW Fisheries "focuses on optimising the use of hormones to stimulate spawning of captive-held Macquarie perch broodstock and the development of tools to assess reproductive development in captivity and in response to tailored diets". Towards this aim, the following activities were conducted in 2024 (details are found in Section 3):

(1). Spawned captive-held F1 Macquarie perch broodstock at Narrandera Fisheries Centre (NFC).
(2). Evaluated the effect of water source and temperature on spawning of Macquarie perch in tanks.
(3). Trials to spawn wild-caught (Cataract) and F2 Macquarie perch.
(4). Evaluated the safety of Formalin, Boric acid and NaCl on Macquarie perch eggs as controls for aquatic fungal infection.
(5). Harvested Macquarie perch fingerlings (from October 2024 spawning) grown in the ponds at NFC and released into Winburndale Dam.
(6). Collected blood (plasma) from oestradiol-induced golden perch for vitellogenin ELISA development.

(7). Produced recombinant Macquarie perch follicle stimulating hormone β subunit and generated polyclonal antibodies.

Repeat the following three sections for each milestone in the period being reported on:

1. ORIGINAL MILESTONE DATE AND DETAIL:

Milestone 1

Attended and presented progress report at Project Steering Committee Meeting 3; 5-6 March 2024 Narrandera Fisheries Centre, Narrandera, NSW.

Attendees from UniSC and NSW Fisheries: Stewart Fielder, Luke Pearce, Tomer Ventura, Josephine Nocillado and Abigail Elizur

Stewart Fielder presented the outcomes of the Macquarie perch spawning at Narrandera Fisheries Centre for the October 2023 season.

Josephine Nocillado presented additional key points regarding the spawning in 2023, the assays being developed at UniSC, and the preliminary results of possible pheromones associated with Macquarie perch spawning.

Milestone 2

Provide second progress report to VFA.
This report.

2. REVISED MILESTONE DATE AND DETAIL:

NA.

3. PROGRESS AGAINST MILESTONES DETAIL (Achieved):

(1). Spawned captive-held Macquarie perch broodstock at Narrandera Fisheries Centre.

The UniSC Team prepared GnRHa implants. The UniSC Team (Abigail Elizur, Tomer Ventura, Josephine Nocillado, Lachlan Dennis) and NSW Fisheries Team (Stewart Fielder, Luke Pearce, Tim McGarry, Simone Mabon) travelled to Narrandera Fisheries Centre (NFC) in October to conduct the spawning activities (Fig. 1). NFC staff, including Lachlan Jess, Tim McGarry and Jonathan Doyle, provided assistance in several aspects of the activities.

As in the preceding spawning seasons (2020-2023), intramuscular implantation of slow-release GnRHa stimulated spawning in the treated fish. Details are discussed in the sections below (Studies 1 and 2) as it was combined with an experiment to determine the effects of water source and temperature on spawning response.

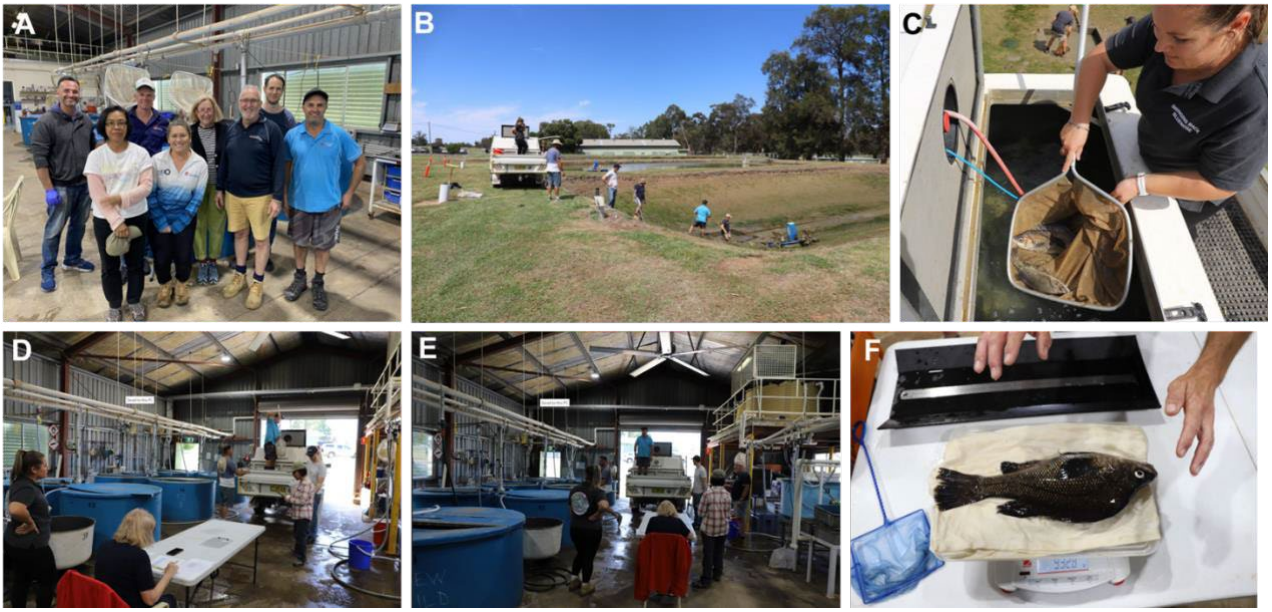

Fig. 1. NSW Fisheries and UniSC "Mac" Team (A); transferring Macquarie perch broodstock from the pond and into the spawning tanks (B-E); length weight measurement (C). (Photos by L. Pearce.)

(2). Evaluation of the effect of water source and water temperature on spawning of Macquarie perch in tanks (Study 1)

An experiment was conducted on F1 captive and wild-caught broodstock to determine whether water source (bore and river) and water temperature (20°C and 23°C) affected spawning in tanks. Previous spawning of Macquarie perch at NFC since 2020 was done using groundwater sourced from an onsite bore. This was done because bore water was better filtered and was more stable in temperature than river water. However, the chemistry of bore water, including factors such as higher water hardness and salinity (196 mg/L and 0.8 g/L, respectively), is different to river water (62 mg/l and 0.1 g/L, respectively) (Table 1), and we were concerned this may affect egg quality, especially initial water hardening stage of the eggs. We rebuilt influent filtration and egg incubation systems for both bore and river water. A temperature of 20°C had been routinely used to spawn Macquarie perch at NFC; however, observations by Victorian fisheries ecologists of wild spawning Macquarie perch aggregations suggest that spawning behaviour increased as water temperature was increased to 23°C (Zeb Tonkin, pers. comm).

Therefore, the design of the 2x2 factorial experiment was as follows:

Broodstock were collected from the ponds and transferred to temporary holding tanks in the hatchery (Fig. 1). Then, fish were weighed, biopsied for gonad samples and randomly assigned into duplicate tanks (2500L) for each treatment combination. A total of 4/5 females/tank (3F1 and 1-2 Wild – newly caught) where 2-4 females/tank had oocyte >1300um (P=0.46; Fig. 2), were combined with 3/4 mature males/tank (2F1, wild).

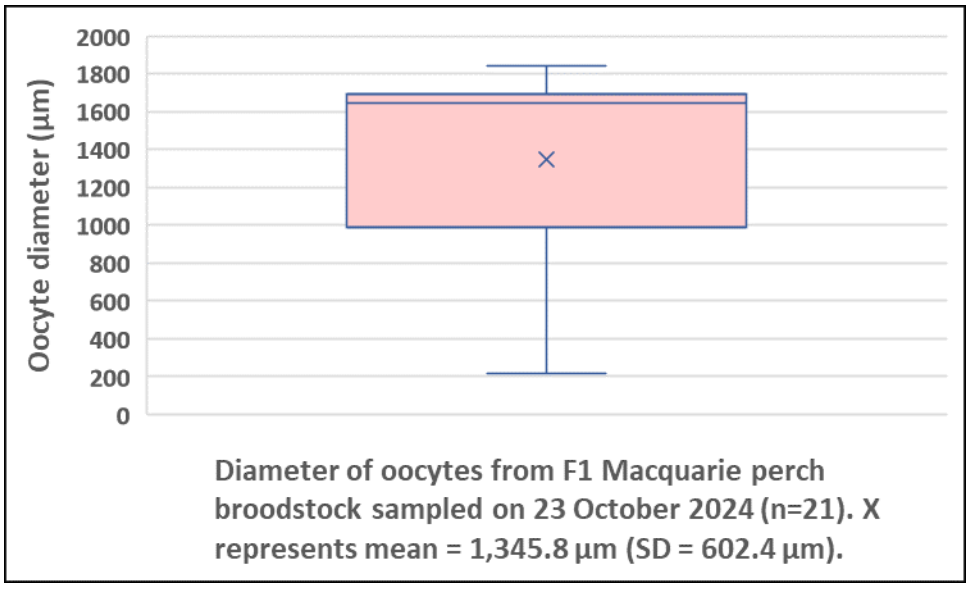

Fig. 2. Range of oocyte diameters from F1 captive-held Macquarie perch broodstock at Narrandera Fisheries Centre sampled on 23 October 2024. The overall average oocyte diameter (1,345.8 µm; n=21 fish) is represented by X (SD was 602.4 µm). From each fish, 10 oocytes were measured.

Of interest was that the condition factor of individual male and female F1 fish was, in general, significantly lower in 2024 compared with 2023 (Fig. 3). The reasons are unknown but could include overstocking in the ponds, inadequate natural feed and/or differences between seasons which affected the condition of the fish.

Slow-release GnRHa pellets were administered via an intramuscular implant at a dose of 150 µg/kg for the females and 40 µg/kg for the males. Each tank was operated using an independent recirculation system to allow the passive collection of spawned eggs in an external egg trap (Fig. 4).

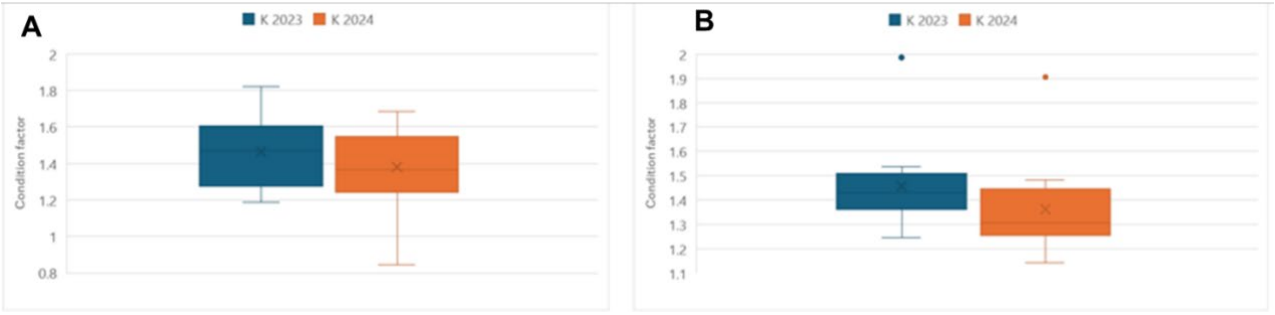

Fig. 3. Comparison of the condition factor of females (A; n = 24) and males (B; n = 16) Macquarie perch broodstock in 2023 (blue) and 2024 (orange). Means were significantly different between years for each group ($p < 0.01$).

Figure 4. Broodstock spawning tanks and recirculation system for egg collection. River and bore water assigned tanks (A, B); implantation (C); egg collection system (D, E). (Photos by L. Pearce.)

Spawning was monitored from 12 h post-implantation. Spawned eggs were collected from the egg traps as soon as they were observed, counted, measured under a compound microscope and then assigned to an egg incubation system (Fig. 5) corresponding to the water source in which they were spawned.

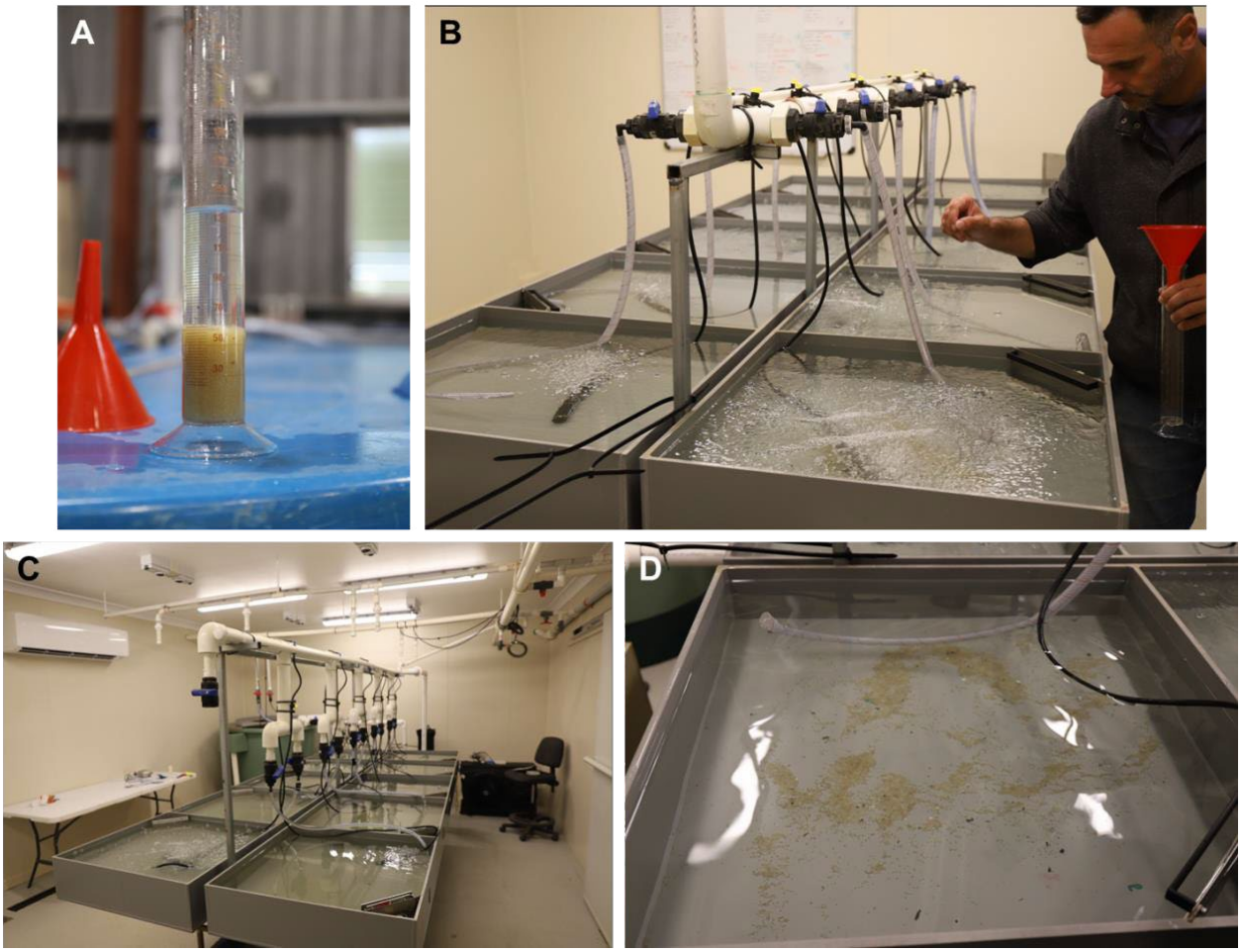

Fig. 5. Incubation system comprised of trays of the spawns during the October 2024 season. Volumetric determination of number of eggs (A); transferring spawned eggs into the incubation trays (B); a view of the incubation system (C); eggs incubating in the trays (D). (Photos by L. Pearce.)

Spawning occurred in all tanks, and there was no significant effect of water source or water temperature on spawning (Fig. 6). A total of 21 spawning events were recorded and produced approximately 315,684 eggs, which equated to a mean of 15,033 eggs/spawn.

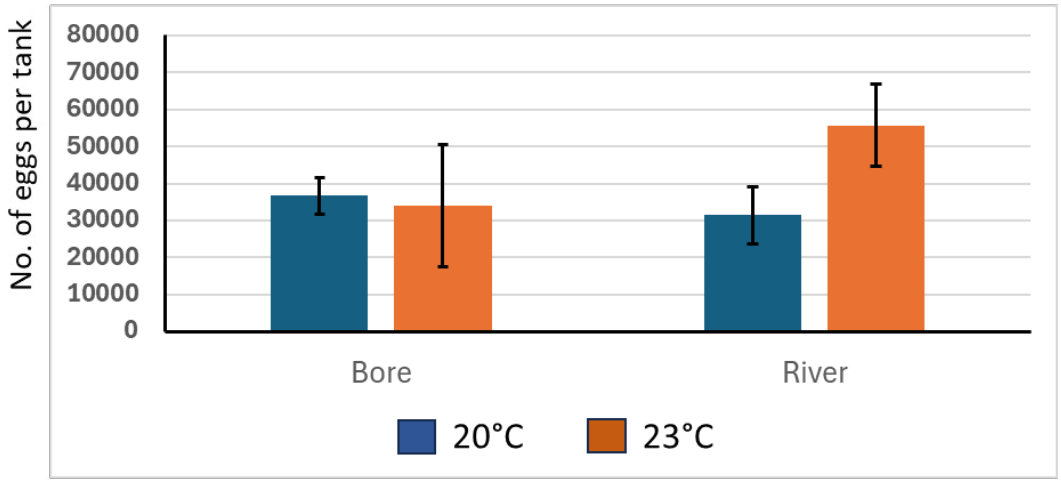

Fig. 6. Comparison of the number of spawned eggs in bore and river water and at different water temperatures. Data are mean±SD (n=2 tanks; 4 female/tank). No significant difference was observed between the water sources or between the temperature treatments ($p > 0.05$).

Approximately 80% of viable females spawned, and there was no difference between F1 and wild female spawners (Fig. 7).

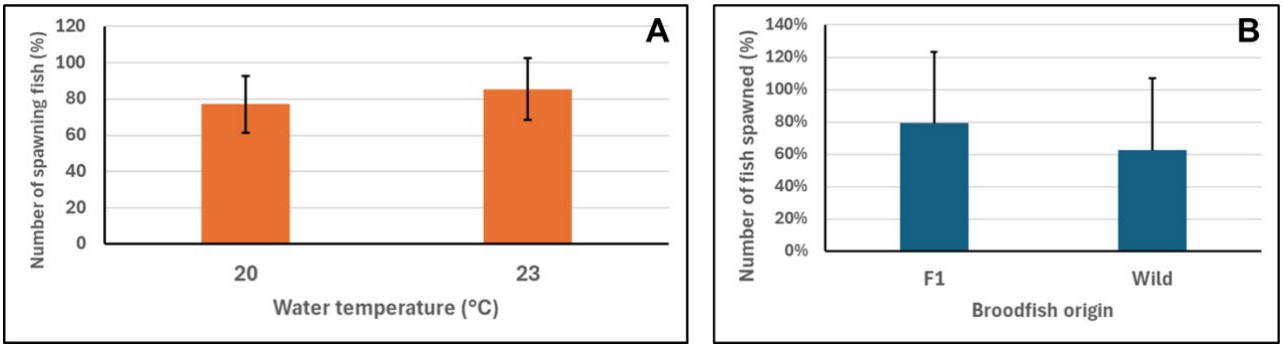

Fig. 7. Comparison of percentage of fish that spawned when held in tanks at different temperatures (A) and fish from different sources (B).

Water source and temperature did not significantly affect the latency period of spawning (mean ~41h post-induction); however, spawns at 20°C occurred over a wider range of time than those at 23°C (Fig. 8).

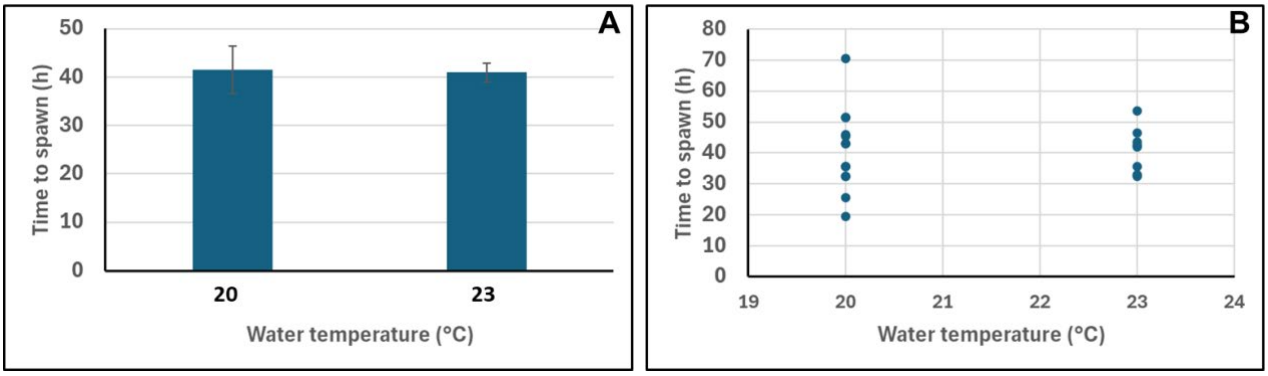

Figure 8. Latency period of GnRHa-induced Macquarie perch broodstock held at different water temperatures (A). Individual latency responses are plotted on B.

Initial fertilisation was not affected by water temperature but was significantly greater in river water compared with bore water ($p < 0.05$; Fig. 9).

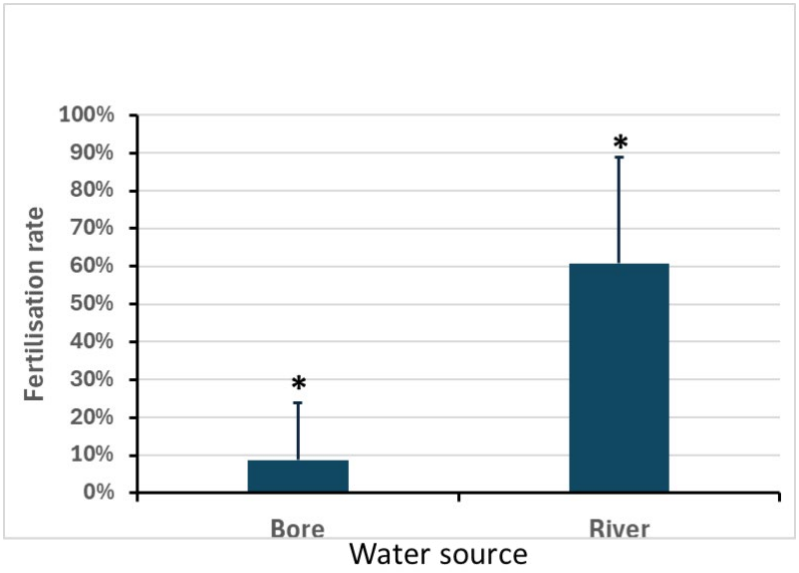

Fig. 9. Estimate of initial fertilisation rate of Macquarie perch eggs spawned naturally in tanks in different water source. Data are mean±SD (n = 4 tanks). Asterisks denote significant difference between water source ($p < 0.05$).

In addition to low initial fertilisation in bore water, there were major problems with egg development, and most batches of eggs failed, with only 3 spawns producing hatched larvae, representing approximately 0.5% survival of eggs spawned. This was especially pronounced in eggs spawned in bore water, where embryos failed to develop within several days of spawning (Fig. 10). There are a number of possible reasons for this, including: (1) the initial poor condition of the female and male fish (suggesting inadequate nutrition during gonad maturation) resulted in poor quality eggs; (2) the new external egg harvest method was not suitable, although it was used successfully in 2023; (3) unknown seasonal effects in ponds where the fish had been held prior to spawning induction; (4) unknown water quality issues, however, bore water has been used in previous years with successful fertilisation and hatching of ~13,000 eggs. The fact that eggs spawned in bore water this year showed low initial fertilisation followed by complete failure of eggs to develop and hatch suggests poor egg quality.

Table 1. Water parameters analysis of bore and river water that supplied the spawning tanks for Macquarie perch in October 2024.

Test	**Unit**	**Water source**			
		Bore water		**River water**	
		2023	2024	2023	2024
Conductivity	uS/cm	1260	1230	145	207
Salinity	g/L	0.8	0.8	0.1	0.1
Calcium (dissolved)	mg/L	22.4	25.4	7.46	13.2
Total hardness as $CaCO_3$	mg/L	165	196	37	62
Magnesium (dissolved)	mg/L	26.4	32.1	4.57	7.19
pH	pH units	8.7	6.3	9.1	6.4
Total dissolved solids	mg/L	637	789	149	135
Biochemical oxygen demand	mg/L	<2	<2	<2	2

Water samples were collected in 2023 (23 February) and 2024 (24 February). CSU Environmental and Analytical Laboratories, Wagga Wagga.

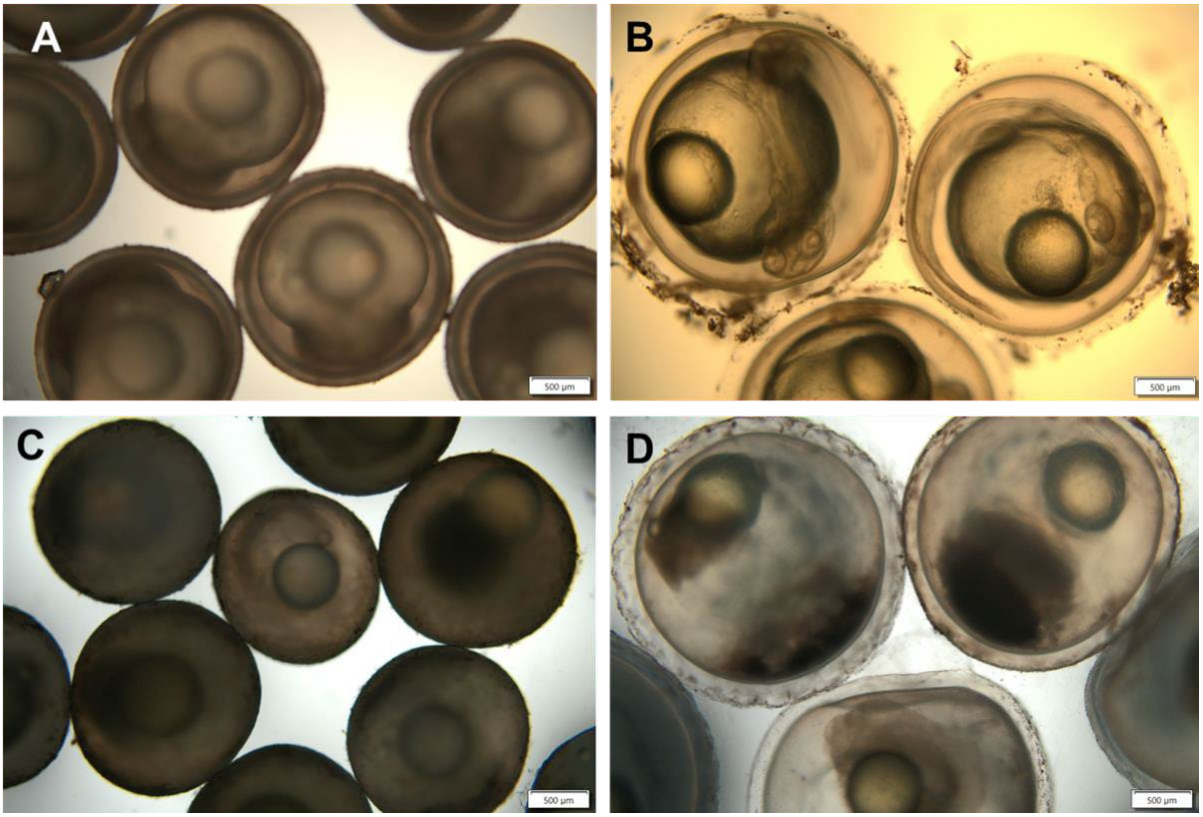

Figure 10. Healthy developing Macquarie perch embryos (A, B) and dead eggs (C, D). (Photos by J. Nocillado.)

(3). Trials to spawn wild-caught (Cataract) and F2 Macquarie perch.

A study was designed to evaluate whether small F2 broodfish (spawned in 2020) and wild - collected fish from the Cataract Dam were mature and able to spawn. To avoid possible inbreeding from the F2 population, we combined F2 female/Cataract male in tanks and Cataract female/F2 male in a tank. The initial diameters of oocytes collected from females of both groups were approximately 1400 um (comparable to those observed for the F1 and deemed mature, Fig. 11), and males were mostly running ripe with milt. Fish were hormone-induced following the protocol for Study 1 and allocated into 3 spawning tanks filled with river water and maintained at approximately 20^0C. A total of 8-9 females and 5 running males were placed together in each tank.

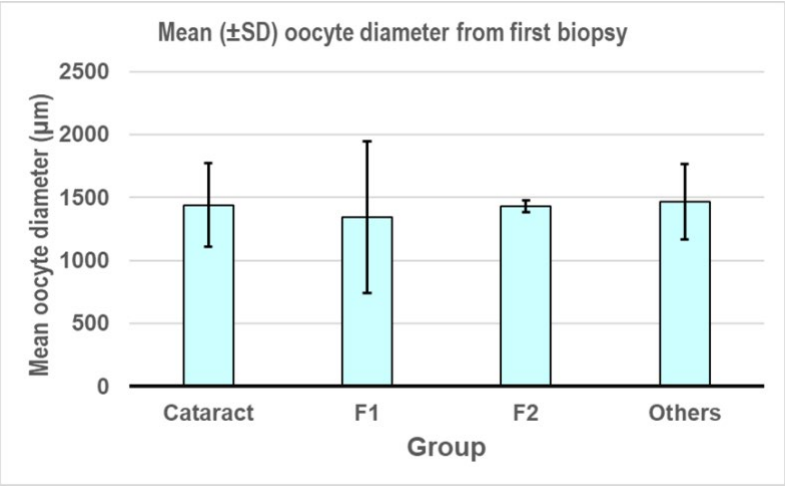

Fig. 11. Mean±SD oocyte diameter from different groups of captive-held Macquarie perch broodstock at Narrandera Fisheries Centre during the October 2024 spawning season.

Spawning was not observed from any of the three tanks and the study was terminated after about 72 post hormone induction. The reasons are unclear, as based on initial oocyte size, the fish were considered mature. However, 4-year-old F2 female fish could potentially be immature. The current cohort of F1 Macquarie perch spawned in 2013/14 were not successfully hormonally induced until 2020 (6-7 years old) and evidence from wild populations, including Dartmouth Dam, suggest the fish that contribute to spawning are older than 4 years (Zeb Tonkin, pers. comm.). The Cataract fish are likely older than the F2 fish, however, these have always been very small fish (possibly stunted) and have not spawned well in previous years. Both cohorts may require longer in captivity to reach spawning condition.

(4). Evaluated the safety of Formalin, Boric acid and NaCl on Macquarie perch eggs as controls for aquatic fungal infection (Study 2).

Aquatic fungus (*Saprolegnia spp*.) can be a major problem with incubation of freshwater fish eggs including Macquarie perch, where it can spread rapidly from dead/decaying eggs to surrounding live eggs, which become trapped in the fungal hyphae and die (Fig. 12). The current standard treatment to control aquatic fungus infection is daily baths of formalin at high concentrations (~1500 mg/l) for 15-30 mins. Formalin is dangerous to use (for the hatchery operators) as it is a known carcinogen and alternative methods to control aquatic fungus in hatcheries are needed. Boric acid and salt (NaCl) have been shown to be effective treatments for fungal infections of fish eggs, and they are safe to hatchery operators, cheap, and readily available. However, the effect of exposure to these chemicals on egg development and hatching of Macquarie perch eggs was unknown.

A study was designed to evaluate a range of concentrations and exposure times of Boric acid and NaCl compared with formalin on their safety for Macquarie perch eggs post water hardening (24-48h post spawn). Each treatment (Table 2) was replicated in triplicate 100 mL vials with lids. The vials were filled with 50 ml of treatment solution, which was changed daily. A total of 5 viable eggs were stocked into each vial which was then placed into a water bath and maintained at 23°C (Fig. 13A, 13B). Eggs were observed daily under a dissecting microscope, and any mortalities and hatched larvae were counted and removed.

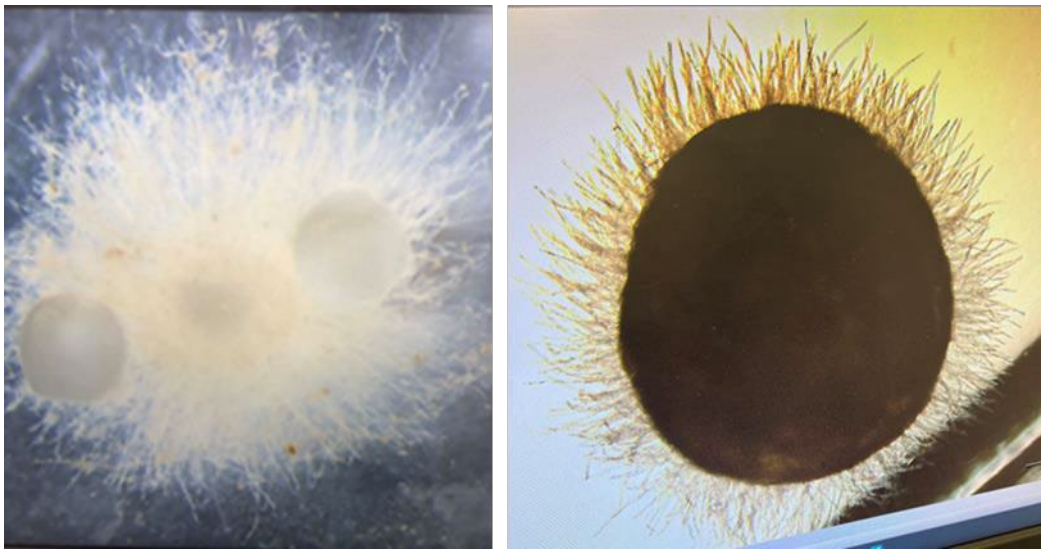

Figure 12. Dead Macquarie perch eggs covered with aquatic fungal hyphae. (Photos by S. Fielder and A. Elizur.)

Table 2. Concentration and exposure time of different treatments for Saprolegnia prevention in spawned Macquarie perch eggs.

Treatment	**Concentration (g/L)**	**Frequency**
Control (river water)		
Formalin	1.5	Every 15 min
Boric acid	0.2	Continuous
	0.4	Continuous
	0.6	Continuous
	1	Continuous
Boric acid	1	Every 4h
	1	Every 4h
	2	Every 4h
	4	Every 4h
NaCl	2.5	Continuous
	5	Continuous
	10	Continuous
	25	Every 15 min

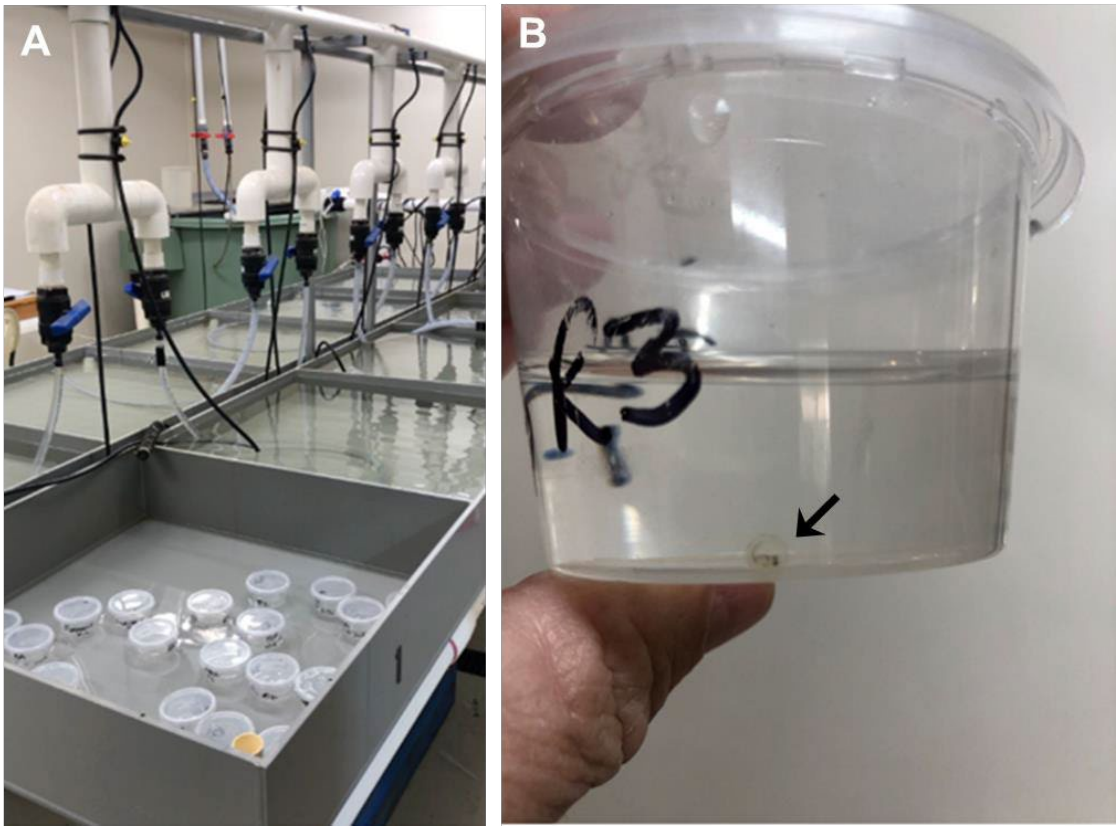

Figure 13. Experiment vials in water bath (A) and closeup view of developing Macquarie perch embryo (arrow) in a 10 ppt NaCl treatment (B). (Photos by S. Fielder.)

There was no difference among the treatment groups in hatch rate and survival (Fig. 14) to hatch. However, eggs held in the control and formalin treatments hatched more slowly than those in boric acid and salt (Fig. 15).

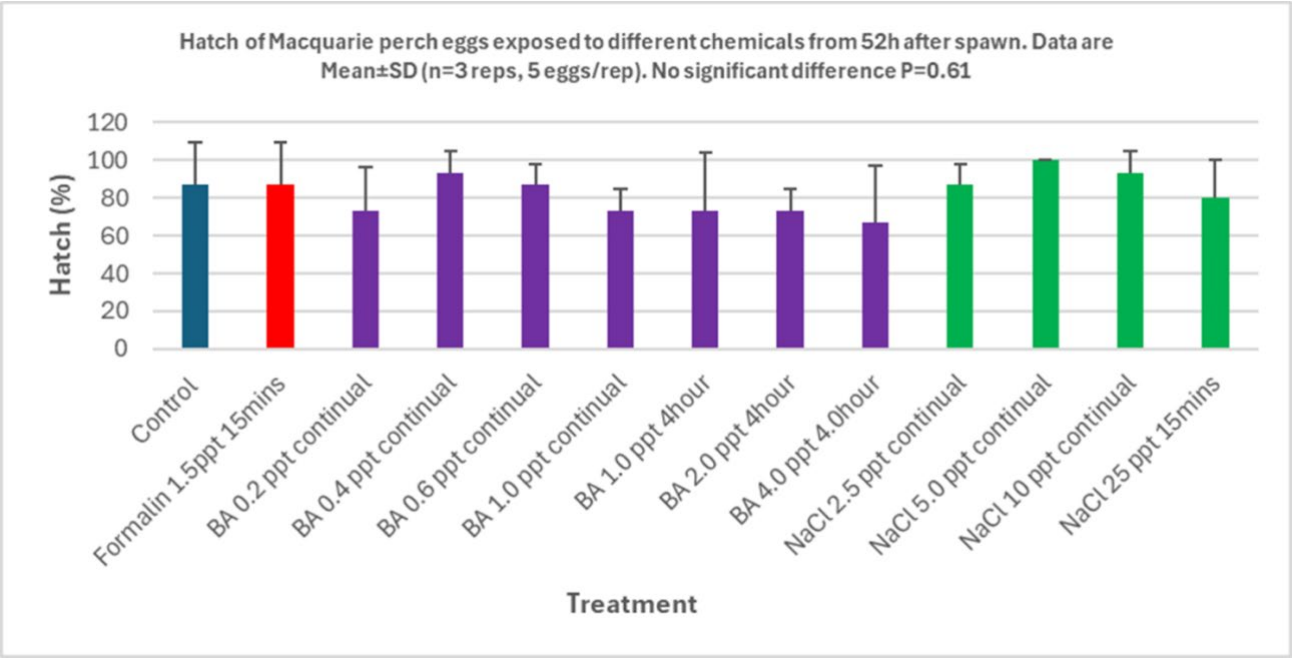

Figure 14. Hatching rate of Macquarie perch embryos incubated in different chemical solutions (formalin, boric acid, NaCl) that control Saprolegnia infestation. There was no significant difference among the treatment groups ($p > 0.05$).

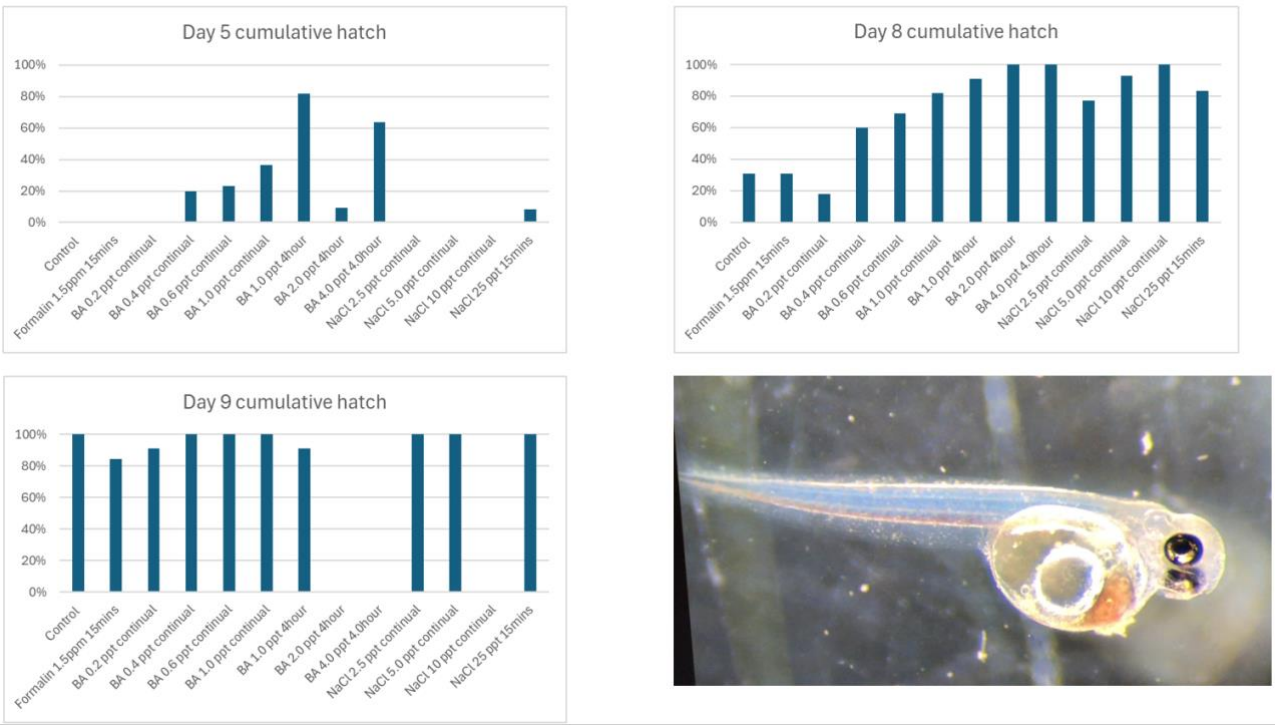

Figure 15. Cumulative hatch of Macquarie perch embryos incubated in different Saprolegnia-controlling treatments. (Photo by S. Fielder.)

All treatments for 52h post-spawn Macquarie perch eggs and hatchery operators were safe and offer cheap and effective alternatives to formalin for control of aquatic fungus infection. The use of Boric acid for the treatment of eggs is currently approved by APVMA (Permit: 94366 /142235**)** for 2 years. Further use after this period will require approval in GLP studies, which will be difficult to develop. Salt, on the other hand, is widely used at concentrations lower (3 ppt) than we tested in freshwater fish hatcheries to successfully treat aquatic fungal infections of all life stages (eggs to adult) in salt-tolerant fish species. Given the Macquarie perch eggs and larvae (this study and 2023 study) were remarkably tolerant of concentrations up to 10ppt, we recommend continual exposure of water-hardened Macquarie perch eggs to 5-10 ppt NaCl for control of aquatic fungus infection.

(5). Harvested Macquarie perch fingerlings (from October 2024 spawning) grown in the ponds at NFC and released into Winburndale Dam.

Approximately 1500 larvae were hatched, and these were grown in the incubation trays and then transferred to a 2500l tank. The larvae were reared intensively and fed a combination of Artemia nauplii and then zooplankton that was caught from ponds at NFC using plankton tow nets. A total of 300 fry were stocked at Winburndale Dam just before Christmas 2024.

(6). Collected blood (plasma) from oestradiol-induced golden perch for vitellogenin ELISA development.

The aim of this activity is to develop an enzyme-linked immunosorbent (ELISA) assay for vitellogenin, which is a defining marker of ovarian development in fish. The tool can then be used to confirm gonadal development towards the reproductive season, enabling the identification of faster-developing broodstock. The varied latency period observed after implantation with slow-release GnRHa implants suggests that gonadal development is not uniform among fish during the spawning season. Individual variation can be

determined using the vitellogenin ELISA, which may help tailor the GnRHa treatment according to maturation stage. The tool would also support the broodstock diet development in Deakin University.

As antibodies are essential to develop the ELISA, and production of antibodies require the collection of a significant volume of blood as plasma source of vitellogenin. We are using the golden perch (Fig. 16) as a substitute for the Macquarie perch as the species are closely related, and mature golden perch could be spared. With the approval of the animal ethics for this purpose, we carried out the injection of golden perch with E_2 and the subsequent collection of blood during our visit at Narrandera Fisheries Centre in October 2024.

Fig. 16. E_2-stimulated golden perch, considered as a sister species of Macquarie perch, is being used as plasma source for vitellogenin ELISA development. (Phot by A. Elizur.)

A total of 6 ml plasma was collected, quick frozen on dry ice and stored at -80°C. The plasma samples were transported to UniSC in a dry shipper. Currently, the samples are being fractionated by HPLC to isolate the vitellogenin molecules. Once isolated, antibodies will be generated by a commercial provider (Walter and Eliza Hall Institute Antibody laboratories in Melbourne), and the ELISA developed at UniSC. The long-term aim is to confirm whether the vitellogenin ELISA can be used to detect vitellogenin from mucus samples, hence avoiding invasive procedures such as blood collection and biopsy, especially for such rare captive Macquarie perch broodstock at NFC. We have previously shown this to be feasible in the giant grouper (Palma et al. 2019). We have collected mucus samples from the golden perch when we collected blood from them, and these will be used to validate the applicability of the vitellogenin ELISA.

(7). Produced recombinant Macquarie perch follicle stimulating hormone β and generated polyclonal antibodies.

A key hormone that regulates vitellogenesis in fish is the follicle-stimulating hormone (Fsh), which is produced in the pituitary gland. Circulating levels of Fsh can be measured by ELISA. As in the vitellogenin ELISA, Fsh ELISA requires homologous antibodies, which can be generated if a sufficient quantity of Fshβ subunit is available. The production of Fshβ by recombinant means is currently the best approach to achieve this. We obtained the DNA encoding sequence of Macquarie perch Fshβ from the publicly available genome sequence and designed an expression construct so that the hormone peptide can be produced in yeast as illustrated in Fig. 17. Polyclonal antibodies have now been produced, and we are currently developing the Fsh ELISA following the methods described in Nocillado et al. (2023), which was an ELISA we developed for the Macquarie perch luteinizing hormone.

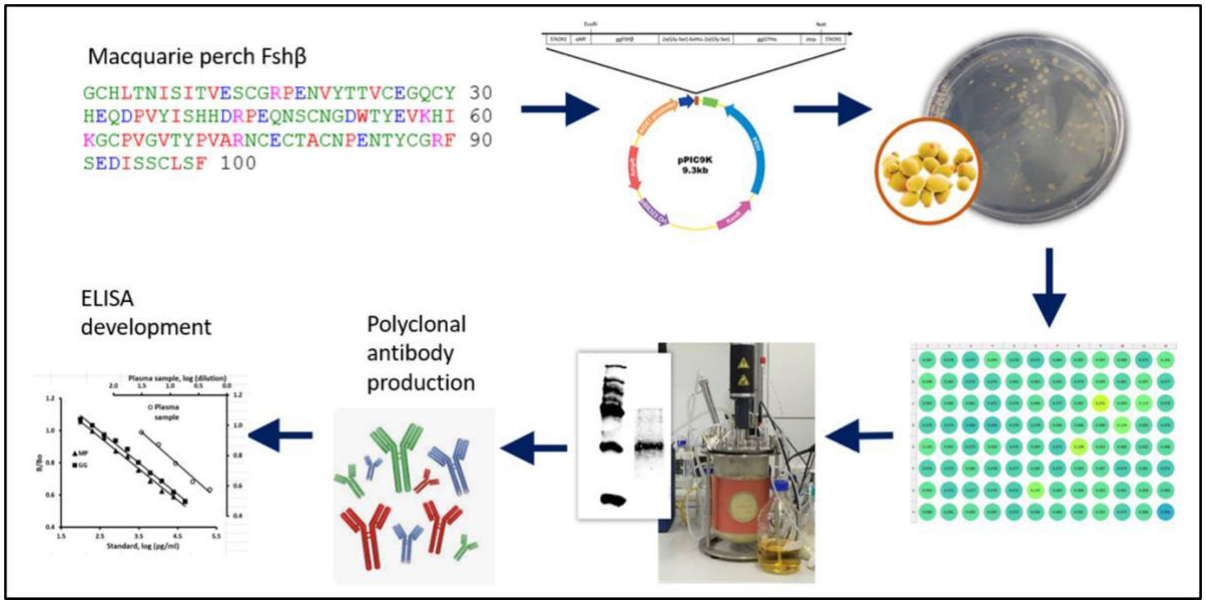

Fig. 17. Schematic diagram of the development of follicle-stimulating hormone ELISA for Macquarie perch.

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Nocillado J, **Gilligan D**, **Fielder S**, **Dennis LP**, Wang T, **Ventura T**, **Elizur A**. Recombinant luteinizing hormone as a tool towards understanding reproductive dysfunction in captive Macquarie perch *Macquaria australasica*. Endangered Species Research 51: 285-291.

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Acknowledgements

We thank the NFC staff for their assistance throughout the year. We thank Dr. Tianfang Wang from UniSC for assistance on pheromone analysis.

PUBLICATIONS/PRODUCTS

We are working towards a publication describing the spawning success achieved using the slow-release GnRHa implants.

SPECIAL CONDITIONS

NA.

INTELLECTUAL PROPERTY ISSUES ARISING:

NA.

CONTACT WITH BENEFICIARIES:

NA.

PROGRESS AGAINST COMMUNICATION & EXTENSION PLAN:

NA.

VARIATIONS TO PROJECT: NA.

Original due date	Original Detail	Original Cost	Status	Requested due date	Requested Detail	Requested new Cost

Appendix H

Stocky Galaxias catchment survey 2025

Stocky Galaxias (*Galaxias tantangara*) catchment survey 2025: search for relictual populations and potential translocation sites

Preliminary report

T.A. Raadik, H. Allan and L. Pearce

August 2025

Arthur Rylah Institute for Environmental Research Report

NSW GOVERNMENT

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VICTORIA State Government | Energy, Environment and Climate Action

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Front cover photo: Rules Creek Falls, Yarrangobilly, NSW (Tarmo A. Raadik).

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it.

We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

DEECA is committed to genuinely partnering with Victorian Traditional Owners and Victoria's Aboriginal community to progress their aspirations.

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Stocky Galaxias (*Galaxias tantangara*) catchment survey 2025: search for relictual populations and potential translocation sites

Preliminary report

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Summary

Context:

Snowy 2.0 is a major hydro-electric project connecting Talbingo and Tantangara reservoirs in southeastern Australia. While it brings energy benefits, it creates risks for native fish, especially the Stocky Galaxias (*Galaxias tantangara*). In response, one of the management measures was a Threatened Fish Management Plan (TFMP), which was developed to manage impacts and support the species' long-term survival.

The catchment survey is a key component of the TFMP measures for Stocky Galaxias. In involved surveys focusing on trout-free, permanent streams, mostly upstream of natural or artificial barriers. It aimed to confirm the species' distribution and assess habitat suitability across several alpine catchments. Due to the difficulty of field identification, species-level analysis on any galaxiids found during the surveys is still pending. This report presents initial results from the first survey year.

Aims:

The primary aims of the catchment survey for Stocky Galaxias are to:

- Determine the current distribution by searching for additional relictual populations.
- Identify potential habitats suitable for future translocations.

Methods:

The catchment survey followed the TFMP methodology and the design by Raadik and Lintermans (2022c), with updates reflecting the discovery of a second population and new LiDAR-based techniques for identifying instream barriers. The survey included three phases: desktop analysis to identify potential trout-free reaches, a field assessment to confirm habitat suitability, and additional later assessment of priority sites (not included in this report).

Desktop assessments excluded reaches likely to contain trout or dry seasonally, using historical fish data and, initially, mapping. The mapping was replaced by a new LiDAR-based method to detect steep gradients as potential trout barriers. Reaches were filtered by elevation, stream order, and land use, and prioritised based on barrier size, upstream habitat length, and accessibility.

Field assessments were conducted at 110 sites across 60 streams using single-pass electrofishing. Galaxiids were photographed, measured, and sampled for genetic and morphological analysis. The sites were selected upstream of known or likely barriers, reducing the need for on-ground barrier checks. Water quality and habitat features were recorded at each site.

Post-survey reach prioritisation excluded trout-occupied or marginal sites and ranked remaining reaches based on fish absence, galaxiid presence, catchment size, and water permanency. Fishless reaches were favoured as potential translocation sites while those with galaxiids have been flagged for genetic and taxonomic assessment to determine if any contain Stocky Galaxias. The final prioritisation identifies the best candidates for future use in translocations, based on ecological suitability and feasibility.

Results:

Field Assessment Summary:

Surveys at 110 sites across southern NSW were completed between November 2024 and April 2025. Three fish species were detected: native galaxiids (*Galaxias* spp.) and introduced Brown and Rainbow Trout. Two native crayfish species were also recorded. Of the sites, 42 had trout, 30 had galaxiids, 34 were fishless, and 4 were dry. Trout and galaxiids were mutually exclusive at nearly all sites, with only one exception.

Site Prioritisation and Exclusions:

Following initial screening, 64 sites remained after excluding those with trout or dry conditions. These were grouped by stream reach and assessed against three exclusion criteria: no downstream trout barrier, catchment area under 2 km², or concerns about water permanency. This led to the removal of 22 more sites, mainly in the Goodradigbee and Murrumbidgee catchments. In total, 32 trout-free stream reaches were identified as suitable for potential galaxiid translocation.

Final Rankings and Next Steps:

The 32 suitable reaches were ranked in order of potential suitability for translocations with seven reaches identified as potentially suitable ‘fishless’ translocation sites and 25 sites where galaxiids were detected. All sites require further assessment, including confirming fish identity, verifying of reconfirming downstream barriers, and evaluating habitat suitability. These results will guide Stocky Galaxias conservation and translocation planning.

Conclusions and Implications:

This first catchment survey made strong progress in identifying suitable habitats for future translocations of Stocky Galaxias. Thirty-five trout-free reaches were prioritised from 110 assessed, with several high-ranking sites considered strong candidates for early-stage translocations. While species distribution could not yet be confirmed due to identification limits in the field, genetic and morphological analyses are underway. These will help confirm potential range extensions and refine conservation priorities.

The survey also revealed the critical role of natural barriers, like waterfalls, in protecting upland galaxiids from trout. Sites were prioritised using ecological criteria such as water permanency, catchment size, and absence of trout. Fishless sites were given higher priority, although some may later prove unsuitable. Field assessments were limited to single points per reach, introducing some uncertainty. However, this was balanced by focusing on short, uniform stream sections likely to reflect upstream conditions.

This project significantly advances the conservation of Stocky Galaxias by identifying locations where translocated populations could persist and expand. If newly collected galaxiids include previously undocumented populations, they may offer valuable genetic diversity for breeding programs. These findings lay the groundwork for the next recovery steps and highlight the urgent need to act while suitable, trout-free habitats remain available.

1 Introduction

In 2020, Snowy Hydro Limited received approval to implement a large-scale pumped hydro-electric storage and generation scheme known as Snowy 2.0. This ambitious project aims to enhance the hydro-electric capacity of the existing Snowy Mountains Hydro-electric Scheme by connecting the Talbingo and Tantangara reservoirs. The connection will involve a series of underground pipes and a power generation station, allowing for water to be transferred between two separate river catchments in both directions. While the project offers significant energy benefits, it also raises concerns about potential environmental impacts, particularly for native threatened fish species.

As part of the approval process for Snowy 2.0, both the NSW and Commonwealth governments required the development of a Threatened Fish Management Plan (TFMP). This plan outlines a range of monitoring and management actions for threatened and alien fish species (Snowy Hydro 2023). Among the species identified as being at greatest risk is the Stocky Galaxias (*Galaxias tantangara*) (Cardno 2019; Lintermans and Allan 2019; TSSC 2021).

To address the conservation needs of this species, the TFMP includes several specific management actions informed by key documents developed between 2020 and 2022 (Raadik and Lintermans 2022a, b, c, Raadik et al. 2022, Stoessel and Raadik 2022). The primary objective of the TFMP for Stocky Galaxias is to establish baseline data and implement targeted conservation management measures to support the species' long-term survival.

Recovery objectives and survey rationale

The primary goal in managing threatened species is to recover their populations, both in terms of abundance and geographic range, with the longer-term aim of delisting them from threatened species legislation. Achieving this requires a clear understanding of the species' status, which can only be gained through targeted surveys across its historical or predicted former range.

As specified in the consent conditions (Schedule 3, Condition 24) of the Snowy 2.0 Main Works approval (Snowy Hydro 2023), the TFMP outlines the following actions for Stocky Galaxias, as part of an overall captive breeding program:

1. Population monitoring, surveillance and research on the Stocky Galaxias in the Upper Murrumbidgee catchment.
2. Habitat surveys to identify suitable receiving sites for stocking insurance populations of Stocky Galaxias.
3. Captive breeding, stocking and monitoring of Stocky Galaxias with the aim of achieving self-sustaining populations of these species.

To primarily address action 2, while also potentially contribute to actions 1 and 3 (e.g. through the potential discovery of previously unknown populations), a catchment survey was designed (Raadik and Lintermans 2022c). This report details its implementation.

Terminology note: While the TFMP uses the term 'habitat surveys', we follow Raadik and Lintermans (2022c) in using 'catchment surveys', as these surveys focus on stream catchments within particular catchments, not just specific instream habitats. For consistency, the term 'catchment survey', should be understood as synonymous with 'habitat survey' as used in the Snowy 2.0 Main Works consent conditions and the TFMP (Snowy Hydro 2023).

The primary objectives of the catchment survey, as defined by Raadik and Lintermans (2022c), are to:

- Identify potential habitats suitable for future translocations.
- Determine the species' current distribution (i.e., search for additional relictual populations).

This information is crucial for guiding conservation decisions aimed at improving the species' long-term viability. Once the distribution and abundance of extant populations are better understood, recovery strategies can be refined. These may include:

- Enhancing protection of existing populations.
- Establishing new populations via translocation.

Identifying suitable translocation sites is a key component of the overall recovery planning process. Like many other highly threatened galaxiids in south-eastern Australia, the Stocky Galaxias cannot persist in streams where introduced trout species (Brown Trout (*Salmo trutta*) and/or Rainbow Trout (*Oncorhynchus mykiss*)) are present (Raadik et al. 2010, Raadik 2014, Lintermans and Allan 2019, Lintermans et al. 2020; Raadik and Lintermans 2022a). This intolerance is clearly demonstrated in the distribution of both known populations, which are limited to trout-free stream reaches located upstream of waterfalls.

Consequently, the catchment survey prioritised stream reaches with the following characteristics:

1. Absence of trout, typically located upstream of natural (e.g., waterfalls) or artificial barriers (e.g., weirs).
2. Permanent water, with sufficient flow and habitat conditions to support self-sustaining fish populations.

This approach represents a refinement of the earlier prioritisation framework developed by Raadik and Lintermans (2022c), which included stream reaches with trout or trout access, but ranked them lower in priority. In the revised framework, such reaches are excluded entirely due to the high cost, logistical complexity, and varying effectiveness associated with trout management

This report presents the implementation and results from the first year of the Stocky Galaxias Catchment Survey. It is considered preliminary, as it does not include species-level identification of any galaxiids from the Mountain Galaxias species complex (as defined by Raadik 2014) encountered during fieldwork. This limitation is due to the difficulty of distinguishing Stocky Galaxias in the field from the morphologically similar Mountain Galaxias (*Galaxias olidus*), which is also present in the study area (Raadik 2019).

Accurate identification of collected specimens requires detailed morphological and genetic analysis, which is being undertaken as a separate but complementary component of the catchment survey. This species-level analysis is expected to be completed during the early part of the 2025–2026 TFMP implementation period.

1.1 Project area

As defined by Raadik and Lintermans (2022c), the overall project area comprises the following catchments (Figure 1):

- The headwaters of the Murrumbidgee River, which still contain a viable population of Stocky Galaxias.
- The upper reaches of the Goodradigbee River catchment, where a population of Stocky Galaxias was recently found (Lintermans et al. 2021).
- Several neighbouring catchments, including the Yarrangobilly River, the Tumut River upstream of Talbingo Reservoir, and the headwaters of the Goobarragandra and Eucumbene rivers.
- A section of the Murrumbidgee River catchment located downstream of the Tantangara Reservoir.

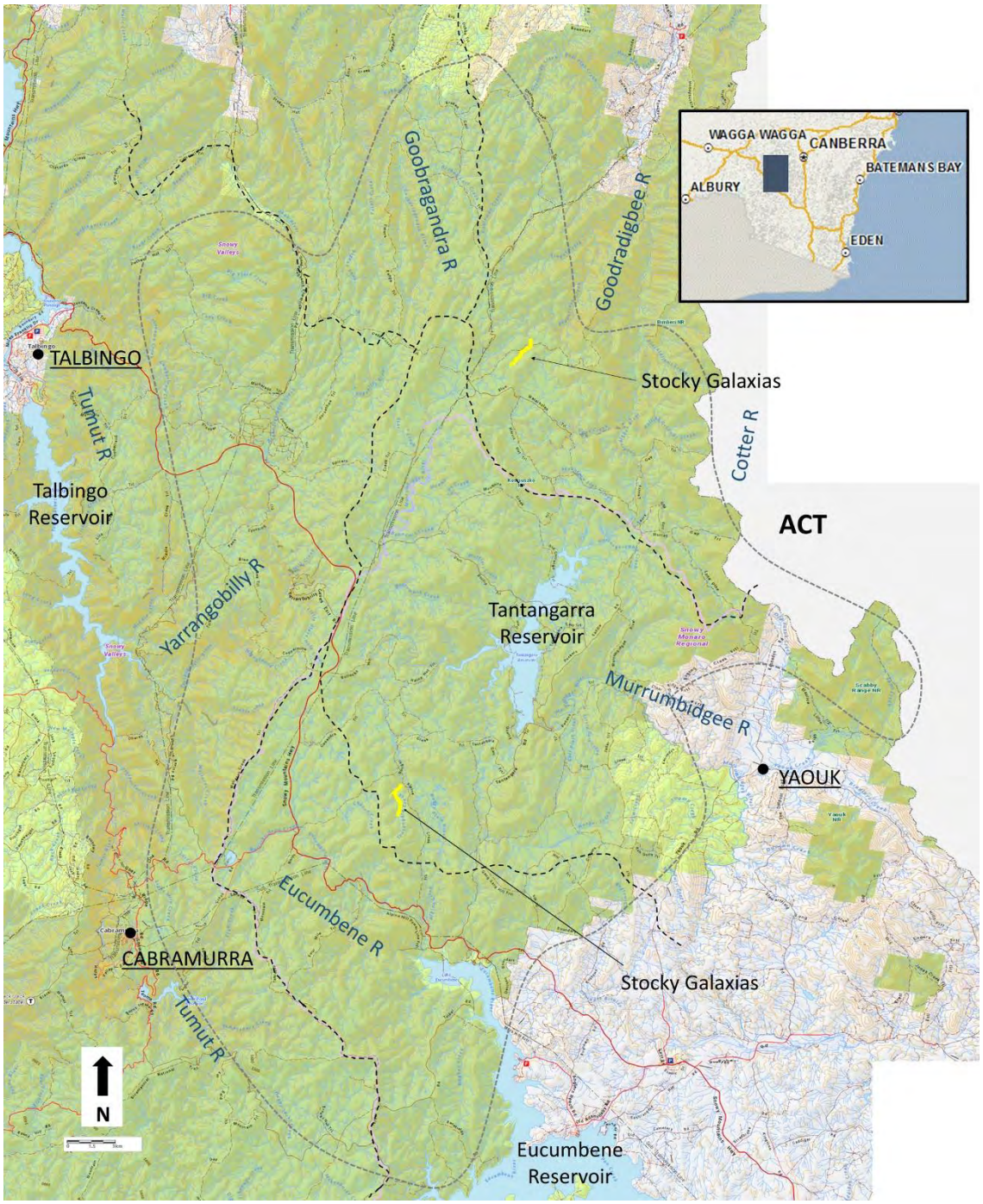

Figure 1. Broad project area for the Stocky Galaxias catchment survey in south-eastern New South Wales, encompassing the region between Talbingo, Cabramurra, and Yaouk.

Black dashed lines represent catchment boundaries, while the grey dashed line outlines the approximate extent of the Stocky Galaxias survey area. Short yellow lines represent the extent of the distribution of both known Stocky Galaxias populations. Adapted from Raadik and Lintermans (2022c).

2 Methods

The Stocky Galaxias catchment survey followed the TFMP methodology (Snowy Hydro 2023) and the detailed survey design by Raadik and Lintermans (2022c).

As the first field implementation of this design, the survey also served as a valuable opportunity to assess its practical effectiveness, particularly considering two significant developments since the design was finalised three years prior:

- The discovery of a second Stocky Galaxias population (Lintermans et al. 2021).
- The development of an improved method for identifying potential instream barrier locations (Allan et al. 2025), discussed further below.

The survey approach comprised three key phases, as outlined by Raadik and Lintermans 2022c and illustrated in Figure 2:

1. Desktop assessment
   Identification and prioritisation of potentially suitable stream reaches based on trout distributions and dispersal barriers, followed by selection of representative field sites within reaches for field assessment.
2. Initial 'rapid' field survey
   Field assessment for the presence of trout and species of galaxiids and suitable habitat, leading to the exclusion of unsuitable reaches and prioritisation of suitable reaches for implementation or further investigation.
3. Detailed field survey
   Comprehensive assessment of sites where galaxiids were detected or where translocation may be feasible, focusing on Priority A and B sites.

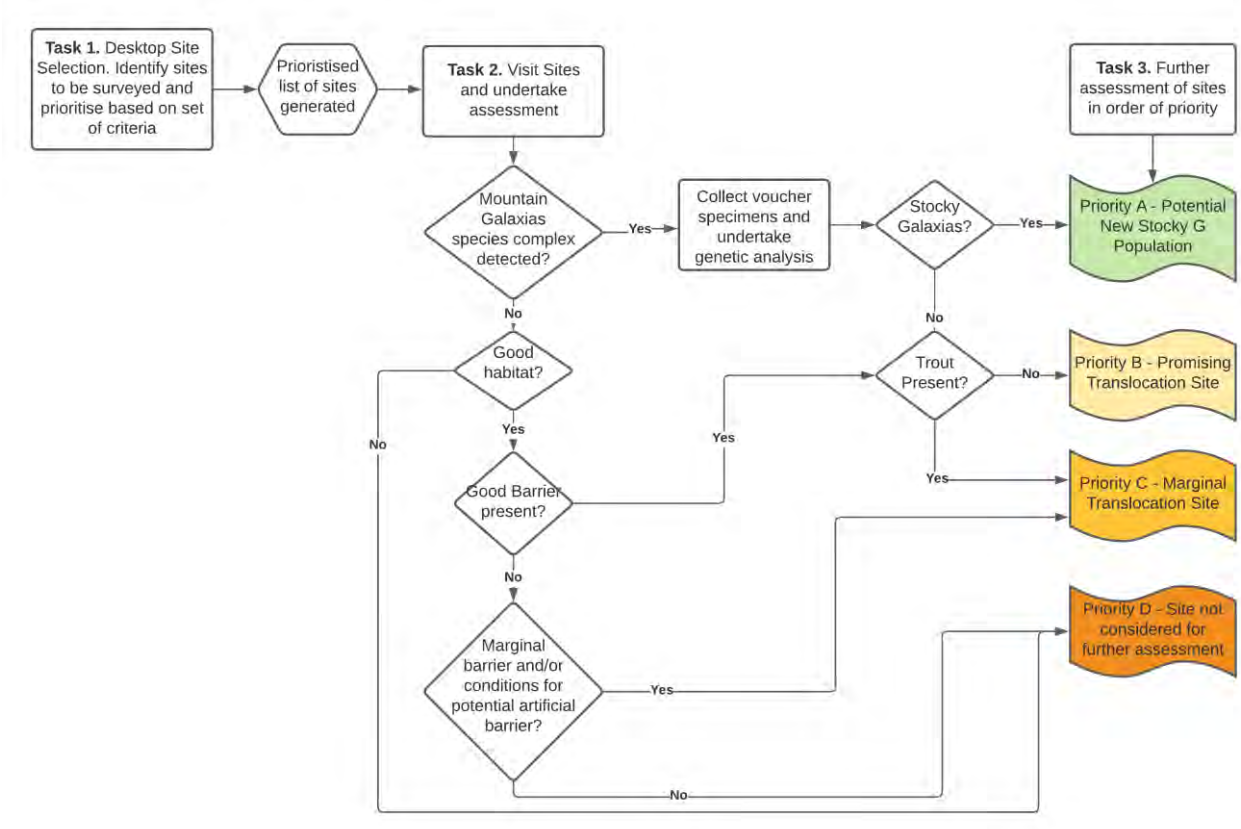

Figure 2. Flow chart summarising the catchment survey tasks and associated activities for Stocky Galaxias (from Raadik and Lintermans 2022c).

Note: Task 3, the detailed field survey, is not part of the current catchment survey and is therefore not discussed further in this report.

2.1 Desktop site selection

Site selection within the project area (Figure 1) began with refining the stream network to exclude reaches known or suspected to contain trout, the competitor species Climbing Galaxias (*Galaxias brevipinnis*), or be seasonally dry (Figure 3). This refinement was based on existing datasets (Allan and Lintermans 2019, Lintermans 2019, Raadik 2019, Weeks et al. 2019), and recent survey data (Cardno 2019, Austral 2022, Hugh Allan, unpublished PhD project data).

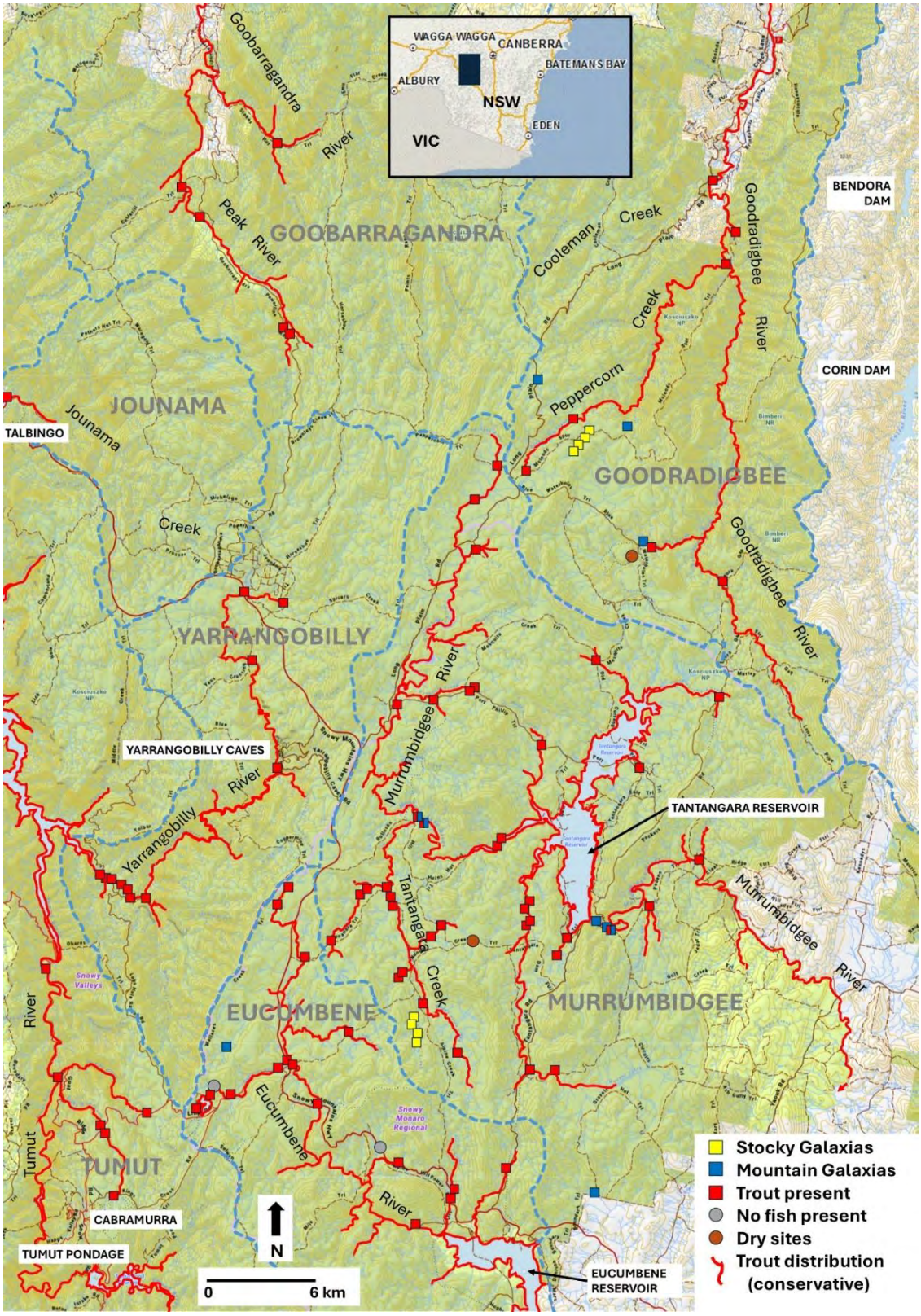

Figure 3. Location of the catchment survey area showing major stream catchments and previous fish survey records.

Dashed light blue lines indicate catchment boundaries.

Additional occurrence records were sourced from the biodiversity databases, including the NSW BioNet and Atlas of Living Australia. However, a significant dataset collected from the study area as part of the *Saving the Spinys'* project (part of the Australian Government's Bushfire Recovery for Wildlife and their Habitats initiative) was not made available for this study.

Further, during data compilation, several spurious records were identified in the biodiversity databases, including one in Austral (unpublished). These included apparent new populations of Stocky Galaxias, detections of trout in known galaxiid reaches, and galaxiid occurrences in reaches known or suspected to support trout. These important inconsistencies were flagged as priorities for field verification during the catchment survey (see later).

For the reach exclusion analysis, all mainstem stream sections downstream of the most upstream confirmed trout detection were assumed to contain trout. It was also assumed that trout extend beyond their last known upstream detection, including into major side tributaries of the mainstem.

Analysis of the constrained stream network followed the methodology outlined by Raadik and Lintermans (2022c). This involved using topographic survey maps and high-resolution aerial imagery to identify stream reaches within the target area likely to contain waterfalls or instream barriers.

Where available, fine-scale topographic maps were examined to locate areas with tightly spaced contour lines adjacent to streams, typically indicative of steep, incised gorges. These landforms often feature step changes in elevation or waterfalls. Steep stream gradients were also inferred where streamlines crossed multiple contour lines over short distances. Additionally, abrupt changes in stream direction were considered as possible signs of resistant bedrock, which may be associated with the formation of waterfalls.

These potential barrier sites were then cross-checked using aerial imagery. Additional features such as exposed bedrock across stream channels, whitewater, and plunge pools were used as visual indicators to confirm likely waterfall presence and prioritise sites for field assessment. However, this method was often limited by factors such as dense vegetation cover, which obscured stream channels, and variability in image resolution. As a result, the approach yielded few confirmed sites.

Because aerial and topographic assessments were time-consuming, often inconclusive, and led to the identification of only a limited number of potential barrier sites –especially when waterfalls were not directly visible, a recently developed, more efficient approach was adopted. This involved using high-resolution Light Detection and Ranging (LiDAR) data to detect steep stream gradients over short distances, a characteristic commonly associated with waterfalls. Unlike aerial imagery, LiDAR is not obstructed by vegetation, and its outputs can be validated against known locations of waterfalls. This method significantly improved the efficiency and accuracy of potential barrier detection, allowing unsuitable stream reaches (e.g., those potentially accessible to trout) to be excluded early in the process.

The LiDAR-based method, described by Allan et al. (2025), involves analysing Digital Elevation Models (DEMs) and derived digital stream networks. The workflow used available 2 m pixel resolution LiDAR data and includes the following steps:

- DEM processing and stream network extraction were conducted using WhiteboxTools (ver. 2.4.0, J. Lindsay, see https://www.whiteboxgeo.com/) in R (ver. 4.4.1, R Foundation for Statistical Computing, Vienna, Austria, see https://www.r-project.org/), accessed through the QGIS interface (ver. 3.20.3, see https://github.com/qgis/QGIS).
- Additional analyses and site inspections were conducted in R (ver. 4.4.1).
- DEMs were pre-processed using the *BreachDepressionsLeastCost* and *FillSingleCellPits* functions to correct elevational anomalies.
- Stream networks were generated from *D8Pointer* and *D8FlowAccumulation* rasters, applying a flow accumulation threshold of 800,000 m^2 to define stream headwaters.

Once the digital stream network was constructed, key metrics were calculated for all stream points:

- Stream slope (*StreamSlopeContinuous*)
- Available stream habitat (*LengthOfUpstreamChannels* and *FarthestChannelHead*)

These same metrics were also calculated for preliminary sample sites identified through earlier topographic and aerial assessments, enabling direct comparison and validation.

In the DEM-based analysis, stream slope was the primary metric used to identify potential survey sites. As demonstrated by Allan et al. (2025), stream slope is a reliable predictor of waterfalls, and therefore a strong proxy for potential trout barriers and trout-free reaches.

Sites with a stream slope of less than 18° were excluded from further consideration, based on recent analysis (Allan, H. unpublished data), which showed that slopes below this threshold are generally insufficient to prevent the upstream movement of trout. Sites with a slope of 18° or greater were retained and categorised according to potential waterfall size:

- Small 18°–20° (yellow open circle; Figure 4.).
- Medium 20°–25° (orange open circle; Figure 4.).
- Large >25° (red open circle; Figure 4.).

Potential barrier locations were calculated across the study area and classified into these three categories. Only those located within the defined target reaches (see Figure 3) were retained for prioritisation. A visual example of a portion of this DEM-based analysis is provided in Figure 4.

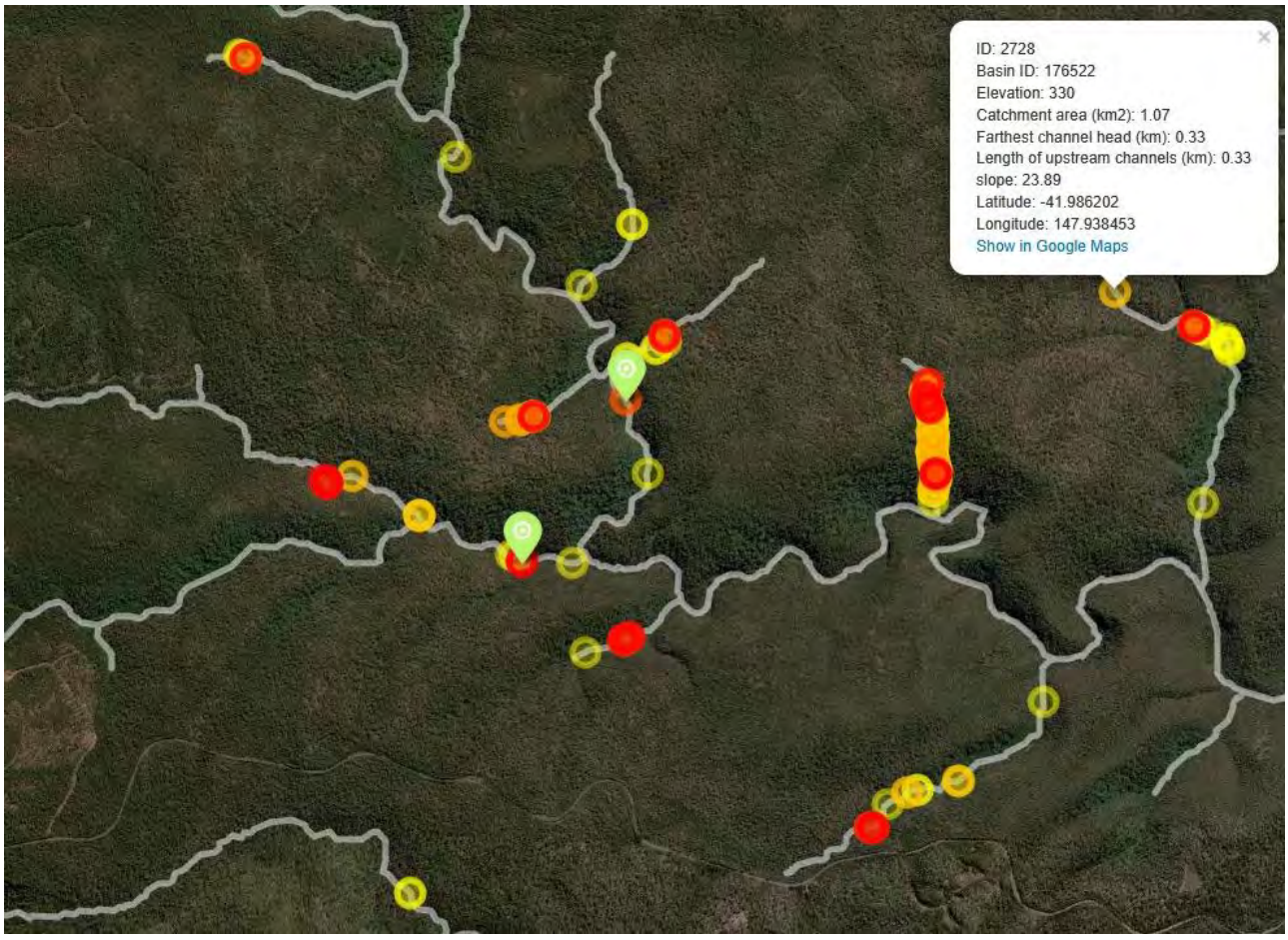

Figure 4. Example output of a DEM-based instream barrier analysis.
The stream network is delineated as white lines overlaid on the ESRI WorldImagery aerial layer. Instream barriers are represented by open circles, colour-coded to indicate size class (yellow = small; orange = medium, red = large; see above). Candidate barrier locations for assessment are marked with green pins. A sample attribute window displays derived metrics associated with each barrier. Existing access tracks appear as thin, wavy lines across the terrain. The direction of flow is to the right in the image.

2.2 Selection of stream reaches and sites for field assessment

Following the DEM-based instream analysis of potential instream barrier locations across the target stream reaches, the dataset was further refined to focus on the area selected for Year 1 of the catchment survey. This subset included reaches within the following catchments (Figure 4):

- The Goobarragandra River catchment.
- The Goodradigbee River catchment.

- The Murrumbidgee River catchment upstream of the Tantangara Reservoir wall, including Paytens Creek, located just downstream of the reservoir.
- The uppermost section of the Eucumbene River catchment.
- Part of the Tumut River catchment near Cabramurra.
- The mid- to upper reaches of the Yarrangobilly River catchment.
- The Jounama Creek catchment.

Within this refined area, stream reaches upstream of, and including DEM-identified barrier locations, were prioritised for field assessment using a set of ecological and physical criteria derived from Raadik and Lintermans (2022c) and Allan et al. (2025). Some criteria were slightly modified based on local knowledge to reduce the loss of potentially suitable reaches, particularly where uncertainty remained due to environmental variability.

Exclusion criteria

Additional filtering was applied to remove stream reaches which met any of the following conditions:

- Elevation below 900 m (1000 m in Raadik and Lintermans 2022c).
- Stream order of 1 or >5 (as defined by Strahler (1952) at 1:25,000 scale).
- Location within cleared agricultural land.

These exclusions were designed to remove areas that are:

- Outside the predicted historical range of Stocky Galaxias.
- Likely too small or intermittent to support fish populations/
- Already likely to be occupied by trout.
- Significantly disturbed by anthropogenic activity.

Prioritisation criteria

The prioritisation of the remaining stream reaches, and the selection of a representative assessment site/s within each reach, guided by the following criteria:

- Downstream barrier size: Reaches with steeper slopes (i.e. larger barriers) were preferred, as they are more likely to prevent trout passage (Allen et al. 2025).
- Multiple barriers: Reaches with more than one barrier were prioritised.
- Upstream habitat availability: Greater length of accessible upstream habitat was favoured, increasing the potential area available for galaxiid populations.
- Accessibility: To optimise time and resources, preference was given to reaches/sites that could be reached by vehicle or hiking. However, helicopter access was allocated for two days to enable assessment of a small number of high-priority, remote reaches.

An example of stream reach prioritisation for a headwater reach of Peppercorn Creek, located in the upper Goodradigbee catchment, is shown in Figure 5. This output includes the DEM-derived stream network, locations of primary and secondary access tracks, identified instream barriers with their size categories, known trout records, and potential field assessment sites within selected stream reaches. Although these sites are not always located directly at barrier points, often due to access constraints, they are positioned within the upstream reaches protected by those barriers.

Site prioritisation for assessment in this example was as follows:

- High priority
  - Site PEC2: Prioritised due to the absence of trout records and the presence of multiple barriers (large and moderate-sized), suggesting a potentially trout-free upstream reach.
  - Sites LPC1 and TR25-024: Prioritised based on a large barrier, indicating potentially trout-free upstream habitat.
- Low Priority
  - Sites PEC1, TR25-022, TR25-055, TR25-056 and TR25-057: Lower Priority because no barriers were detected in the analysis between the sites and downstream areas known to contain trout.

Sallys Flat Creek (Figure 5) was not included in the catchment survey, as it supports the second known population of Stocky Galaxias, which persists upstream of known waterfalls. The cluster of red and yellow circles in the lower reaches of the creek represents DEM-identified barriers, verifying the process. This also demonstrates the effectiveness of the Dem-based approach in locating and characterising potential trout barriers, and in identifying trout-free refuge streams that may support galaxiid populations.

A minimum headwater stream length of 2 km, as recommended by Raadik and Lintermans (2022c), was not applied during the initial prioritisation of assessment sites. Since the DEM analysis identified key barriers, applying this threshold too early risked excluding stream reaches that may support galaxiids. Instead, catchment area, which served as a good proxy for stream length and water persistence, was evaluated and used in the prioritisation process following the field assessment.

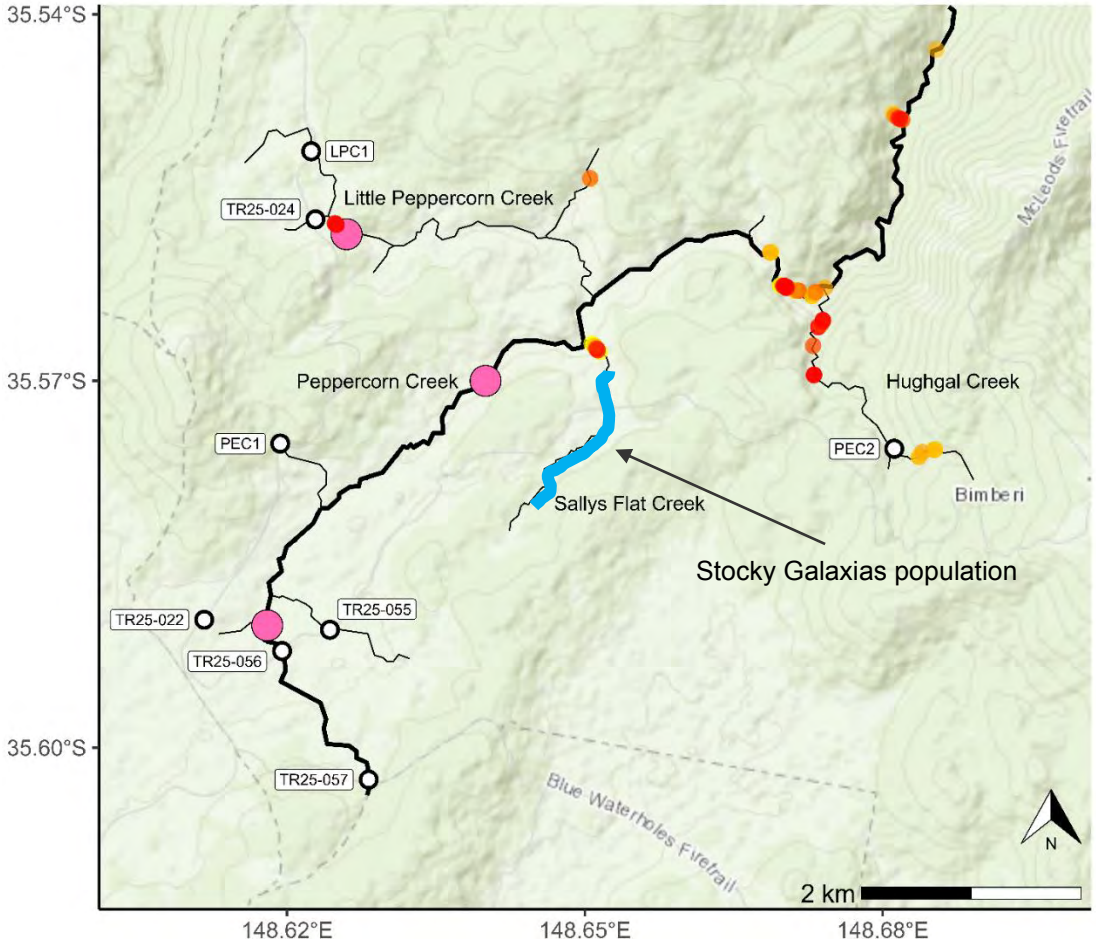

Figure 5. Example of a DEM-derived stream network barrier analysis in the headwaters of the Peppercorn Creek. The map shows potential barrier sites by stream gradients ≥18° (small, coloured circles), the location of the existing Stocky Galaxias population, recorded trout occurrence (large pink circles), and selected sampling sites (white circles) within the targeted reaches.

Stream network shown as black lines, sampling sites are indicated by white circles, and stream gradient categories are colour coded: Yellow = small (18°–20°), Orange = medium (>20°–25°), and Red = large (>25°).

Following the site prioritisation process, a total of 110 sites were selected for field assessment across suitable reaches in 60 streams within the study area (Table 1). These comprised:

- 100 sites identified through the prioritisation process described above.
- 8 of the 11 important sites identified earlier due to spurious data requiring verification (sites BR1/YBBC, LPC1, MBC, MDC3, MMcPT, PEC4, TRT3) (see Appendix 1).
- 2 sites in Dodgers Creek (Tumut catchment) used during a pilot study to test the field verification method (sites HDC1 and HDC2).

The location of each site is presented in Appendix 2 and shown in Figure 6.

Table 1. The number of streams and survey sites for assessments in the study area, grouped according to main catchments.

Catchment	Drainage Division / River Basin / Sub-basin	Number of streams	Number of survey sites
Eucumbene River	South-East Coast / Snowy River	2	2
Goobarragandra River	Murray-Darling / Murrumbidgee River / Tumut River	9	12
Goodradigbee River	Murray-Darling / Murrumbidgee River	14	34
Jounama Creek	Murray-Darling / Murrumbidgee River / Tumut River	5	6
Murrumbidgee River	Murray-Darling / Murrumbidgee River	14	22
Tumut River	Murray-Darling / Murrumbidgee River	7	10
Yarrangobilly River	Murray-Darling / Murrumbidgee River / Tumut River	9	24
Total		**60**	**110**

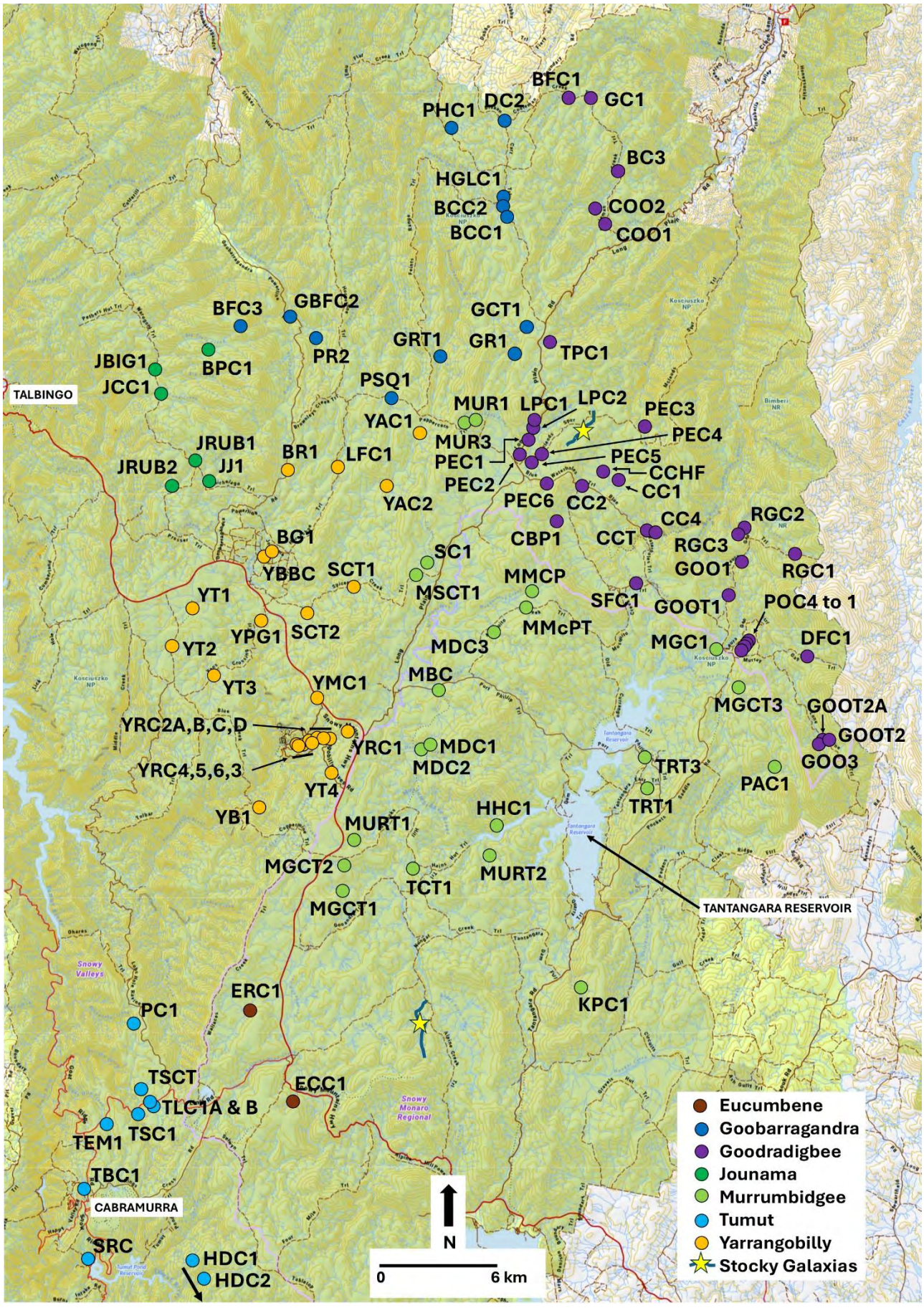

Figure 6. Location of the 110 assessment sites in the study area, including site codes.
The circle colours indicate the mainstream catchment in which each site is located (see legend).

2.3 Field site assessment process

The field assessment method for priority sites followed the recommendations of Raadik and Lintermans (2022c), except for water sample collection for eDNA analysis, which was excluded due to time and budget constraints.

Fish sampling

Fish sampling was undertaken by a team of two qualified staff, using a backpack electrofisher (Smith-Root® Model 20B), equipped with a standard braided wire cathode and an anode net covered by soft mesh. The electrofisher was operated at 700 to 990 V, with voltage adjusted based on site-specific water conductivity, at a frequency of 100 Hz with a duty cycle of 20–30%. Sampling was performed in wadable stream reaches during daylight hours.

At each site, the team proceeded in an upstream direction, with the operator and dip-netter conducting a single pass through the designated reach, sampling across all available habitat types. Stunned fish were captured using a large dipnet and transferred to fresh water in a 20 L plastic bucket.

The start and end locations of each sampling reach were georeferenced to calculate reach length. The start and end times of each sampling event were recorded to determine sampling duration. Additional data collected included:

- Power-on time of the electrofisher (in seconds).
- Average reach width (m; estimated).
- Average and maximum reach water depth (m; estimated).

Following the recommendation of Raadik and Lintermans (2022c), the sampling approach was designed to be adaptive, in recognition of the likely variation in site conditions and aquatic fauna. Accordingly, the sampling reach length was modified, adjusted at each site based on the fish assemblage detected during sampling, as follows:

- Only trout detected: reach length 30–75 m.
- Only native fish detected: minimum reach length 75 m.
- No fish detected: minimum reach length 120 m.

These modified reach lengths were implemented to improve time efficiency while maintaining a high level of confidence that a sufficient portion of the narrow upland streams had been sampled to reliably detect species presence, or to confirm their absence.

Fish processing

Following electrofishing, captured fish were removed from the 20 L holding bucket using a wet, soft, fine-mesh aquarium dip net. Fish were identified to species where possible and counted.

For galaxiids, or a subsample if more than 30 individuals were captured, caudal fork length (mm) was measured using a wetted measuring board, and weight was recorded to the nearest 0.1 g using a wet weighing dish. All fish were handled with wet hands to minimise stress and injury. Other aquatic fauna were also identified and counted.

Due to the difficulty of distinguishing Stocky Galaxias in the field from the morphologically similar Mountain Galaxias, which also occurs in the study area, genetic and morphological vouchers were collected to enable later species delineation.

The Specimen examination and voucher collection protocol consisted of the following steps:

1. Initial screening:
   All captured galaxiids were carefully visually examined to exclude individuals of Climbing Galaxias (*Galaxias brevipinnis*), if present.
2. Morphological grouping:
   The remaining galaxiids were visually assessed for variation in body pattern, colour, head and mouth shape, fin position, and other distinguishing features potentially indicative of different species or lineages.

3. Live photographic vouchers:
   Up to two representative individuals from each identified morphological group were placed alive into a plastic fish bag or an aerated, insulated holding drum and kept dark and cool. Later that evening, these fish were photographed in an aquarium to document their live body pattern and colour variation. After photography, the individuals were fixed for morphological analysis, as described below.
4. Voucher selection and collection:
   Up to 16 representative individuals from each site, reflecting observed morphological variation, were selected for tissue sampling and/or preservation as whole specimens:
   - Tissue for genetic analysis:
     A <2 mm^2 clip was taken from the caudal fin of up to 10 fish using sterile medical-grade scissors. Each sample was placed in a labelled 3 ml vial containing 100% ethanol and stored in a portable field fridge.
   - Whole specimens for morphological analysis:
     Up to 15 representative specimens (including those sampled for tissue) were over-anaesthetised and fixed as vouchers. The specimens were placed in a 250–300 ml polypropylene plastic jar containing a 10 % formaldehyde solution. A waterproof label was included, detailing the date, site code, waterbody name, collector initials and a reference to the specimen group.

After processing, all remaining fish were returned to the water at the site of capture.

Additional site characteristics

In addition to fish data, the following water quality parameters were measured:

- Water temperature (°C).
- Electrical conductivity (µS/cm @ 25°C).
- Dissolved oxygen (mg/L).
- pH.

Water hardness (expressed as ppm $CaCO_3$) was also recorded if equipment was available. Turbidity was not formally measured but was visually assessed and consistently observed to be low or negligible across sites.

The following additional site characteristics, relevant to determining fish habitat suitability, were coarsely assessed through visual observation:

- Water presence: presence or absence of surface water.
- Water flow: presence or absence of flow.
- Water volume: categorised as isolated pools, trickle, low, moderate or high.
- Likelihood of water permanency: qualitatively assessed based on indicators such as fish presence, pool depth, flow characteristics, stream shading, aquatic vegetation, presence of submerged bryophytes on instream substrates, and overall channel morphology.
- Degree of instream disturbance (e.g. sedimentation): classified as low, moderate, or high.

To support visual assessments, digital images were taken at each site, capturing key instream and riparian features.

Barrier assessment

As described in section 2.1, changes to the site selection methodology meant that a full barrier search at each site, as recommended by Raadik and Lintermans (2022c), was not necessary. All selected sites were deliberately located upstream of known or likely instream barriers, eliminating the need for on-ground verification during the initial assessment phase.

The presence or absence of trout at each site provided an additional means of inferring the effectiveness of downstream barriers, with the absence of trout suggesting a likely functional barrier to upstream movement, or other catchment conditions unsuitable to fish.

For any sites later prioritised as potentially suitable for Stocky Galaxias translocation, a detailed assessment of the downstream barrier should be undertaken before any translocation activities. This assessment would aim to confirm the barrier's effectiveness in preventing upstream trout movement and would also help to determine the full extent of trout-free stream habitat available upstream.

2.4 Post assessment site prioritisation

The post-assessment site prioritisation method originally proposed by Raadik and Lintermans (2022c) was found to be impractical. Several key limitations were identified:

- Difficulty in reliably distinguishing Stocky Galaxias from Mountain Galaxias during field assessments.
- Larger than expected catchment sizes, which reduced the fine-scale resolution and effectiveness of the original prioritisation framework.
- A revised objective to avoid sites containing trout, due to the high cost and logistical complexity involved in trout management (e.g. removal and artificial barrier construction) prior to making a site suitable for Stocky Galaxias translocation.

Consequently, a more practical and ecologically meaningful prioritisation framework was developed to guide in the identification of sites for future Stocky Galaxias translocations. This revised method incorporates a broader set of criteria to more accurately reflect site suitability for the translocation of Stocky Galaxias. Key criteria include:

- Presence or absence of trout.
- Presence and effectiveness of instream barriers.
- Combined presence/absence of galaxiid species (Stocky Galaxias and Mountain Galaxias).
- Upstream catchment area.
- Likely water permanency of the site.

This multi-criteria approach enables a more nuanced evaluation of site suitability. It provides a two-stage approach:

1. Initial filtering to exclude sites based on:
    - Presence of trout or potential trout access.
    - Very small upstream catchment area.
    - Low likelihood of water permanency.
2. Fine-scale prioritisation of the remaining sites, based on:
    - Galaxiid presence or absence.
    - Catchment size.

A decision tree outlining the revised prioritisation process is presented in Figure 7.

Increased upstream catchment size is given more weight in the ranking process, reflecting ecological principles: larger stream reaches are generally more likely to support larger, more resilient fish populations.

The rationale for prioritising fishless reaches over those with existing galaxiid populations is more complex. Firstly, there is a lack of reliable field-based methods for distinguishing Stocky Galaxias from Mountain Galaxias, which compromises the accuracy of site assessments. Once this is resolved, any sites confirmed to contain existing populations of Stocky Galaxias will be ranked highest.

Secondly, although one known Stocky Galaxias population exists with Mountain Galaxias, the feasibility of establishing a new, viable Stocky Galaxias population within an existing, viable Mountain Galaxias population remains unknown. Given this uncertainty and the high conservation status of Stocky Galaxias, fishless reaches that meet all other ecological criteria are currently prioritised higher than those with existing populations of galaxiids.

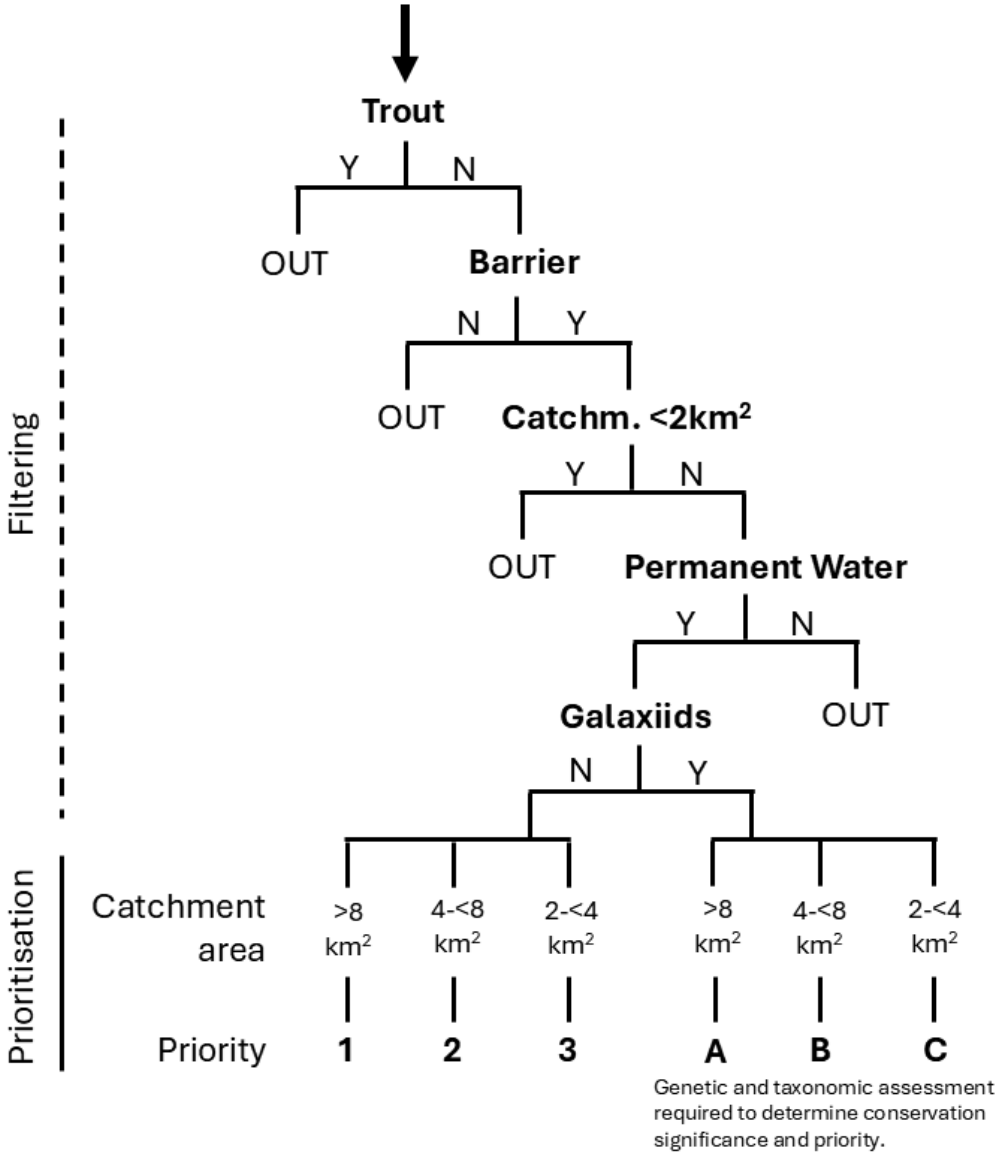

Figure 7. Post assessment sampled site filtering and prioritisation process for translocation.

Additionally, stream length as a prioritised metric, originally proposed by Raadik and Lintermans (2022c), was replaced with catchment area, following the recommendation of Allan et al. (2025). Their study reported a strong, near 1:1 correlation between stream length and catchment area in headwater systems and recommended catchment area as providing greater consistency and standardisation across regions and studies. Therefore, a minimum catchment area threshold of 2 km^2 was adopted.

Once a final list of prioritised sites is generated, additional, finer-scale criteria will need to be applied to account for site-specific or context-dependent factors that may influence final decision making (e.g. these may include aspects requiring further investigation or verification before translocation and can affect the sequencing of timing of site implementation. As such, these criteria assist in refining the post-assessment prioritisation by incorporating practical, logistical, or ecological considerations not captured in the broader assessment, potentially influencing the order in which priority sites are actioned.

3 Results

3.1 Field assessment

Field assessments were conducted at the two pilot sites in Dodger Creek in late November 2024, followed by surveys in the remaining 108 sites over three weeks in early 2025: two weeks in March (3rd–7th and 10th–14th) and one week in April (7th–11th) (see Appendix 2). Most sites were accessed by vehicle or a combination of vehicle and hiking; however, due to remoteness, six sites required helicopter access: BPC1, MDC1, MDC2, PAC1, SCI and YAC2. A complete set of survey datasheets and site images has been submitted to NSW DPIRD.

Appendix 3 provides sampling results for each site, including sampling date, species detected and their abundance, and the number of galaxiid tissue samples and voucher specimens retained. Fauna data are summarised in Table 2 and Figure 8. Selected site images are included in Appendix 4, and examples of fauna collected and backpack electrofishing are presented in Figure 9.

Table 2. The number of survey sites for assessment in the study area, grouped according to main catchments.

Catchment	Fishless sites	Galaxiid only sites	Trout only sites	Dry Sites
Eucumbene River (2)			2	
Goobarragandra River (12)	1	6	5	
Goodradigbee River (34)	10	10[1]	12	2
Jounama Creek (6)	1	4	1	
Murrumbidgee River (22)	10[2]	1	10	1
Tumut River (10)	2	3	5	
Yarrangobilly River (24)	10	6	7	1
Totals	**34**	**30**	**42**	**4**

Assessment sites ranged in elevation from 970 m (Cooleman Creek: site COO1) to 1495 m (Murrumbidgee River: MUR3).

The aquatic fauna sampled included:

- Three species of fish:
  - Native galaxiids (*Galaxias* spp.).
  - Introduced Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*).
- Two species of native crayfish:
  - Common Yabby (*Cherax destructor*) and Riek's Spiny Crayfish (*Euastacus reiki*).

Notably, no individuals of Climbing Galaxias (*Galaxias brevipinnis*) were detected.

Of the 110 sites assessed:

- 4 (4%) were dry.
- 42 (38%) contained trout.
- 30 (27%) contained galaxiids.
- 34 (31%) had no fish present.

1 Site CC4, which contains a few galaxiids and many trout, was included as a trout-only site.

2 Site MBC contained no fish but was included as a trout site as it previously held trout and has no instream barrier.

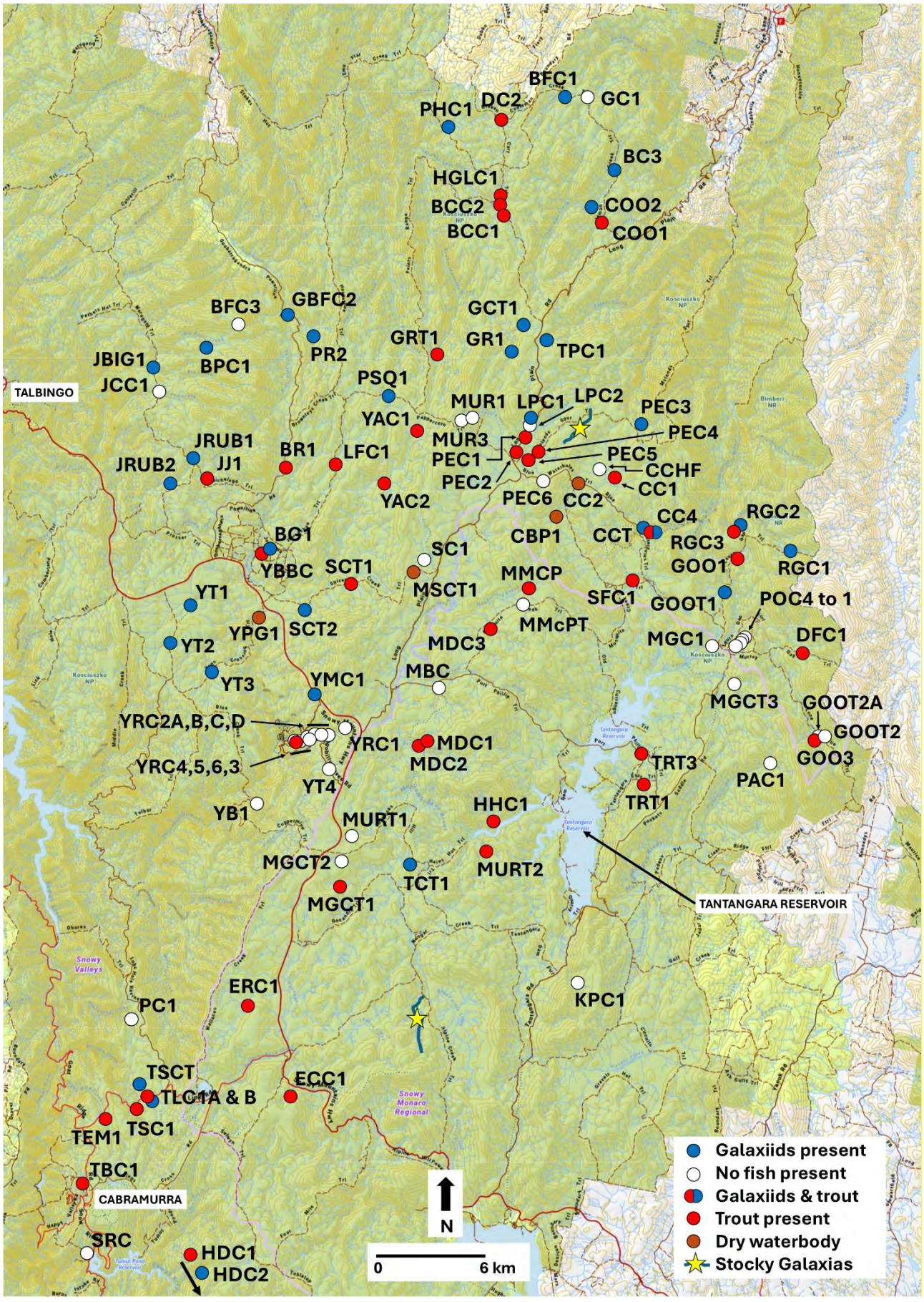

Figure 8. Results of fauna assessments at sampling sites.
See text box for explanation of coloured circles.

Excluding dry sites, trout-only sites accounted for nearly 40% of the 106 assessment sites that contained water. These sites outnumbered galaxiid-only and fishless sites, which occurred in relatively similar numbers. At all sites where fish were detected, only one fish group was present, either galaxiids or trout, but not both. The sole exception was Cave Creek (site CC4), where three adult galaxiids were recorded alongside seven Rainbow Trout. For this project, the presence of the trout resulted in the site being classified as a trout-only.

Figure 9. Examples of fauna collected during sampling, and backpack electrofishing.

A–C - *Galaxias* sp. collected from Rolling Grounds Creek (RGC1), Goodradigbee River tributary (GOOT1) and a tributary of Cave Creek (CCT), respectively; D - Rainbow Trout (*Oncorhynchus mykiss*), collected from a tributary of the Murrumbidgee River (MURT2); E - sampled fish in a collecting bucket; F - Reik's Spiny Crayfish (*Euastacus reiki*) from Seventeen Flat Creek (SFC1); G–H - backpack electrofishing in an overgrown and an open creek.

3.2 Post-assessment site prioritisation

Post-assessment prioritisation was conducted using the site prioritisation decision tree (see section 2.4).

An initial screen excluded 42 sites where trout were present and four dry sites from further consideration (represented by red and brown circles, respectively, in Figure 8), leaving 64 sites (Figure 10).

Next, catchment area calculations for each site were adjusted to represent the area upstream of the downstream barrier to trout. This ensured that the metric was equivalent to the total effective catchment area contributing to the trout-free reach, consistent with the intent of the prioritisation framework.

In some cases, the most downstream trout barrier protecting a site from trout was located a significant distance downstream, resulting in multiple sites falling within the same trout-free reach. In such instances, these sites were grouped and treated as a single stream unit. The stream name was updated to reflect the waterway containing the relevant trout barrier. The grouped sites are as follows:

- Big Creek: JBIG1 (Big Creek) and BPC1 (Big Plain Creek).
- Little Peppercorn Creek: LPC1 and LPC2 (Little Peppercorn Creek and its tributary).
- Goobarragandra River: GR1 and GCT1 (Goobarragandra River and its tributary).
- Rolling Grounds Creek: RGC1 and RGC2.
- Rules Creek: YRC1, YRC2A, YRC2B, YRC2C, YRC2D, YRC3, YRC4,and YRC6

A subsequent screening step applied three exclusion criteria, prioritised in the following order:

1. Absence of a downstream barrier, allowing potential trout access.
2. Upstream catchment area smaller than 2 km^2.
3. Potential issues with water permanency.

This screening identified an additional 22 sites for exclusion (see Table 3; Figure 10), comprising:

- 13 sites that lacked a downstream barrier, permitting trout access. (red circles).
- 8 sites with upstream catchment areas smaller than 2 km^2 (purple circles).
- 1 site with potential water permanency concerns (pale orange circle).

Most sites lacking a downstream trout barrier were in the Murrumbidgee River (7 sites) and Goodradigbee River (5 sites) catchments. Of the eight sites excluded due to a small upstream catchment area, five were also situated in the Goodradigbee River catchment (see Table 3).

Data on catchment area and water permanency for these sites is not provided.

The inclusion of a contiguous stream length upstream of a trout barrier in the prioritisation process necessitated a change in terminology, with each location now referred to as a ‘reach’ rather than a ‘site’. This change more accurately defines the unit of prioritisation as a length of stream network that could potentially sustain a population of Stocky Galaxias.

Table 3. Catchment, waterbody name, and site number of the 22 additional sites identified for exclusion during prioritisation, based on trout access, small upstream catchment area, or water permanency concerns.

Primary exclusion criterion for each site is indicated in bold text.

Catchment	Waterbody	Site Number	Trout access	Catchment < 2km2	Water permanency issue
GOODRADIGBEE	Cave Creek	CCT	**Yes**	Yes	
	Cave Creek	CCHF	**Yes**		
	Goodradigbee River	GOOT2	**Yes**	Yes	
	Goodradigbee River	GOOT2A	**Yes**	Yes	
	Peppercorn Creek	PEC6	**Yes**	Yes	Yes
MURRUMBIDGEE	Bally Creek	MBC	**Yes**		
	Gurrangorambla Creek	MGC1	**Yes**	Yes	
	McPhersons Creek	MMcPT	**Yes**	Yes	
	Murrumbidgee River	MUR1	**Yes**	Yes	
	Murrumbidgee River	MUR3	**Yes**	Yes	Yes
	Murrumbidgee River	MURT1	**Yes**	Yes	Yes
	Starvation Creek	SC1	**Yes**	Yes	
YARRANGOBILLY	Rules Creek	YRC4	**Yes**		
GOODRADIGBEE	Pocket Creek	POC1		**Yes**	
	Pocket Creek	POC2		**Yes**	
	Pocket Creek	POC3		**Yes**	
	Pocket Creek	POC4		**Yes**	
	Tin Pot Creek	TPC1		**Yes**	
MURRUMBIDGEE	Gooandra Creek	MGCT2		**Yes**	
TUMUT	Snow Ridge Creek	SRC		**Yes**	
YARRANGOBILLY	Little Glory Hole Creek	YT4		**Yes**	Yes
TUMUT	Prospector Creek	PC1			**Yes**

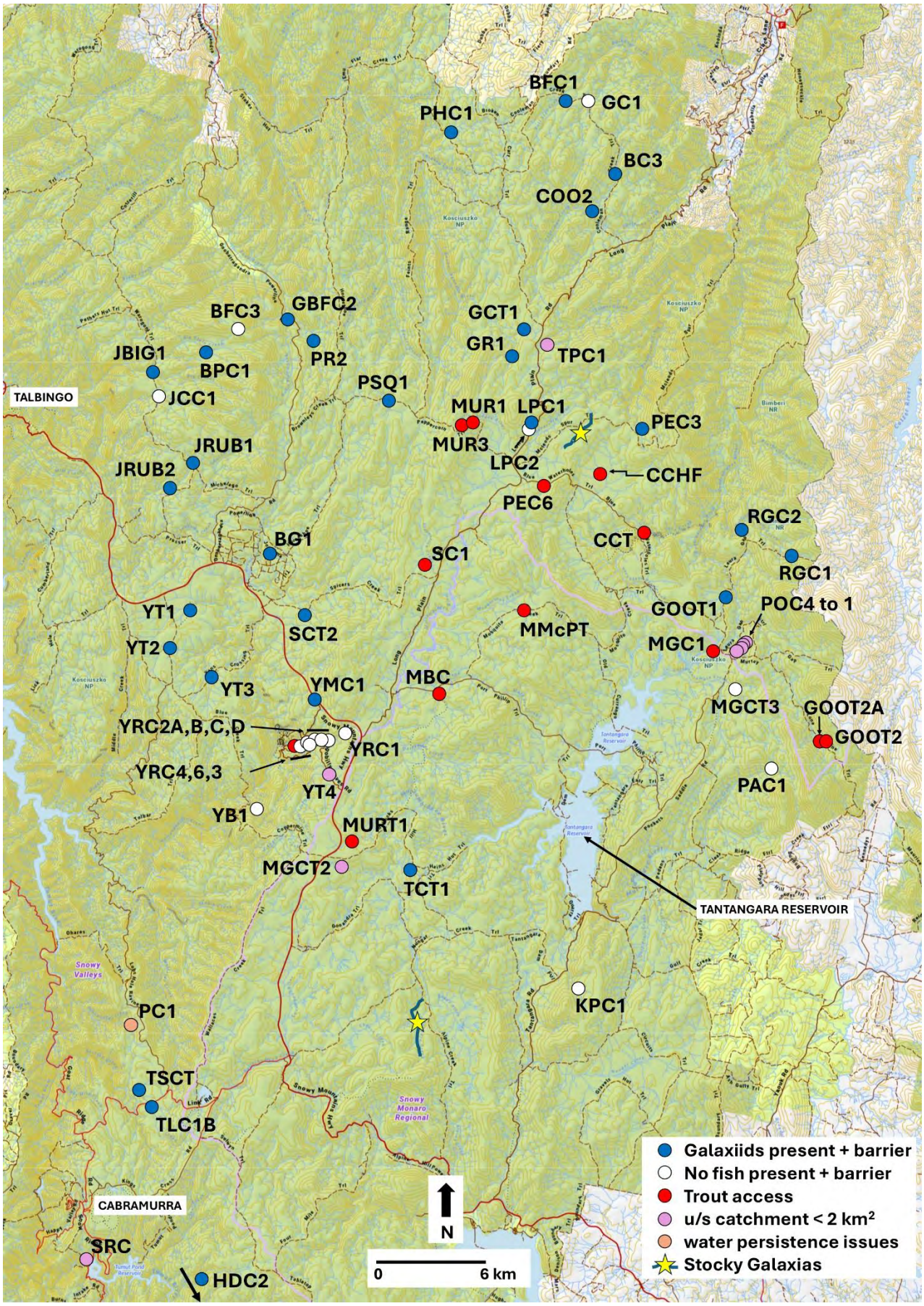

Figure 10. Sites remaining after the removal of trout-inhabited and dry sites, highlighting additional sites identified for exclusion based on: trout access (no effective downstream trout barrier), very small upstream catchment area (< 2 km^2), and potential water permanency issues.

Coloured circles. Correspond to exclusion criteria – see text box for legend.

Following the application of exclusion criteria, 32 stream reaches were identified as potential suitable future translocation locations for Stocky Galaxias. These are shown in Figure 11, which displays reach numbers, grouped site locations (where multiple assessment sites occur within a single trout-free reach), and the position of the downstream trout barrier. Note that reach YRC1 is grouped with YRC2A,B,C,D,3,6 as these reaches are located on the same stream and hydraulically connected.

The distribution of suitable reaches across the mainstream catchments is as follows:

- Goobarragandra: 6 reaches
- Goodradigbee: 8 reaches.
- Jounama: 3 reaches.
- Murrumbidgee: 4 reaches.
- Tumut: 3 reaches.
- Yarrangobilly: 8 reaches.

Key characteristics of these sites are presented in Table 4, including:

- Upstream catchment area and elevational range.
- Presence or absence of galaxiids.
- Presence of stream flow.
- Reach parameters, including average width, average and maximum water depth.

Note: The criterion water permanency is not included in Table 4, as all sites at this prioritisation stage were assessed as highly likely to contain permanent water.

Water quality data for the suitable reaches are presented in Table 5. All values fall within ranges considered suitable for the survival of small stream fish.

Final prioritisation

The final step in the assessment process involved ranking the 32 suitable reaches on the presence/absence of galaxiids and the size of the upstream catchment area. The results are provided in Table 6, where reaches are listed alphabetically within each priority rank, and visualised in Figure 11.

The distribution of the preliminarily prioritised categories and associated reaches is summarised below:

- **Priority 1:** Fishless reach and a large upstream catchment area:
    - Goodradigbee: Greenhide Creek - GC1.
- **Priority 2:** Fishless reach and a moderately sized upstream catchment:
    - Three reaches
        - Jounama: Cave Creek - JCC1.
        - Murrumbidgee: Gurrangorambla Creek tributary - MGCT3.
        - Yarrangobilly: Rules Creek - (YRC1, 2A–D,3 & 6).
- **Priority 3:** Fishless reach and a relatively small upstream catchment area:
    - Three reaches:
        - Murrumbidgee: Kellys Plain Creek – KPC; Paytens Creek - PAC1.
        - Yarrangobilly: Blue Creek - YB1.

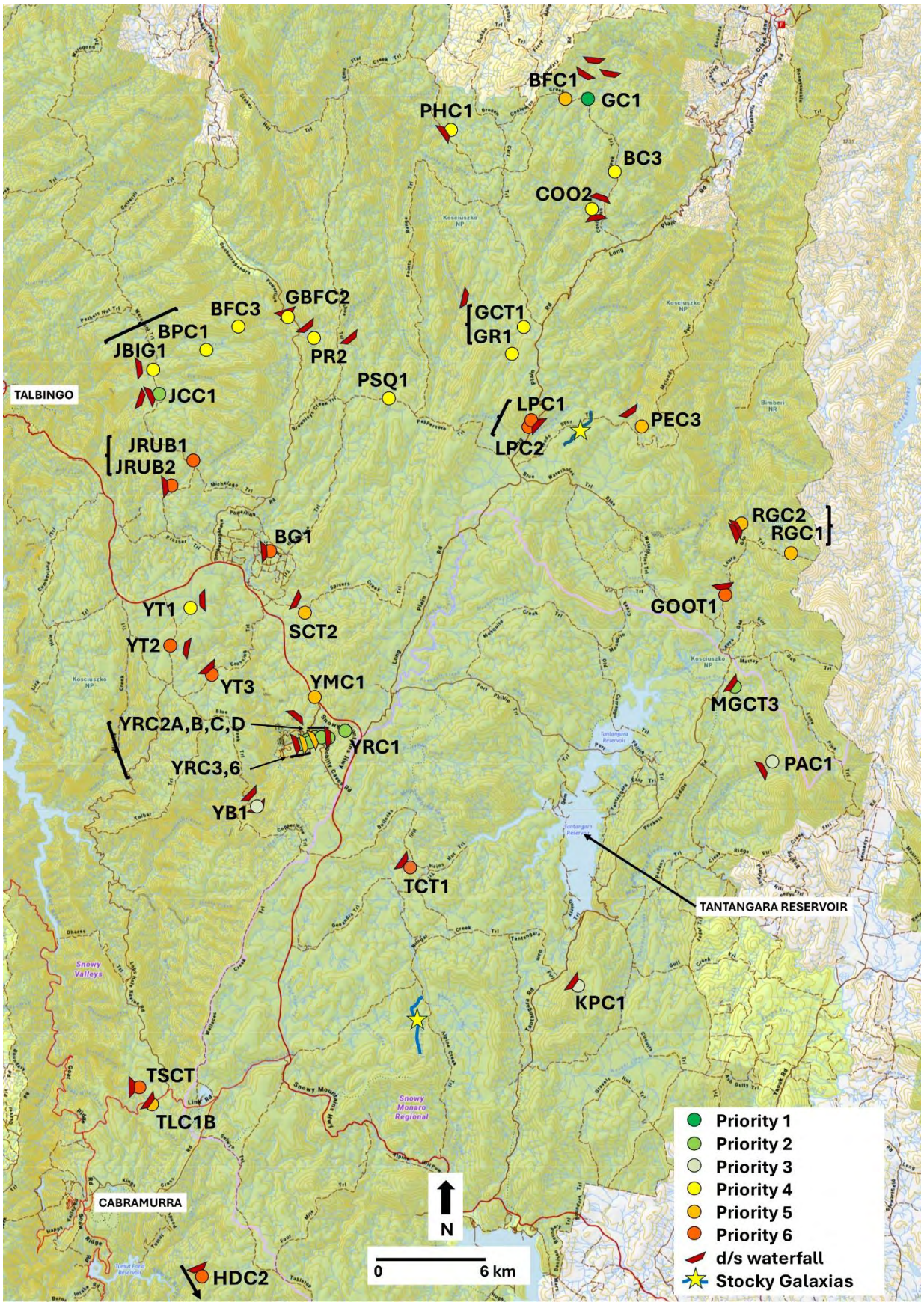

Figure 11. Remaining waterway reaches signified by sites after sites with trout access, small catchment area, and potential water persistence issues removed, ranked for usefulness as potential translocation sites for Stocky Galaxias (differing coloured circles), including the location of the closest downstream (d/s) trout barrier.

Single brackets show sites grouped into a one waterway; brown trapezoids illustrate the location of the downstream trout barriers.

Table 4. Relevant site criteria data for the 32 suitable stream reaches identified in this study.

Catchments: GA – Goobarragandra; GE – Goodradigbee; J – Jounama; M – Murrumbidgee; T – Tumut; Y – Yarrangobilly.

Site characteristics: Ave – average; Catch. – catchment; Elev. – elevation; Galax – galaxiids; max – maximum; mod – moderate flow; perm. – permanency; R – River; trib. – tributary

Waterbody (catchment)	Reach code	Catch. area (km^2)	Elev. range (m)	Galaxiids	Flow	Ave. Width (m)	Depth ave. / max. (m)
Bulls Flat Creek (GA)	GBFC2	10.2	980–1640	Yes	Mod	1.5	0.2 / 0.4
Bulls Flat Creek trib. (GA)	BFC3[3]	2.1	1475	No			
Goobarragandra River (GA)	(GCT1 & GR1)	15.2	1155–1505	Yes	Trickle–mod	1.0–2.5	0.1 / 0.4
Pheasant Creek (GA)	PHC1	8.1	1050–1295	Yes	Low	3.0	0.3 / 0.6
Peak River (GA)	PR2	8.2	1075–1355	Yes	Low	2.0	0.15 / 0.25
Pigeon Square Creek (GA)	PSQ1	9.6	1215–1355	Yes	Trickle	0.5	0.1 / 0.3
Browns Creek (GE)	BC3	9.7	1025–1330	Yes	Low–mod	1.5	0.1 / 0.24
Bull Flat Creek (GE)	BFC1	7.6	1080–1320	Yes	Low	1.3	0.1 / 0.4
Cooleman Creek (GE)	COO2	18.7	1030–1380	Yes	Low	5.0	0.3 / 0.6
Greenhide Creek (GE)	GC1	8.8	1000–1385	No	Low–mod	2.0	0.15 / 0.4
Goodradigbee River trib. (GE)	GOOT1	3.2	1210–1305	Yes	Low	0.4	0.1 / 0.2
Little Peppercorn Creek (GE)	(LPC1 & LPC2)	3.4	1375–1470	Yes	Low	1.2	0.1 / 0.4
Hughgal Creek (GE)	PEC3	4.0	1305–1575	Yes	Low–mod	1.7	0.1 / 0.4
Rolling Grounds Creek (GE)	(RGC1 & RGC2)	6.6	1220–1640	Yes	Mod	1.4–5.0	0.1–0.2 / 0.3–0.5
Big Creek (J)	(BPC1 & JBIG1)	17.0	1060–1660	Yes	Low–mod	2.2	0.15 / 0.4
Cave Creek (J)	JCC1	6.0	1105–1555	No	Mod	1.0	0.2 / 0.4
Ruby Creek (J)	(JRUB1 & JRUB2)	3.9	1090–1420	Yes	Mod	1.2	0.05–0.2 / 0.1–1.0

[3] Flow, width and depth data not given as not representative of the rest of the reach further downstream.

Waterbody (catchment)	Reach code	Catch. area (km^2)	Elev. range (m)	Galaxiids	Flow	Ave. Width (m)	Depth ave. / max. (m)
Kellys Plain Creek (M)	KPC1	2.5	1425–1565	No	Low	1.0	
Gurrangorambla Creek trib. (M)	MGCT3	4.8	1310–1545	No	Low–mod	1.1	0.075 / 0.2
Paytens Creek (M)	PAC1	3.8	1390–1625	No	Low	0.4	0.1 / 0.3
Tantangara Creek trib. (M)	TCT1	3.0	1315–1445	Yes	Low	1.0	0.08 / 0.2
Dodger Creek (T)	HDC2	2.1	1440–1660	Yes	mod	2.3	0.3 / 0.6
Larrys Creek (T)	TLC1B	6.1	1250–1590	Yes	Low	3.5	0.3 / 0.5
Section Creek (T)	TSCT	2.0	1240–1385	Yes	None	2.0	0.2 / 0.4
Back Gully (Y)	BG1	3.9	1075–1335	Yes	Low	1.5	0.1 / 0.3
Yarrangobilly River trib. (Y)	SCT2	4.2	1120–1555	Yes	Trickle	1.5	0.1 / 0.3
Blue Creek (Y)	YB1	2.6	980–1470	No	Low–mod	0.5	0.1 / 0.2
Mill Creek (Y)	YMC1	4.5	1145–1555	Yes	low	0.5	0.05 / 0.25
Rules Creek (Y)	(YRC1, YRC2A–D, YRC3, & 6)	6.5	1040–1470	No	low	1.8-2.5	0.1 / 0.7
Yarrangobilly River trib. (Y)	YT1	8.7	1055–1280	Yes	Trickle–low	2.0	0.3 / 1.1+
Yarrangobilly River trib. (Y)	YT2	2.1	1080–1165	Yes	Trickle	0.4	0.05 / 0.15
Yarrangobilly River trib. (Y)	YT3	3.2	1055–1205	Yes	Low	0.6	0.1 / 0.4

- **Priority A:** Galaxiids present and a large upstream catchment area (Genetic and taxonomic assessments required to determine species and priority):
    - Ten reaches:
        - Goobarragandra: - BFC3, GBFC2, (GR1&GCT1), PHC1, PR2, PSQ1.
        - Goodradigbee: Browns Creek - BC3; Cooleman Creek - COO2.
        - Jounama: Big Creek - (JBIG1&BPC1).
        - Yarrangobilly: Yarrangobilly River tributary - YT1.
- **Priority B**: Galaxiids present and a moderately sized upstream catchment area (Genetic and taxonomic assessments required to determine species and priority):
    - Six reaches:
        - Goodradigbee: Hughgal Creek - PEC3; Rolling Grounds Creek – (RGC1&RGC2); Bull Flat Creek - BFC1.
        - Tumut: Larrys Creek - TLC1B.
        - Yarrangobilly: Yarrangobilly River tributary - SCT2; Mill Creek - YMC1.

- **Priority C**: Galaxiids present and a relatively small upstream catchment area (Genetic and taxonomic assessments required to determine species and priority):
    - Nine reaches:
        - Goodradigbee: Goodradigbee River tributary - GOOT1; Little Peppercorn Creek tributary - (LPC1&LPC2).
        - Jounama: Ruby Creek - (JRUB1&JRUB2).
        - Murrumbidgee: Tantangara Creek tributary - TCT1.
        - Tumut: Dodger Creek - HDC2; Section Creek - TSCT.
        - Yarrangobilly: Back Gully - BG1; Yarrangobilly River tributaries - YT2 and Y3.

Although stream reaches within each priority rank share similar overall suitability scores, they still vary to some extent across individual assessment criteria. These variations included differences in:

- Physical stream and catchment characteristics.
- Water quality and instream habitat conditions.
- Fish abundance, where galaxiids were present.

Additional notes on required pre-translocation or stocking actions have been provided for all 35 ranked suitable stream reaches (Table 6). More detailed information is included for reaches within the top four priority ranks to support early-stage implementation planning.

Table 5. Water quality data for the 32 suitable stream reaches identified in this study.

Catchments: GA – Goobarragandra, GE – Goodradigbee, J – Jounama, M – Murrumbidgee, T – Tumut, Y – Yarrangobilly. **Abbreviations:** DO – dissolved oxygen; EC – electrical conductivity; Hard – hardness; Temp. – temperature; Turb. – turbidity.

Waterbody (catchment)	Reach code	Water Temp. (°C)	EC (µS/cm)	DO (mg/L)	pH	Hard (ppm $CaC0_3$)	Turb. (NTU)
Bulls Flat Creek (GA)	GBFC2	11.5	46	7.9	7.3	-	<5
Bulls Flat Creek trib. (GA)	BFC3[4]						
Goobarragandra River (GA)	(GCT1 & GR1)	7.1, 12.0	27, 52	8.0, 10.2	6.9, 7.5	-	<5
Pheasant Creek (GA)	PHC1	15.9	35	8.4	6.8	-	<5
Peak River (GA)	PR2	14.1	38	7.1	8.1	-	<5
Pigeon Square Creek (GA)	PSQ1	12.7	153	5.5	7.6	-	<5
Browns Creek (GE)	BC3	14.0	67	-	6.7	36	<5
Bull Flat Creek (GE)	BFC1	15.7	38	-	6.2	20	<5
Cooleman Creek (GE)	COO2	16.0	63	6.5	7.3	-	<5
Greenhide Creek (GE)	GC1	14.8	52	-	6.0	32	<5
Goodradigbee R trib. (GE)	GOOT1	13.3	59	7.3	7.3	-	<5
Little Peppercorn Creek (GE)	(LPC1 & LPC2)	18.2, 19.5	18	-	6.2, 6.3	6, 8	<5

[4] Site was dry, consequently water quality parameters not given. Site is not representative of the rest of the reach further downstream where water is present.

Waterbody (catchment)	Reach code	Water Temp. (°C)	EC (µS/cm)	DO (mg/L)	pH	Hard (ppm $CaC0_3$)	Turb. (NTU)
Hughgal Creek (GE)	PEC3	13.4	22	-	6.2	8	<5
Rolling Grounds Creek (GE)	RGC1; RGC2	15.3, 17.9	16, 18	7.2	6.0, 6.4	4	<5
Big Plain Creek (J)	(BPC1 & JBIG1)	14.0	12	-	6.3	-	<5
Cave Creek (J)	JCC1	13.9	17	5.9	7.2	-	<5
Ruby Creek (J)	(JRUB1 &JRUB2)	10.4, 12.9	23, 27	6.8, 7.2	7.3	-	<5
Kellys Plain Creek (M)	KPC1	14.6	13	7.8	7.2	-	<5
Gurrangorambla Crk trib. (M)	MGCT3	14.0	30	-	6.0	12	<5
Paytens Creek (M)	PAC1	16.4	19	-	6.0	8	<5
Tantangara Creek trib. (M)	TCT1	13.9	19	8.6	6.3	12	<5r
Dodger Creek (T)	HDC2	13.7	11	8.2	5.0	-	<5
Larrys Creek (T)	TLC1B	14.5	35	7.2	7.4		<5
Section Creek trib. (T)	TSCT	14.2	68	-	6.2	20	<5
Back Gully (Y)	BG1	18.0	125	-	6.9	52	<5
Yarrangobilly R trib. (Y)	SCT2	18.0	43	-	6.2	24	<5
Blue Creek (Y)	YB1	12.5	90	-	7.5	60	<5
Mill Creek (Y)	YMC1	11.0	30	-	7.3	16	<5
Rules Creek (Y)	(YRC1; YRC2A–D; YRC3, 6)	11.0	41	-	7.3	24	<5
Yarrangobilly R trib. (Y)	YT1	13.2	99	-	7.3	76	<5
Yarrangobilly R trib. (Y)	YT2	11.2	119	-	7.4	80	<5
Yarrangobilly R trib. (Y)	YT3	8.9	83	-	7.4	48	<5

Table 6. Final prioritisation of suitable stream reaches for Stocky Galaxias translocation.

Catchments: GA – Goobarragandra; GE – Goodradigbee; M – Murrumbidgee; T – Tumut; Y – Yarrangobilly. Colour coding of priority ranking matches Figure 10.

Priority	Waterbody & catchment	Reach code	Comment
1	Greenhide Creek (GE)	GC1	The reach lies near the proposed lower elevational limit for Stocky Galaxias, and, unusually, contains no galaxiids despite neighbouring catchments supporting them. The downstream barrier (a waterfall) has not been inspected. Further work is needed to assess the barrier's integrity, check for trout presence below the falls, and conduct additional surveys upstream in the lower portion of the trout-free reach.
2	Cave Creek (J)	JCC1	Further work is needed to confirm fish absence, and to assess the two large barriers downstream of the track, including fish sampling above and below, to determine the extent of the trout-free reach.
2	Gurrangorambla Creek trib. (M)	MGCT3	Further work is needed to confirm trout absence upstream and to identify additional barriers to trout movement that could improve site security against trout incursion.
2	Rules Creek (Y)	YRC1, YRC2A–D; YRC3 & YRC6	The reach has been well surveyed and, pending confirmation of trout and other fish absence before translocation, is **currently suitable** for establishing a new Stocky Galaxias population. Initial stocking should focus upstream of the large waterfall, with later expansion into the middle section between the waterfall and the reservoir.
3	Blue Creek (Y)	YB1	The reach downstream of the waterfall and old copper mine has not been surveyed for fish or additional barriers. Further work is needed to identify waterfalls and to survey for trout and galaxiids to determine the extent of the downstream trout-free reach. Detailed water quality analysis, particularly alkalinity and metals, is also required due to potential contamination from mine-related groundwater, which may impact galaxiids.
3	Kellys Plain Creek (M)	KPC1	Further work is needed to confirm fish absence, and to assess downstream barrier numbers and water permanency, including the availability of deeper water habitat.
3	Paytens Creek (M)	PAC1	Further work is needed to confirm fish absence, and to assess the location of the downstream barrier to determine the extent of the trout-free reach.
4	Big Plain Creek (J)	BPC1 & JBIG1	Further work is needed to determine the species of galaxiids present, and assess the downstream barrier, including fish sampling above and below, to define the extent of the trout-free reach.
4	Browns Creek (GE)	BC3	Further work is needed to determine the species of galaxiids present and assess the structure of the downstream barrier.
4	Bulls Flat Creek (GA)	GBFC2	Further work is needed to determine the species of galaxiids present, and assess the integrity of the two downstream barriers, including sampling for trout below, to define the extent of the trout-free reach.
4	Cooleman Creek (GE)	COO2	Determine the species of galaxiids present.

Priority	Waterbody & catchment	Reach code	Comment
4	Goobarragandra River (GA)	GCT1 & GR1	Further work is needed to determine the species of galaxiids present, and assess the integrity of the main downstream barrier, including sampling for trout below, to define the extent of the trout-free reach.
4	Pheasant Creek (GA)	PHC1	Further work is needed to determine the species of galaxiids present.
4	Peak River (GA)	PR2	Further work is needed to determine the species of galaxiids present, and assess the integrity of the downstream barrier, including sampling for trout below, to define the extent of the trout-free reach.
4	Pigeon Square Creek (GA)	PSQ1	Further work is needed to determine the species of galaxiids present, and assess the integrity of the downstream barrier, including sampling for trout below, to define the extent of the trout-free reach.
4	Yarrangobilly R trib. 1 (Y)	YT1	Further work is needed to determine the species of galaxiids present, and assess the integrity of the downstream barrier, including sampling for trout below, to define the extent of the trout-free reach.
5	Bull Flat Creek (GE)	BFC1	Further work is needed to determine the species of galaxiids present.
5	Hughgal Creek (GE)	PEC3	Further work is needed to determine the species of galaxiids present.
5	Rolling Grounds Creek (GE)	RGC1 & RGC2	Further work is needed to determine the species of galaxiids present.
5	Larrys Creek (T)	TLC1B	Determine the species of galaxiids present. This catchment is recovering from the 2019–20 fires.
5	Yarrangobilly R trib. (Y)	SCT2	Further work is needed to determine the species of galaxiids present.
5	Mill Creek (Y)	YMC1	Further work is needed to determine the species of galaxiids present and to identify the location of the downstream barrier to determine the extent of the trout-free reach.
6	Dodger Creek (T)	HDC2	Further work is needed to determine the species of galaxiids present.
6	Back Gully (Y)	BG1	Further work is needed to determine the species of galaxiids present.
6	Goodradigbee R trib. (GE)	GOOT1	Further work is needed to determine the species of galaxiids present.
6	Little Peppercorn Creek (GE)	LPC1 & LPC2	Further work is needed to determine the species of galaxiids present.
6	Ruby Creek (J)	JRUB1 & JRUB2	Further work is needed to determine the species of galaxiids present.
6	Section Creek trib. (T)	TSCT	Further work is needed to determine the species of galaxiids present.

Priority	Waterbody & catchment	Reach code	Comment
6	Tantangara Creek trib. (M)	TCT1	Further work is needed to determine the species of galaxiids present.
6	Yarrangobilly R trib. 2 (Y)	YT2	Further work is needed to determine the species of galaxiids present.
6	Yarrangobilly R trib. 3 (Y)	YT3	Further work is needed to determine the species of galaxiids present.

4 Discussion

This first catchment survey for Stocky Galaxias (*Galaxias tantangara*) made significant progress toward achieving both key project objectives:

1. Determining the species' distribution, and
2. Identifying potential habitats suitable for future translocations.

While the second objective was fully addressed, the first, defining the species' distribution, remains partly achieved at this stage, pending genetic and taxonomic assessment of galaxiid specimens collected during the survey.

A total of 27 new stream reaches containing galaxiid populations were identified during field assessment. However, species-level identification of these galaxiids could not be confirmed in the field. Voucher specimens from these sites are scheduled for genetic and morphological analysis, which will be critical for:

- Confirming potential range extensions for Stocky Galaxias.
- Refining post-assessment prioritisation of suitable translocation reaches (if required).
- Enhancing understanding of co-occurrence patterns between Stocky Galaxias and other species, such as Mountain Galaxias.
- Updating conservation and management priorities.

In terms of translocation planning, the project successfully identified and prioritised 35 stream reaches, from the 110 assessed, as suitable for the future translocation of Stocky Galaxias. These reaches represent 32% of those assessed and were grouped into six priority categories, based on their potential to support new, self-sustaining populations. Of particular interest are the seven reaches within the top three priority categories, including one Priority 1 site and three sites each in Priority 2 and 3.

These high-priority reaches are strong candidates for early-stage translocations, but further evaluation is required to assess their readiness for implementation, both between and within priority categories.

For example:

- Greenhide Creek (site GC1) ranks highest due to its large, fish-free catchment, but it also presents potential challenges:
    - It is located at one of the lowest elevations among all suitable reaches (1090 m vs. 1335 m typical for Stocky Galaxias).
    - It contains a single, moderately large waterfall that has not yet been physically inspected.
- In contrast, Cave Creek (JCC1) and Rules Creek (both priority 2) have:
    - Moderate-sized fishless catchments.
    - Multiple confirmed large waterfalls serving as trout barriers.
    - Require only minor preparatory works before translocations could feasibly proceed.

Several trout-free reaches removed during the prioritisation process, primarily due to small upstream catchment size or potential water security issues, may still hold value for supportive conservation purposes. These sites could function as temporary grow-out habitats or native fish hatchery sites for juvenile Stocky Galaxias before their release into long-term translocation sites.

Examples of such sites, which contain a pool upstream of a small diversion weir, include:

- Pocket Creek (sites POC1 to 4).
- Snowy Ridge Creek (site SRC).

To progress from prioritisation to implementation, the next critical stage is to undertake the preparatory works outlined by Raadik and Lintermans (2022c). These include, importantly, reconfirming the absence of trout from each reach.

Additional site-level investigations may also be required to address:

- The status of Stocky Galaxias populations (relative abundance, recent recruitment, distribution extent, and potential threats), as per Raadik and Lintermans (2022b).
- The abundance and distribution of Mountain Galaxias, if present.
- The presence and condition of additional instream barriers.
- A revised estimate of upstream catchment size .

The identification of the 35 suitable trout-free reaches across multiple streams is a notable outcome, given the widespread presence of introduced trout across the study area. These findings reinforce the critical role that instream barriers, particularly natural waterfalls, play in the long-term persistence of upland galaxiids by providing natural refuges from trout predation.

Specific aspects of the prioritisation process.

The prioritisation process developed for this project was deliberately structured around ecological and habitat criteria important for the long-term survival of Stocky Galaxias, but it remains a coarse-level framework due to various limitations. As such, the process includes multiple sources of uncertainty, largely stemming from:

- Limited ecological knowledge of upland galaxiid biology and specific habitat requirements.
- Constraints in spatial and temporal replication.
- Selection limits for field assessment sites.
- The qualitative nature of many field observations.
- Inherent variability in upland stream environments.

Several key considerations and assumptions underlying the prioritisation process are outlined below.

Each stream reach selected through the desktop analysis was field assessed at a single site, with the assumption that this site adequately represented the conditions throughout the reach upstream of the nearest trout barrier. This approach was dictated by budget and logistical constraints, but was generally considered reasonable, as many upper reaches were found to be relatively short and homogenous in structure.

Fishless sites were straightforward to prioritise as trout-free, but the absence of any fish may not always indicate suitable habitat. In some cases, fish absence could result from seasonal stream drying or from temporary trout incursions followed by die-off due to stream drying or poor habitat conditions. At these sites, greater emphasis was placed on assessing the likelihood of water permanency and the effectiveness and integrity of waterfall barriers.

Water permanency was assessed during the autumn period, when flows are typically at their lowest. Sites were assessed for:

- Visible stream flow or sufficient water depth.
- Presence of instream water-dependent plants, such as some bryophytes.
- Evidence of non-migratory fish species, such as upland galaxiids.

Sites containing galaxiids were generally assumed to have permanent water, as the presence of fish in these suggests long-term persistence despite the lack of recolonisation opportunities from nearby catchments due to intervening trout populations.

Upstream catchment area was given substantial weight in the ranking process, reflecting ecological principles: larger stream reaches are generally more likely to support larger, more resilient fish populations (Fausch et al. 2002, Jackson et al. 2001). These populations are more likely to persist over the long term and maintain higher evolutionary potential (Hughes et al. 2008, Frankham et al. 2010, Lintermans 2013, Huey et

al. 2019, Pavlova et al. 2017). These attributes are fundamental to establishing long-term, viable translocated populations.

The decision to prioritise fishless reaches over those with existing galaxiid populations is complex.

1. Identification limitations
   There is currently no reliable field-based method to distinguish Stocky Galaxias from Mountain Galaxias, particularly in remote or time-constrained conditions. This compromises the accuracy of site assessments and means some existing Stocky Galaxias sites may not yet be appropriately prioritised. Once species identities are confirmed through genetic and morphological analysis, the prioritisation framework will be revised accordingly, with verified Stocky Galaxias sites moved to higher priority depending on their population status
2. Uncertainty around co-occurrence feasibility
   Although one known Stocky Galaxias population co-occurs with Mountain Galaxias, it remains unclear whether viable translocated populations can be established in reaches already occupied by Mountain Galaxias. Potential issues include:
   - Interspecific competition.
   - Niche overlap.
   - Risk of hybridisation (where relevant)(McDowall 2006, Lintermans et al. 2015).

Given this uncertainty, fishless reaches that meet all other ecological criteria are currently prioritised higher than occupied reaches for translocation. If any streams containing galaxiid populations are later identified as containing Stocky Galaxias, based on genetic and taxonomic assessments, these streams would be given higher priority as they would represent new, previously undiscovered populations of the species.

Survey intensity and broader value

This project represents one of the most comprehensive catchment-scale surveys for upland galaxiids conducted in southeast Australia to date, both in terms of sampling density and geographic coverage. Importantly, the survey incorporated previous findings of Raadik (2011, 2014), emphasising the need for intensive sampling to detect rare galaxiids due to the widespread presence of introduced trout. This dense survey design greatly improved detection probabilities and refined out understanding of:

- Stocky Galaxias habitat suitability.
- The true extent of trout distribution in upland environments.

In addition to its relevance for Stocky Galaxias conservation, the survey also generated valuable occurrence data for native spiny crayfish (*Euastacus* spp.) and further highlighted the persistent impact of introduced trout across highland catchments.

5 Conclusion

This project has successfully addressed a major barrier to the effective conservation of upland galaxiids in southeastern Australia by identifying trout-free stream reaches suitable for future translocation of Stocky Galaxias within trout-dominated catchments. These newly identified sites provide a unique and critical opportunity to establish additional, geographically dispersed populations, which have the potential to become robust, self-sustaining, and resilient over time, thereby significantly reducing the species' extinction risk.

Equally valuable is the potential that galaxiid specimens collected from newly discovered populations may include previously undocumented Stocky Galaxias. If confirmed, these populations could harbour novel genetic diversity, which would enhance the evolutionary potential of the species and support efforts to increase the genetic diversity in conservation breeding and translocation programs.

These outcomes represent a major step forward in the conservation of Stocky Galaxias and provide a strong foundation for the next recovery actions.

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Appendices

Appendix 1. Incorrect data found during the collation of fish data for the project area.

[A] – from Atlas of Living Australia, [B] – from NSW BioNet, [C] – incorrect record in Austral (unpublished); N. – number. Trib. – tributary; Trl - Trail. Species codes: Galoli – *Galaxias olidus*, Galtan – *Galaxias tantangara*, Oncmyk – *Oncorhynchus mykiss*, Saltru – *Salmo trutta*.

Catchment and waterbody	Location	Latitude	Longitude	Date	Species	N.	Comment
GOOBARRADANDRA							
Pigeon Square Creek	Peppercorn Trail [A,B]	-35.56576	148.52039	20/10/2020	Oncmyk	7	Resampled 13/03/2025 (site PSQ1); no trout, and the whole upper reach of the stream contains *Galaxias olidus*.
		-35.5668	148.54014	27/01/2021	Oncmyk	19	
GOODRADIGBEE							
Little Peppercorn Creek	Long Plain Road [A,B]	-35.55133	148.62244	15/11/2020	Galoli	1	Resampled 5/03/2023 (site LPC1); *Galaxias olidus* found.
					Saltru	2	
Peppercorn Creek	trib. McLeods Spur Trl [A,B]	-35.59039	148.62432	2/12/2020	Saltru	1	The whole upper section of Peppercorn Creek is known to contain only a large population of *Oncorhynchus mykiss*. Tributary site off McLeods Spur Track resampled 13/03/2025 (site PEC4); only *O. mykiss* found. The other tributary site is plotting off-stream.
	trib. off Long Plain Road [A,B]	-35.58992	148.60143	27/01/2021	Galtan	40	
MURRUMBIDGEE							
Bally Creek	Port Phillip Trail [A,B]	-35.69815	148.57175	4/11/2020	Galoli	2	Resampled 17/01/2022 and 10/03/2025; not found.
Dip Creek	Hainsworth Hut [A,B]	-35.6711	148.60167	4/11/2020	Galoli	5	Resampled 10/03/2025 (site MDC3); not found. The creek contains trout.
Gurrangorambla Creek	Pocket Saddle Road [A,B]	-35.69011	148.73206	20/01/2021	Galtan	40	Known trout stream; trout also seen on 6/03/2025.
Gulf Plain Creek	Gulf Creek Trail [A,B]	-35.82378	148.69065	1/12/2020	Galoli	2	Site not resampled, but no barriers identified, and the stream contains trout.

McPhersons Creek	trib. Mosquito Creek Trl [A,B]	-35.65892	148.61955	15/11/2020	Galoli	14	Resampled 10/03/2025 (site MMcPT); not found; McPhersons Creek is known to have a large trout population.
Tantangara Reservoir	trib. just downstream of Port Phillip Trail [C]	-35.72498	148.68803	23/01/2022	Galoli	1	Resampled 4/04/2025 (site TRT3); not found. The system has a large trout population.
YARRANGOBILLY							
Brownleys Back Creek	Jounama Track [A,B]	-35.62945	148.47274	4/11/2020	Galoli	13	Stream sampled upstream and downstream of the site on 8/04 and 13/03/2025 (respectively; *Galaxias olidus* not found, but stream contains Brown Trout and Rainbow Trout.

Appendix 2. Location data for prioritised field assessment sites.

DD – Drainage Division (2 – South East Coast; 4 – Murray-Darling), RB – River Basin (10 – Murrumbidgee River; 22 – Snowy River). See Figure 1 for mapped locations.

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
2	22	Eucumbene	ECC1	Cemetery Creek	Eucumbene River	upstream of Snowy Mountains Highway, upstream of old Kiandra Cemetery, Kosciuszko National Park	-35.885837	148.498732	1400
2	22	Eucumbene	ERC1	Racecourse Creek	Eucumbene River	off old track off Snowy Mountains Highway, upstream of falls, Kosciuszko National Park	-35.845803	148.471807	1410
4	10	Goobarragandra	BCC1	Broken Cart Creek	Goobarragandra River	~700 m upstream of Broken Cart campground, off Broken Cart Trail, Kosciuszko National Park	-35.48041	148.59892	1240
4	10	Goobarragandra	BCC2	Broken Cart Creek	Goobarragandra River	at culvert on Broken Cart Trail, Kosciuszko National Park	-35.477177	148.596105	1200
4	10	Goobarragandra	BFC3	Bulls Flat Creek	Goobarragandra River	tributary, headwaters on plateau, Bogong Peaks Wilderness, Kosciuszko National Park	-35.53396	148.45259	1475
4	10	Goobarragandra	DC2	Dubbo Creek	Goobarragandra River	downstream from overgrown section of Cooleman Creek Trail, Kosciuszko National Park	-35.437723	148.595018	1175
4	10	Goobarragandra	GBFC2	Bulls Flat Creek	Goobarragandra River	at Goobarragandra Road to 50 m upstream, upstream of falls, Kosciuszko National Park	-35.531502	148.481783	1010
4	10	Goobarragandra	GCT1	Goobarragandra River	Tumut River	headwater tributary, off Broken Cart Trail, Kosciuszko National Park	-35.532379	148.611354	1330

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Goobarragandra	GR1	Goobarragandra River	Tumut River	headwaters, off Long Plain Road, Kosciuszko National Park	-35.545354	148.607676	1330
4	10	Goobarragandra	GRT1	Goobarragandra River	Tumut River	tributary, off Feints Range Trail, Kosciuszko National Park	-35.546279	148.566523	1160
4	10	Goobarragandra	HGLC1	Happy Go Lucky Creek	Goobarragandra River	at culvert on Broken Cart Trail, Kosciuszko National Park	-35.476043	148.596017	1200
4	10	Goobarragandra	PHC1	Pheasant Creek	Goobarragandra River	at Boundary Road, Kosciuszko National Park	-35.443932	148.567422	1075
4	10	Goobarragandra	PR2	Peak River	Goobarragandra River	at Atkinson Creek Trail, Kosciuszko National Park	-35.39932	148.496728	1084
4	10	Goobarragandra	PSQ1	Pigeon Square Creek	Goobarragandra River	at Peppercorn Trail, Kosciuszko National Park	-35.566589	148.540087	1300
4	10	Goodradigbee	BC3	Browns Creek	Goodradigbee River	from culvert on Cooleman Creek Trail to 100 m downstream, Kosciuszko National Park	-35.45985	148.660337	1075
4	10	Goodradigbee	BFC1	Bull Flat Creek	Goodradigbee River	upstream and downstream of Cooleman Creek Trail, Kosciuszko National Park	-35.426851	148.630459	1150
4	10	Goodradigbee	CBP1	Cave Creek	Goodradigbee River	tributary, upstream of Harris Hut Track, Kosciuszko National Park	-35.61964	148.63528	1310
4	10	Goodradigbee	CC1	Cave Creek	Goodradigbee River	upstream of Blue Waterholes Trail, Kosciuszko National Park	-35.600445	148.666232	1280
4	10	Goodradigbee	CC2	Cave Creek	Goodradigbee River	tributary, at Blue Waterholes Trail, Kosciuszko National Park	-35.60305	148.64752	1295
4	10	Goodradigbee	CC4	Cave Creek	Goodradigbee River	below the Blue Waterholes campground, Kosciuszko National Park	-35.622774	148.68656	1190

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Goodradigbee	CCHF	Cave Creek	Goodradigbee River	tributary, upstream of Blue Waterholes Trail, Kosciuszko National Park	-35.594415	148.657433	1285
4	10	Goodradigbee	CCT	Cave Creek	Goodradigbee River	small tributary which emerges from a small cave below Blue Waterholes Camp Ground, Kosciuszko National Park	-35.623031	148.685452	1190
4	10	Goodradigbee	COO1	Cooleman Creek	Goodradigbee River	at Cooleman Creek Trail, Kosciuszko National Park	-35.483856	148.653857	970
4	10	Goodradigbee	COO2	Cooleman Creek	Goodradigbee River	~1.2 km upstream of Cooleman Creek Trail, upstream falls, Kosciuszko National Park	-35.476686	148.647955	1040
4	10	Goodradigbee	DFC1	Dunns Flat Creek	Goodradigbee River	at Murray Gap Trail, Kosciuszko National Park	-35.67519	148.77631	1420
4	10	Goodradigbee	GC1	Greenhide Creek	Goodradigbee River	from culvert on Cooleman Creek Trail to 100 m downstream, Kosciuszko National Park	-35.427758	148.643933	1090
4	10	Goodradigbee	GOO1	Goodradigbee River	Lake Burrinjuck	tributary, off Leura Gap Trail, south of Rolling Grounds Creek, Kosciuszko National Park	-35.634475	148.737233	1210
4	10	Goodradigbee	GOO3	Goodradigbee River	Lake Burrinjuck	downstream from Lone Pine Trail, Kosciuszko National Park	-35.713311	148.785966	1440
4	10	Goodradigbee	GOOT1	Goodradigbee River	Lake Burrinjuck	tributary, near Pockets Hut, off Leura Gap Trail, Kosciuszko National Park	-35.647043	148.731033	1215
4	10	Goodradigbee	GOOT2	Goodradigbee River	Lake Burrinjuck	tributary, off Lone Pine Trail, at granite boulder falls, Kosciuszko National Park	-35.71277	148.78734	1465

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Goodradigbee	GOOT2A	Goodradigbee River	Lake Burrinjuck	tributary, off Lone Pine Trail, two pools below granite boulder falls, Kosciuszko National Park	-35.712752	148.787187	1460
4	10	Goodradigbee	LPC1	Little Peppercorn Creek	Peppercorn Creek	downstream to upstream of Long Plain Road, upstream of falls, Kosciuszko National Park	-35.55141	148.62262	1380
4	10	Goodradigbee	LPC2	Little Peppercorn Creek	Peppercorn Creek	tributary, at Long Plain Road, Kosciuszko National Park	-35.556788	148.622859	1375
4	10	Goodradigbee	PEC1	Peppercorn Creek	Goodradigbee River	tributary, at Long Plain Road, Kosciuszko National Park	-35.575718	148.619487	1380
4	10	Goodradigbee	PEC2	Peppercorn Creek	Goodradigbee River	tributary, at Long Plain Road, Kosciuszko National Park	-35.584538	148.611659	1355
4	10	Goodradigbee	PEC3	Hughgal Creek	Goodradigbee River	from junction with tributary to 75 m upstream, off McLeods Spur Trail, Kosciuszko National Park	-35.57575	148.681008	1350
4	10	Goodradigbee	PEC4	Peppercorn Creek	Goodradigbee River	tributary, at culvert on McLeods Spur Trail, Kosciuszko National Park	-35.59036	148.62432	1350
4	10	Goodradigbee	PEC5	Peppercorn Creek	Goodradigbee River	tributary, at culvert on McLeods Spur Trail, Kosciuszko National Park	-35.5921	148.6195	1350
4	10	Goodradigbee	PEC6	Peppercorn Creek	Goodradigbee River	tributary, at culvert on Blue Waterholes Trail, Kosciuszko National Park	-35.602611	148.628223	1390
4	10	Goodradigbee	POC1	Pocket Creek	Goodradigbee River	headwaters, upstream of the aqueduct, Kosciuszko National Park	-35.677	148.73694	1280

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Goodradigbee	POC2	Pocket Creek	Goodradigbee River	headwaters, upstream of the aqueduct, Kosciuszko National Park	-35.67416	148.73908	1285
4	10	Goodradigbee	POC3	Pocket Creek	Goodradigbee River	headwaters, upstream of the aqueduct, Kosciuszko National Park	-35.67102	148.74034	1285
4	10	Goodradigbee	POC4	Pocket Creek	Goodradigbee River	headwaters, upstream of the aqueduct, Kosciuszko National Park	-35.66921	148.74152	1290
4	10	Goodradigbee	RGC1	Rolling Grounds Creek	Goodradigbee River	off Leura Gap Trail, Kosciuszko National Park	-35.629145	148.765627	1430
4	10	Goodradigbee	RGC2	Rolling Grounds Creek	Goodradigbee River	off Leura Gap Trail, below falls, ~2 km upstream from junction with Goodradigbee River, Kosciuszko National Park	-35.62069	148.73712	1219
4	10	Goodradigbee	RGC3	Rolling Grounds Creek	Goodradigbee River	from base of large falls to 30 m further upstream, Kosciuszko National Park	-35.62189	148.73659	1200
4	10	Goodradigbee	SFC1	Seventeen Flat Creek	Goodradigbee River	off Mosquito Creek Trail, Kosciuszko National Park	-35.646473	148.678675	1250
4	10	Goodradigbee	TPC1	Tin Pot Creek	Goodradigbee River	off Long Plain Road, below and above two rock barriers	-35.536285	148.626078	1360
4	10	Jounama	BPC1	Big Plain Creek	Big Creek	on plateau, Bogong Peaks Wilderness	-35.546943	148.438699	1360
4	10	Jounama	JBIG1	Big Creek	Rings Creek	at Warogong Trail, Kosciuszko National Park	-35.558331	148.406756	1110
4	10	Jounama	JCC1	Cave Creek	Jounama Creek	at Warogong Trail, Kosciuszko National Park	-35.568134	148.411555	1130

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Jounama	JJ1	Jounama Creek	Tumut River	at Michelago Trail, Kosciuszko National Park	-35.60861	148.439811	1130
4	10	Jounama	JRUB1	Ruby Creek	Jounama Creek	off Warogong Trail, Kosciuszko National Park	-35.598199	148.43129	1180
4	10	Jounama	JRUB2	Ruby Creek	Jounama Creek	off Warogong Trail, mid reaches, Kosciuszko National Park	-35.61024	148.42035	1115
4	10	Murrumbidgee	HHC1	Hell Hole Creek	Murrumbidgee River	at small falls ~600 m upstream from junction with Murrumbidgee River, Kosciuszko National Park	-35.758852	148.605489	1270
4	10	Murrumbidgee	KPC1	Kellys Plain Creek	Murrumbidgee River	~1 km upstream Tantangara Road, Kosciuszko National Park	-35.830141	148.655392	1430
4	10	Murrumbidgee	MBC	Bally Creek	Murrumbidgee River	at Port Phillip Trail, Kosciuszko National Park	-35.6973	148.571489	1335
4	10	Murrumbidgee	MDC1	Dairymans Creek	Murrumbidgee River	100 m section upstream of waterfall, Kosciuszko National Park	-35.72882	148.57161	1360
4	10	Murrumbidgee	MDC2	Dairymans Creek	Murrumbidgee River	immediately below falls, in larger channel and plunge pool, Kosciuszko National Park	-35.72936	148.56999	1350
4	10	Murrumbidgee	MDC3	Dip Creek	Murrumbidgee River	at Hainsworth Hut, off Mosquito Creek Trail, Kosciuszko National Park	-35.671109	148.601712	1370
4	10	Murrumbidgee	MGC1	Gurrangorambla Creek	Murrumbidgee River	tributary, at Goodradigbee diversion channel outlet structure, Kosciuszko National Park	-35.67485	148.726031	1250
4	10	Murrumbidgee	MGCT1	Gooandra Creek	Tantangara Creek	tributary, upper reaches, downstream to upstream of	-35.79038	148.51947	1410

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
						short rock drops, Kosciuszko National Park			
4	10	Murrumbidgee	MGCT2	Gooandra Creek	Tantangara Creek	tributary, off Bullocks Hill Trail, upstream of falls, Kosciuszko National Park	-35.77806	148.51935	1450
4	10	Murrumbidgee	MGCT3	Gurrangorambla Creek	Murrumbidgee River	tributary, upstream of falls, upstream Pocket Saddle Road, Kosciuszko National Park	-35.691713	148.73945	1310
4	10	Murrumbidgee	MMCP	McPhersons Creek	Murrumbidgee River	at old rock barrier, off Mosquito Creek Trail, Kosciuszko National Park	-35.651996	148.62118	1415
4	10	Murrumbidgee	MMcPT	McPhersons Creek	Murrumbidgee River	tributary, at Mosquito Creek Trail to 100 m downstream, Kosciuszko National Park	-35.658548	148.618708	1390
4	10	Murrumbidgee	MSCT1	Starvation Creek	Murrumbidgee River	tributary, on Spicers Creek Trail, Kosciuszko National Park	-35.64556	148.55664	1400
4	10	Murrumbidgee	MUR1	Murrumbidgee River	Murray River	at small falls off Peppercorn Trail, Kosciuszko National Park	-35.575238	148.585293	1475
4	10	Murrumbidgee	MUR3	Murrumbidgee River	Murray River	at Peppercorn Trail, Kosciuszko National Park	-35.576918	148.581104	1495
4	10	Murrumbidgee	MURT1	Murrumbidgee River	Murray River	tributary, under powerlines next to Snowy Mountains Highway, Kosciuszko National Park	-35.7665	148.528888	1400
4	10	Murrumbidgee	MURT2	Murrumbidgee River	Murray River	tributary, south-east of Hains Hut, Kosciuszko National Park	-35.772978	148.603753	1265
4	10	Murrumbidgee	PAC1	Paytens Creek	Murrumbidgee River	tributary, in headwaters on plateau, Kosciuszko National Park	-35.72758	148.76028	1405
4	10	Murrumbidgee	SC1	Starvation Creek	Murrumbidgee River	2.6 km upstream of Long Plain Road, Kosciuszko National Park	-35.628361	148.563866	1385

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Murrumbidgee	TCT1	Tantangara Creek	Murrumbidgee River	tributary, off Bullocks Hill Trail, upstream of falls, Kosciuszko National Park	-35.77989	148.55942	1330
4	10	Murrumbidgee	TRT1	Tantangara Reservoir	Murrumbidgee River	tributary, at Tantangara East turnoff, off Port Phillip Trail, Kosciuszko National Park	-35.73832	148.68935	1305
4	10	Murrumbidgee	TRT3	Mosquito Creek	Murrumbidgee River	tributary, at Port Phillip Trail, 500 m NW of Currango Homestead, Kosciuszko National Park	-35.725215	148.688312	1230
4	10	Tumut	HDC1	Dodger Creek	Happy Jacks Creek	immediately below falls, upstream of Happy Jacks Road, Kosciuszko National Park	-36.02684	148.46714	1435
4	10	Tumut	HDC2	Dodger Creek	Happy Jacks Creek	above large falls, upstream of Happy Jacks Road, Kosciuszko National Park	-36.02761	148.46728	1445
4	10	Tumut	SRC	Snow Ridge Creek	Tumut River	tributary, upstream of Snow Ridge aqueduct weir, upstream of Tumut Pondage, Kosciuszko National Park	-35.96284	148.38925	1180
4	10	Tumut	TBC1	Boomerang Creek	Tumut River	at old track crossing, next to Cabramurra, Kosciuszko National Park	-35.929595	148.384487	1415
4	10	Tumut	TEM1	Eight Mile Creek	Tumut River	downstream to upstream of Link Road, Kosciuszko National Park	-35.900533	148.395596	1315
4	10	Tumut	TLC1A	Larrys Creek	Tumut River	below falls, downstream of Link Road, Kosciuszko National Park	-35.89007	148.41912	1300
4	10	Tumut	TLC1B	Larrys Creek	Tumut River	upstream from top of falls, downstream of Link Road, Kosciuszko National Park	-35.89027	148.41978	1300

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Tumut	TSCT	Section Creek	Tumut River	tributary, large pool downstream from track, Kosciuszko National Park	-35.883862	148.413453	1285
4	10	Tumut	PC1	Prospector Creek	Tumut River	downstream to upstream of Deadmans Trail, Kosciuszko National Park	-35.854255	148.408102	1175
4	10	Tumut	TSC1	Section Creek	Tumut River	upstream and downstream of Link Road, Kosciuszko National Park	-35.895254	148.413099	1250
4	10	Yarrangobilly	BG1	Back Gully	Yarrangobilly River	from top of waterfall to 75 m upstream, off Jounama Plantation Trail	-35.63854	148.47405	1080
4	10	Yarrangobilly	BR1	Brownleys Back Creek	Yarrangobilly River	at Powerline Trail, Kosciuszko National Park	-35.60332	148.48422	1210
4	10	Yarrangobilly	LFC1	Yarrangobilly River	Talbingo Reservoir	tributary, at Horseshoe Trial, Long Flat Homestead, Kosciuszko National Park	-35.597197	148.510778	1250
4	10	Yarrangobilly	SCT1	Spicers Creek	Yarrangobilly River	at Spicer Creek Trail , Kosciuszko National Park	-35.652656	148.523072	1205
4	10	Yarrangobilly	SCT2	Yarrangobilly River	Talbingo Reservoir	tributary, at Spicers Creek Trail, Kosciuszko National Park	-35.66438	148.49661	1160
4	10	Yarrangobilly	YAC1	Yarrangobilly River	Talbingo Reservoir	headwaters, off Feints Range Trail, Kosciuszko National Park	-35.580942	148.556434	1305
4	10	Yarrangobilly	YAC2	Yarrangobilly River	Talbingo Reservoir	2.5 km off Horseshoe Trail, upstream of falls, Kosciuszko National Park	-35.60633	148.538956	1265
4	10	Yarrangobilly	YB1	Blue Creek	Yarrangobilly River	from 20 m downstream to 60 m upstream of falls, off Blue Creek Trail, Kosciuszko National Park	-35.755478	148.474349	975

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Yarrangobilly	YBBC	Brownleys Back Creek	Yarrangobilly River	immediately at junction with Back Creek (Back Creek waterfalls)	-35.63864	148.47371	1070
4	10	Yarrangobilly	YMC1	Mill Creek	Yarrangobilly River	upstream of Snowy Mountains Highway, Kosciuszko National Park	-35.702917	148.504239	1270
4	10	Yarrangobilly	YPG1	Pub Gully	Yarrangobilly River	at Yans Crossing Trail, Kosciuszko National Park	-35.669771	148.47191	1065
4	10	Yarrangobilly	YRC1	Rules Creek	Yarrangobilly River	downstream of Snowy Mountains Highway crossing, ~100 m downstream of old highway alignment and old culverts, Kosciuszko National Park	-35.716954	148.522172	1280
4	10	Yarrangobilly	YRC2a	Rules Creek	Yarrangobilly River	20 m section below Rules Dam, Kosciuszko National Park	-35.721245	148.504962	1130
4	10	Yarrangobilly	YRC2b	Rules Creek	Yarrangobilly River	195 m section just upstream of Rules Dam, Kosciuszko National Park	-35.720712	148.50577	1140
4	10	Yarrangobilly	YRC2c	Rules Creek	Yarrangobilly River	245 m upstream of Rules Dam to base of large waterfall, Kosciuszko National Park	-35.721116	148.507493	1160
4	10	Yarrangobilly	YRC2d	Rules Creek	Yarrangobilly River	from top of falls to 245 m upstream, Kosciuszko National Park	-35.721837	148.509497	1210
4	10	Yarrangobilly	YRC3	Rules Creek	Yarrangobilly River	upstream from culvert on Yarrangobilly Caves Entry Road, Kosciuszko National Park	-35.72277	148.502326	1095
4	10	Yarrangobilly	YRC4	Rules Creek	Yarrangobilly River	80 m reach at power station, Yarrangobilly, Kosciuszko National Park	-35.724452	148.495631	1005

DD	RB	Catchment	Site No.	Waterbody	Tributary of	Site Location	Latitude (decimal)	Longitude (decimal)	Elev. (m)
4	10	Yarrangobilly	YRC5	Rules Creek	Yarrangobilly River	in waterfall plunge pool, upstream of power station, Yarrangobilly Caves Reserve, Kosciuszko National Park	-35.724814	148.497744	1040
4	10	Yarrangobilly	YRC6	Rules Creek	Yarrangobilly River	reach just upstream of falls, Yarrangobilly Caves Reserve, Kosciuszko National Park	-35.724814	148.497744	1040
4	10	Yarrangobilly	YT1	Yarrangobilly River	Talbingo Reservoir	tributary, upstream of footbridge on Jounama Heritage walk, Kosciuszko National Park	-35.664038	148.432596	1070
4	10	Yarrangobilly	YT2	Yarrangobilly River	Talbingo Reservoir	tributary, on Lobbs Hole Ravine Road, Kosciuszko National Park	-35.68306	148.42329	1105
4	10	Yarrangobilly	YT3	Yarrangobilly River	Talbingo Reservoir	tributary, at Yans Crossing Trail, Kosciuszko National Park	-35.69521	148.44614	1085
4	10	Yarrangobilly	YT4	Little Glory Hole Creek	Yarrangobilly River	tributary, at Yarrangobilly Caves Exit Road, Kosciuszko National Park	-35.73668	148.513024	1300

Appendix 3. Results of field sampling at each assessment site, including date sampled, gear type used, species name and number collected for sampled fauna.

DRY – site had no surface water; EF/BP – electrofisher, backpack; Gen – tissue for genetic analysis; Morph – specimens for morphological analysis; No. – number; No fish – no fish were sampled; Obs – observation; sp. – species identity yet to be determined; * - spiny crayfish (*Euastacus*) present; ** - Common Yabby (*Cherax destructor*) present. See Figure 1 for mapped locations.

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Eucumbene	ECC1	Cemetery Creek	12/04/2025	Obs	*Oncorhynchus mykiss*	10		
Eucumbene	ERC1	Racecourse Creek	8/03/2025	EF/BP	*Salmo trutta* *	1		
Goobarragandra	BCC1	Broken Cart Creek	12/03/2025	EF/BP	*Oncorhynchus mykiss*	5		
Goobarragandra	BCC2	Broken Cart Creek	12/03/2025	EF/BP	*Oncorhynchus mykiss*	1		
Goobarragandra	BFC3	Bulls Flat Creek	11/03/2025	EF/BP	No fish *			
Goobarragandra	DC2	Dubbo Creek	12/03/2025	EF/BP	*Oncorhynchus mykiss* *	1		
Goobarragandra	GBFC2	Bulls Flat Creek	8/04/2025	EF/BP	*Galaxias* sp. *	38	Y	Y
Goobarragandra	GCT1	Goobarragandra River	13/03/2025	EF/BP	*Galaxias* sp.	1	-	-
Goobarragandra	GR1	Goobarragandra River	9/04/2025	EF/BP	*Galaxias* sp.	13	Y	Y
Goobarragandra	GRT1	Goobarragandra River	9/04/2025	EF/BP	*Oncorhynchus mykiss*	5		
Goobarragandra	HGLC1	Happy Go Lucky Creek	12/03/2025	EF/BP	*Oncorhynchus mykiss*	1		
Goobarragandra	PHC1	Pheasant Creek	12/03/2025	EF/BP	*Galaxias* sp. *	37	Y	Y
Goobarragandra	PR2	Peak River	8/04/2025	EF/BP	*Galaxias* sp.	23	Y	Y
Goobarragandra	PSQ1	Pigeon Square Creek	13/03/2025	EF/BP	*Galaxias* sp.	18	Y	Y
Goodradigbee	BC3	Browns Creek	12/03/2025	EF/BP	*Galaxias* sp. *	35	Y	Y
Goodradigbee	BFC1	Bull Flat Creek	12/03/2025	EF/BP	*Galaxias* sp. *	10	Y	Y
Goodradigbee	CBP1	Cave Creek	5/03/2025	Obs	DRY			
Goodradigbee	CC1	Cave Creek	5/03/2025	EF/BP	*Oncorhynchus mykiss*	58		

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Goodradigbee	CC2	Cave Creek	5/03/2025	Obs	DRY			
Goodradigbee	CC4	Cave Creek	5/03/2025	EF/BP	*Galaxias* sp. * *Oncorhynchus mykiss*	3 7	-	-
Goodradigbee	CCHF	Cave Creek	5/03/2025	EF/BP	No fish			
Goodradigbee	CCT	Cave Creek	5/03/2025	EF/BP	*Galaxias* sp.	27	Y	Y
Goodradigbee	COO1	Cooleman Creek	11/03/2025	EF/BP	*Oncorhynchus mykiss* *	2		
Goodradigbee	COO2	Cooleman Creek	11/03/2025	EF/BP	*Galaxias* sp.	28	Y	Y
Goodradigbee	DFC1	Dunns Flat Creek	6/03/2025	EF/BP	*Oncorhynchus mykiss* *	19		
Goodradigbee	GC1	Greenhide Creek	12/03/2025	EF/BP	No fish			
Goodradigbee	GOO1	Goodradigbee River	6/04/2025	EF/BP	*Oncorhynchus mykiss* *	3		
Goodradigbee	GOO3	Goodradigbee River	6/03/2025	EF/BP	*Oncorhynchus mykiss* *	1		
Goodradigbee	GOOT1	Goodradigbee River	6/03/2025	EF/BP	*Galaxias* sp.	10	Y	Y
Goodradigbee	GOOT2	Goodradigbee River	6/03/2025	EF/BP	No fish			
Goodradigbee	GOOT2A	Goodradigbee River	6/03/2025	EF/BP	No fish			
Goodradigbee	LPC1	Little Peppercorn Creek	5/03/2025	EF/BP	*Galaxias* sp. *	112	Y	Y
Goodradigbee	LPC2	Little Peppercorn Creek	5/03/2025	EF/BP	No fish *			
Goodradigbee	PEC1	Peppercorn Creek	5/03/2025	EF/BP	*Oncorhynchus mykiss*	2		
Goodradigbee	PEC2	Peppercorn Creek	5/03/2025	EF/BP	*Oncorhynchus mykiss* *	1		
Goodradigbee	PEC3	Hughgal Creek	13/03/2025	EF/BP	*Galaxias* sp. *	126	Y	Y
Goodradigbee	PEC4	Peppercorn Creek	13/03/2025	EF/BP	*Oncorhynchus mykiss*	1		
Goodradigbee	PEC5	Peppercorn Creek	13/03/2025	EF/BP	*Oncorhynchus mykiss*	4		
Goodradigbee	PEC6	Peppercorn Creek	13/03/2025	EF/BP	No fish			
Goodradigbee	POC1	Pocket Creek	6/03/2025	EF/BP	No fish *			

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Goodradigbee	POC2	Pocket Creek	6/03/2025	EF/BP	No fish			
Goodradigbee	POC3	Pocket Creek	6/03/2025	EF/BP	No fish			
Goodradigbee	POC4	Pocket Creek	6/03/2025	EF/BP	No fish			
Goodradigbee	RGC1	Rolling Grounds Creek	6/03/2025	EF/BP	*Galaxias* sp.	13	Y	Y
Goodradigbee	RGC2	Rolling Grounds Creek	7/03/2025	EF/BP	*Galaxias* sp. *	27	Y	Y
Goodradigbee	RGC3	Rolling Grounds Creek	7/03/2025	EF/BP	*Oncorhynchus mykiss*	5		
Goodradigbee	SFC1	Seventeen Flat Creek	5/03/2025	EF/BP	*Oncorhynchus mykiss* *	1		
Goodradigbee	TPC1	Tin Pot Creek	5/03/2025	EF/BP	*Galaxias* sp.	5	Y	Y
Jounama	BPC1	Big Plain Creek	11/03/2025	EF/BP	*Galaxias* sp. *	55	Y	Y
Jounama	JBIG1	Big Creek	10/04/2025	EF/BP	*Galaxias* sp. *	25	Y	Y
Jounama	JCC1	Cave Creek	10/04/2025	EF/BP	No fish *			
Jounama	JJ1	Jounama Creek	10/04/2025	EF/BP	*Oncorhynchus mykiss*	18		
Jounama	JRUB1	Ruby Creek	10/04/2025	EF/BP	*Galaxias* sp. *	4	Y	Y
Jounama	JRUB2	Ruby Creek	10/04/2025	EF/BP	*Galaxias* sp.	32	Y	Y
Murrumbidgee	HHC1	Hell Hole Creek	4/03/2025	EF/BP	*Oncorhynchus mykiss* * *Salmo trutta*	4 5		
Murrumbidgee	KPC1	Kellys Plain Creek	7/03/2025	EF/BP	No fish *			
Murrumbidgee	MBC	Bally Creek	10/03/2025	EF/BP	No fish *			
Murrumbidgee	MDC1	Dairymans Creek	11/03/2025	EF/BP	*Salmo trutta*	1		
Murrumbidgee	MDC2	Dairymans Creek	11/03/2025	EF/BP	*Oncorhynchus mykiss* *Salmo trutta*	 23		
Murrumbidgee	MDC3	Dip Creek	10/03/2025	EF/BP	*Salmo trutta* *	7		
Murrumbidgee	MGC1	Gurrangorambla Creek	6/03/2025	EF/BP	No fish **			

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Murrumbidgee	MGCT1	Gooandra Creek	4/03/2025	EF/BP	*Oncorhynchus mykiss*	4		
Murrumbidgee	MGCT2	Gooandra Creek	4/03/2025	EF/BP	No fish			
Murrumbidgee	MGCT3	Gurrangorambla Creek	7/03/2025	EF/BP	No fish			
Murrumbidgee	MMCP	McPhersons Creek	10/03/2025	EF/BP	*Salmo trutta*	1		
Murrumbidgee	MMcPT	McPhersons Creek	10/03/2025	EF/BP	No fish *			
Murrumbidgee	MSCT1	Starvation Creek	13/03/2025	Obs	DRY			
Murrumbidgee	MUR1	Murrumbidgee River	5/03/2025	EF/BP	No fish *			
Murrumbidgee	MUR3	Murrumbidgee River	5/03/2025	EF/BP	No fish			
Murrumbidgee	MURT1	Murrumbidgee River	4/03/2025	Obs	No fish			
Murrumbidgee	MURT2	Murrumbidgee River	4/03/2025	EF/BP	*Oncorhynchus mykiss* *	12		
Murrumbidgee	PAC1	Paytens Creek	11/03/2025	EF/BP	No fish *			
Murrumbidgee	SC1	Starvation Creek	12/03/2025	EF/BP	No fish			
Murrumbidgee	TCT1	Tantangara Creek	4/03/2025	EF/BP	*Galaxias* sp. *	19	Y	Y
Murrumbidgee	TRT1	Tantangara Reservoir	6/03/2025	EF/BP	*Salmo trutta* *	1		
Murrumbidgee	TRT3	Mosquito Creek	7/04/2025	EF/BP	*Oncorhynchus mykiss* * *Salmo trutta*	8 1		
Tumut	HDC1	Dodger Creek	20/11/2024	EF/BP	*Oncorhynchus mykiss*	3		
Tumut	HDC2	Dodger Creek	20/11/2024	EF/BP	*Galaxias* sp.	3	Y	Y
Tumut	SRC	Snow Ridge Creek	3/03/2025	EF/BP	No fish *			
Tumut	TBC1	Boomerang Creek	8/03/2025	EF/BP	*Oncorhynchus mykiss* *Salmo trutta*	1 5		
Tumut	TEM1	Eight Mile Creek	8/04/2025	EF/BP	*Oncorhynchus mykiss* *Salmo trutta*	11 45		

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Tumut	TLC1A	Larrys Creek	7/04/2025	EF/BP	*Oncorhynchus mykiss*	30		
Tumut	TLC1B	Larrys Creek	7/04/2025	EF/BP	*Galaxias* sp.	2	-	Y
Tumut	TSCT	Section Creek	8/04/2025	EF/BP	*Galaxias* sp.	49	Y	Y
Tumut	PC1	Prospector Creek	8/04/2025	EF/BP	No fish			
Tumut	TSC1	Section Creek	8/04/2025	EF/BP	*Oncorhynchus mykiss*	15		
Yarrangobilly	BG1	Back Gully	13/03/2025	EF/BP	*Galaxias* sp.	32	Y	Y
Yarrangobilly	BR1	Brownleys Back Creek	8/04/2025	EF/BP	*Oncorhynchus mykiss* *Salmo trutta*	10 40		
Yarrangobilly	LFC1	Yarrangobilly River	9/04/2025	EF/BP	*Salmo trutta*	7		
Yarrangobilly	SCT1	Spicers Creek	13/03/2025	EF/BP	*Oncorhynchus mykiss* *	1		
Yarrangobilly	SCT2	Yarrangobilly River	13/03/2025	EF/BP	*Galaxias* sp.	15	Y	Y
Yarrangobilly	YAC1	Yarrangobilly River	13/03/2025	EF/BP	*Oncorhynchus mykiss*	2		
Yarrangobilly	YAC2	Yarrangobilly River	12/03/2025	EF/BP	*Oncorhynchus mykiss*	2		
Yarrangobilly	YB1	Blue Creek	9/04/2025	EF/BP	No fish			
Yarrangobilly	YBBC	Brownleys Back Creek	13/03/2025	EF/BP	*Oncorhynchus mykiss* *Salmo trutta*	3 1		
Yarrangobilly	YMC1	Mill Creek	8/04/2025	EF/BP	*Galaxias* sp. *	34	Y	Y
Yarrangobilly	YPG1	Pub Gully	9/04/2025	Obs	DRY			
Yarrangobilly	YRC1	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC2a	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC2b	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC2c	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC2d	Rules Creek	10/04/2025	EF/BP	No fish			

Catchment	Site Code	Waterbody	Date Sampled	Gear Type	Species	No.	Gen	Morph
Yarrangobilly	YRC3	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC4	Rules Creek	10/04/2025	EF/BP	No fish *			
Yarrangobilly	YRC5	Rules Creek	10/04/2025	EF/BP	*Oncorhynchus mykiss*	20		
Yarrangobilly	YRC6	Rules Creek	10/04/2025	EF/BP	No fish			
Yarrangobilly	YT1	Yarrangobilly River	9/04/2025	EF/BP	*Galaxias* sp.	149	Y	Y
Yarrangobilly	YT2	Yarrangobilly River	9/04/2025	EF/BP	*Galaxias* sp. *	33	Y	Y
Yarrangobilly	YT3	Yarrangobilly River	9/04/2025	EF/BP	*Galaxias* sp.	7	Y	Y
Yarrangobilly	YT4	Little Glory Hole Creek	10/04/2025	EF/BP	No fish			

Appendix 4. Selected site images.

Goobarragandra Catchment

BFC3: Bulls Flat Creek tributary, headwaters, Bogong Peaks Wilderness, 11/03/2025 (Image credits: Tarmo A. Raadik). **No fish.**

GBFC2: Bulls Flat Creek, upstream and downstream of Goobarragandra Road, 8/04/2025 (Image credit: Luke Pearce). **Galaxiids present.**

GBFC2: Top of waterfall on Bulls Flat Creek, downstream of Goobarragandra Road, 8/04/2025 (Image credit: Luke Pearce). **Galaxiids present.**

GR1: Goobarragandra River headwaters, off Long Plain Road, 9/04/2025 (Image credit: Luke Pearce). **Galaxiids present.**

GRT1: Goobarragandra River tributary, off Feints Range Trail, 9/04/2025 (Image credit: Luke Pearce). **Trout present.**

PR2: Peak River, Atkinson Creek Trail, 8/04/2025 (Image credit: Luke Pearce). **Galaxiids present.**

Goodradigbee catchment

BC3: Browns Creek, Cooleman Creek Trail, 12/03/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present.**

CC1: Cave Creek, upstream of Blue Waterholes Trail, 5/03/2025 (Image credit: Luke Pearce). **Trout present.**

CC4: Cave Creek, downstream of Blue Waterholes campground, 5/03/2025 (Image credit: Luke Pearce). **Trout present, and three galaxiids.**

CCHF: Cave Creek tributary, upstream of Blue Waterholes Trail, 5/03/2025 (Image credit: Luke Pearce). **No Fish.**

CCT: Cave Creek, tributary at Blue Waterholes campground, 5/03/2025 (Image credit: Luke Pearce). **Galaxiids present.**

DFC1: Dunns Flat Creek, Murray Gap Trail, 6/03/2025 (Image credits: Tarmo A. Raadik). **Tout Present.**

GC1: Greenhide Creek, Cooleman Creek Trail, 12/03/2025 (Image credits: Tarmo A. Raadik). **No fish.**

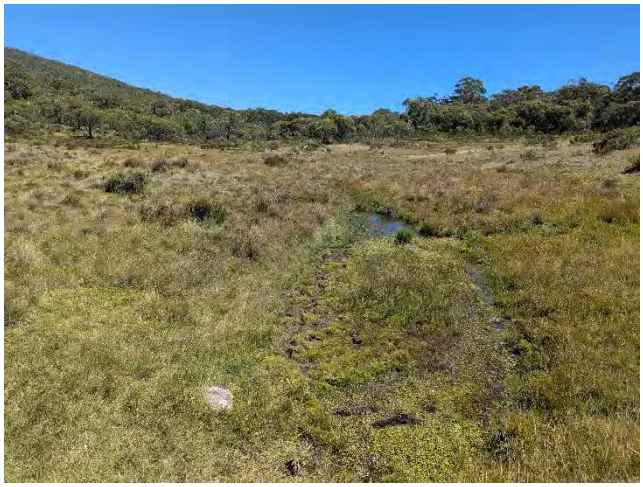
GOO1: Goodradigbee River tributary, off Leura Gap Trail, 6/03/2025 (Image credit: Luke Pearce). **Trout present.**

GOO3: Goodradigbee River, downstream from Lone Pine Trail, 6/03/2025 (Image credits: Tarmo A. Raadik). **Rainbow Trout present.**

GOOT1: Goodradigbee River tributary, near Pockets Hut, 6/03/2025 (Image credit: Luke Pearce). **Galaxiids present**.

LPC1: Little Peppercorn Creek, Long Plain Road, 5/03/2025 (Image credit: Tarmo A. Raadik).

Galaxiids present.



LPC2: Little Peppercorn Creek tributary, Long Plain Road, 5/03/2025 (Image credit: Tarmo A. Raadik).
No fish.

PEC3: Hughgal Creek, off McLeods Spur Trail, 13/03/2025 (Image credits: Tarmo A. Raadik).
Galaxiids present.

PEC4: Peppercorn Creek tributary, McLeods Spur Trail, 13/03/2025 (Image credits: Tarmo A. Raadik).
Trout present.

PEC5: Peppercorn Creek tributary, McLeods Spur Trail, 13/03/2025 (Image credits: Tarmo A. Raadik).
Trout present.

PEC6: Peppercorn Creek tributary, McLeods Spur Trail, 13/03/2025 (Image credits: Tarmo A. Raadik).
No fish.

POC1, POC2, POC4 (clockwise from top left): Pocket Creek tributaries, upstream of aqueduct intakes, 6/03/2025 (Image Credits: Tarmo A. Raadik). **No fish.**

RGC2: Rollin Grounds Creek, lower (left) and second (right) trout barrier waterfalls, upstream from Goodradigbee River, 7/03/2025 (Image credit: Luke Pearce). **Galaxiids present.**

RGC1: Upper reach of Rolling Grounds Creek, off Leura Gap Trail 6/03/2025 (Image credit: Luke Pearce).
Galaxiids present.

SFC1: Seventeen Flat Creek, off Mosquito Creek Trail, 5/03/2025 (Image credit: Luke Pearce).
Trout present.

TPC1: Tin Pot Creek, off Long Plain Road, 5/03/2025 (Image credit: Tarmo A. Raadik). **Galaxiids present.**

Jounama catchment

BPC1: Big Plain Creek, on plateau, Bogong Peaks Wilderness, 11/03/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present.**

Murrumbidgee catchment

HHC1: Hell Hole Creek, at small falls ~600 m upstream from junction with Murrumbidgee River, 4/03/2025 (Image credit: Luke Pearce). **Trout present.**

MDC1: Dairymans Creek, upstream of falls, 11/03/2025 (Image credits: Tarmo A. Raadik). **Trout present.**

MDC2: Dairymans Creek, waterfall, 11/03/2025 (Image credits: Tarmo A. Raadik). **Trout present.**

MGC1: Gurrangorambla Creek tributary, at Goodradigbee diversion channel outlet structure, 6/03/2025 (Image credits: Tarmo A. Raadik).

MGCT1: Gooandra Creek trib., and eroded falls, headwaters 4/03/2025 (Image credit: Tarmo A. Raadik). **Trout present.**

MGCT2: Gooandra Creek trib., off Bullocks Hill Trail, 4/03/2025 (Image credit: Tarmo A. Raadik). **No fish.**

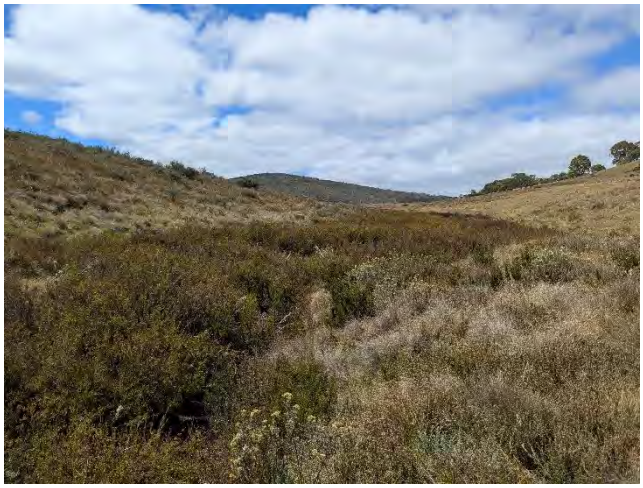
MGCT3: Gurrangorambla Creek tributary, trout barrier waterfall (left) and electrofishing (right), 7/03/2025 (Image credit: Luke Pearce). **No fish.**

MMcPT: McPhersons Creek, off Mosquito Creek Trail, at potential falls (no falls found), 10/03/2025 (Image credit: Tarmo A. Raadik). **Trout present.**

MURT1: Murrumbidgee River tributary, next to Snowy Mountains Highway, 7/03/2025 (Photo credit: Luke Pearce). **No fish.**

MURT2: Murrumbidgee River tributary, southeast side of Hains Hut, 4/03/2025 (Image credit: Luke Pearce). **Trout present.**

PAC1: Paytens Creek tributary, on headwater plateau, 11/03/2025 (Image credit: Tarmo A. Raadik). **No fish.**



TCT1: Tantangara Creek tributary, off Bullocks Hill Trail, 4/03/2025 (Image credit: Tarmo A. Raadik) **Galaxiids present.**

Tumut catchment

HDC1 (left) & **HDC2** (right): Dodgers Creek, upstream from Happy Jacks Road, 20/11/2024 (Image credit: Luke Pearce). **Galaxiids present**.

PC1: Prospector Creek, Deadmans Trail, 8/04/2025 (Image credits: Tarmo A. Raadik). **No fish.**

SRC: Snowy Ridge Creek, at and upstream of the diversion weir, 3/03/2025 (Image credit: Luke Pearce). **No fish.**

TEM1: Eight Mile Creek, Link Road, 8/04/2025 (Image credits: Tarmo A. Raadik). **Trout present.**

TSCT: Section Creek tributary, downstream of unnamed track, 8/04/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present**.

TSC1: Section Creek, Link Road, 8/04/2025 (Image credits: Tarmo A. Raadik). **Trout present.**

Yarrangobilly catchment

BR1: Brownleys Back Creek, Goobarragandra Powerline Road, 8/04/2025 (image credit: Luke Pearce).
Trout present.

YB1: Blue Creek, at falls off Blue Creek Trail, at Coppermine, 9/04/2025 (Image credits: Tarmo A. Raadik).
No fish.

YRC1: Rules Creek, upper reaches, downstream of Snowy Mountains Highway, 10/04/2025 (Image credits: Tarmo A. Raadik. **No fish.**

YRC2A: Rules Creek, below Rules Dam, upstream of Yarrangobilly Caves, 10/04/2025 (Image credits: Tarmo A. Raadik). **No fish.**

YRC2B: Rules Creek, upstream of Rules Dam, upstream of Yarrangobilly, 10/04/2025 (Image credits: Tarmo A. Raadik). **No fish.**

YRC2C: Rules Creek, reach below large waterfall, upstream of Yarrangobilly Caves, 10/04/2025 (Image credits: Tarmo A. Raadik). **No fish.**

YRC2D: Rules Creek, upstream of large waterfall, upstream of Yarrangobilly Caves, 10/04/2025 (image credits: Tarmo A. Raadik). **No fish.**

YRC3: Rules Creek, Yarrangobilly Cave Entrance Road, 10/04/2025 (Image credits: Tarmo A. Raadik). **No fish.**

YRC4: Rules Creek, near power station, Yarrangobilly Caves, 10/04/2025 (Image credits: Tarmo A. Raadik). **Trout present just upstream at YRC5.**

YRC5: Rules Creek, just upstream of power station at Yarrangobilly Caves, at waterfall, 10/04/2025 (Image credits: Tarmo A. Raadik). **Trout present in pool below falls.**

YT1: Yarrangobilly River tributary, Jounama Heritage Walk, 9/04/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present.**

YT2: Yarrangobilly River tributary, Lobbs Hole Ravine Road, 9/04/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present.**

YT3: Yarrangobilly River tributary, Yans Crossing Trail, 9/04/2025 (Image credits: Tarmo A. Raadik). **Galaxiids present.**

Tarmo Raadik, inspecting the main waterfall discovered on Rolling Grounds Creek, which protects a population of galaxiids upstream from trout below, 7/03/2025 (Image credit: Luke Pearce).

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Appendix I

Site descriptions and photos from Macquarie Perch catchment surveys

Appendix I – Site descriptions and photos from Macquarie Perch catchment surveys

Big Badja River

Nursery Hole was identified as a potential reintroduction/stocking site for several reasons. Firstly, an excellent predator barrier is present downstream of the eDNA site (Figure I3). This barrier consists of a series of steep water elevation drops, including falls of up to 3 m observed during the site assessment. Further investigations are needed to determine whether additional barriers occur upstream. The site is a predominately a rocky substrate with boulders, bedrock and cobble dominating the substrate. (Figure I2). A large deep pool (>4 m) provides refuge habitat during low flows, while cobble riffles upstream of the pool offer suitable spawning habitat for Macquarie Perch. As expected with a rocky substrate, shade and macrophyte growth are minimal. The site has reasonable 4WD access during dry conditions. From the Barrier below Nursery Hole a 7.8km reach of the Big Badja River was identified to the bridge on Badja Road as a reach warranting further investigation.

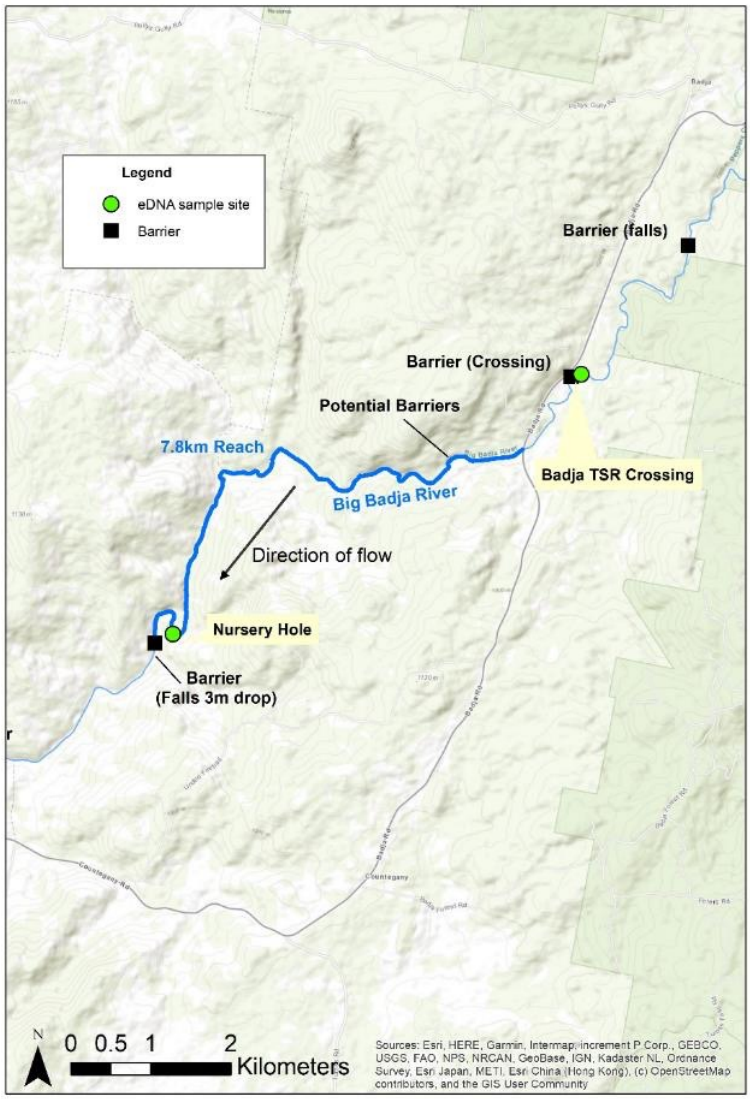

Figure I1. Nursery Hole site on the Big Badja River.

Figure I2. Nursery Hole site – large pool present at site

Figure I3. Big Badja River barrier (Falls 3 metre drop)

Kybeyan River

The Kybeyan East Firetrail site is located within the Kybeyan Nature Reserve. Potential fish barriers occur in the Kybeyan River downstream of the site (Figure I4), although further investigation is required to confirm their effectiveness. The site is easily accessed via the Kybeyan East Firetrail, which crosses the river.

Downstream of the crossing there is a large deep pool, approximately 3 m in depth, with a sandy and bedrock substrate. Upstream of the crossing the habitat consists of a series of riffles dominated by cobble and boulder substrate. The reach is well shaded by native riparian vegetation, and submerged macrophytes, including Milfoil, are present within the site.

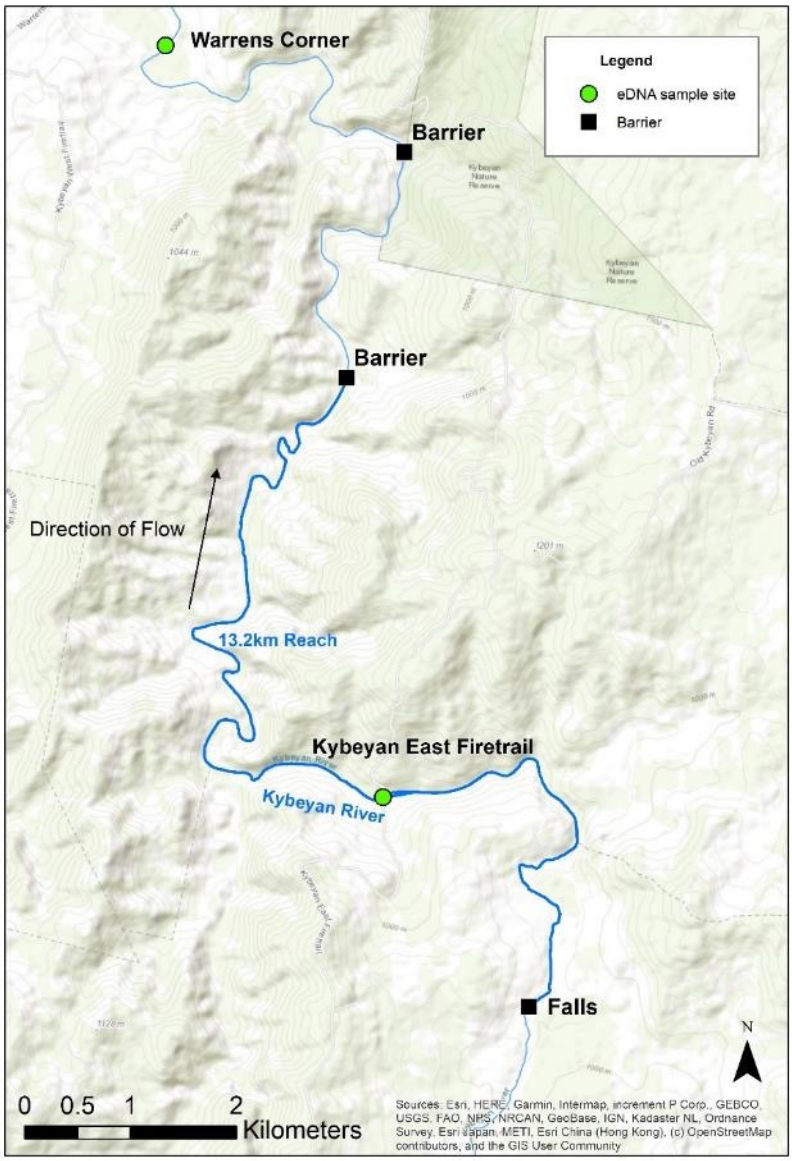

Figure I4. Kybeyan East Firetrail site

Figure I5. Kybeyan East Firetrail site – large pool present downstream of crossing

Figure I6. Kybeyan East Firetrail site – cobble / boulder substrate being eDNA sampled

Cowra Creek

The Peak View Road Crossing site is located on Cowra Creek, offers high-quality habitat, characterised by a bedrock and boulder substrate in the deeper pools (>2m) and gravel substrate in the riffle areas. The pools are quite large, riffle areas a lot smaller with good connectivity. Riparian vegetation is in good condition, providing ample shading, and both emergent and submerged macrophytes, including Milfoil, are present. Further investigation is required to assess potential fish barriers along Cowra Creek and water security.

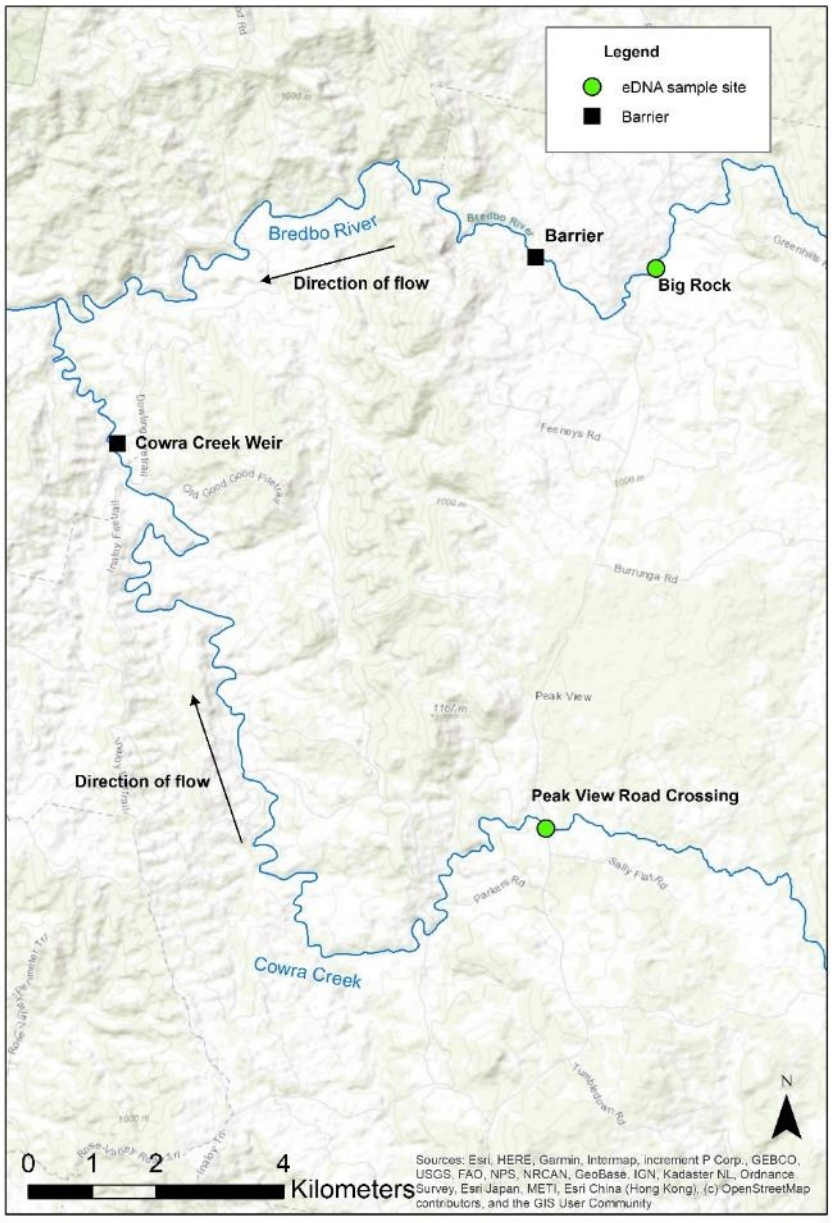

Figure I7. Cowra Creek and Bredbo River sites

Figure I8. The Peak View Road Crossing site.

Figure I9. The Peak View Road Crossing site - large pool present.

Bredbo River

The Big Rock site on the Bredbo River was mostly shallow smaller pools (>1.5m) and riffles dominated with a cobble / gravel substrate The site had dense riparian vegetation and fringing emergent macrophytes (Phragmites) providing excellent shade. The site had good connectivity between riffles and pools, site is predominately made up of a large run. Submerged boulders and snags enhance the habitat features of the site. Additional investigation is needed to assess potential fish barriers along the Bredbo River.

Figure I10. The Big Rock site on the Bredbo River

Figure I11. The Big Rock site on Bredbo River – emergent macrophytes (Phragmites)

Goorudee Rivulet

The Goorudee Rivulet primarily flows through agricultural land before joining the Murrumbidgee River near Adaminaby. While no major barriers have been identified along this waterway, further investigation is needed.

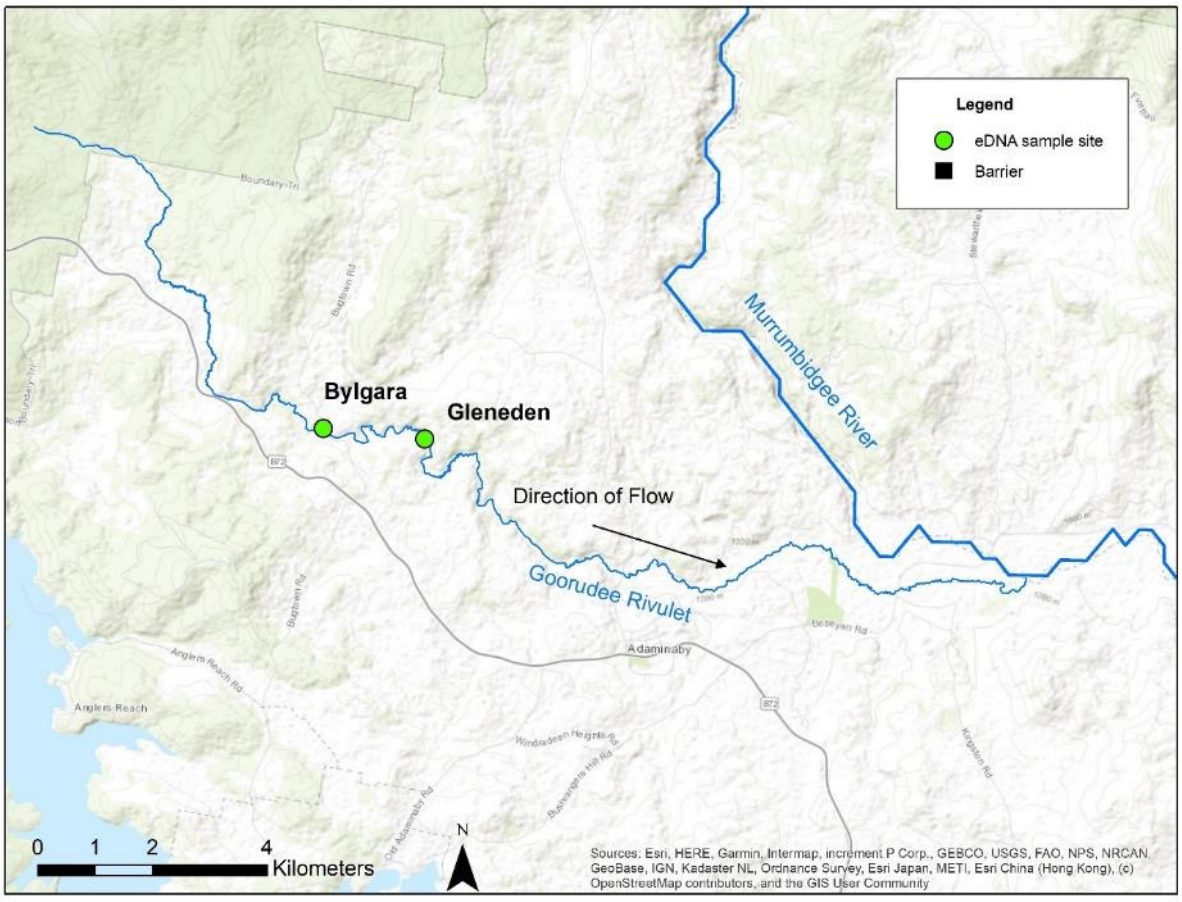

Figure I12. Bylgara and Gleneden sites

The Bylgara site on the Goorudee Rivulet is a relatively narrow stretch of water, measuring up to 2-3 meters in width. The site features mostly shallow mud and bedrock pools (< 1.0m deep) with small cobble riffles. Riparian vegetation is present, along with submerged macrophytes, including Milfoil.

The Gleneden site on the Goorudee Rivulet is a heavily shaded area, with abundant fringing emergent grasses and extensive tree cover offering significant shade. The site features small, shallow pools (< 1.5m deep) with a predominantly boulder and mud substrate. It also offers good shallow riffle habitat made up of cobbles and boulders. Upstream springs help maintain flow during dry periods.

Figure I13. The Bylgara site on the Goorudee Rivulet

Figure I14. The Gleneden site on the Goorudee Rivulet

Numeralla River

The site at Numeralla travelling stock reserve (TSR), located on the Numeralla River above a fish barrier, features a long 200m pool (>3m deep) with a sandy gravel substrate and slow flow. The riffles are small, composed mainly of gravel with some cobble. The stream demonstrates good connectivity and water permanency. While riparian vegetation is present, it is predominantly willows and tea tree brush. Submerged macrophytes, such as Milfoil, and emergent macrophytes, like Sedge, are found throughout the site, along with occasional boulders and snag structures. The fish barrier (Falls) downstream is significant and warrants further investigation.

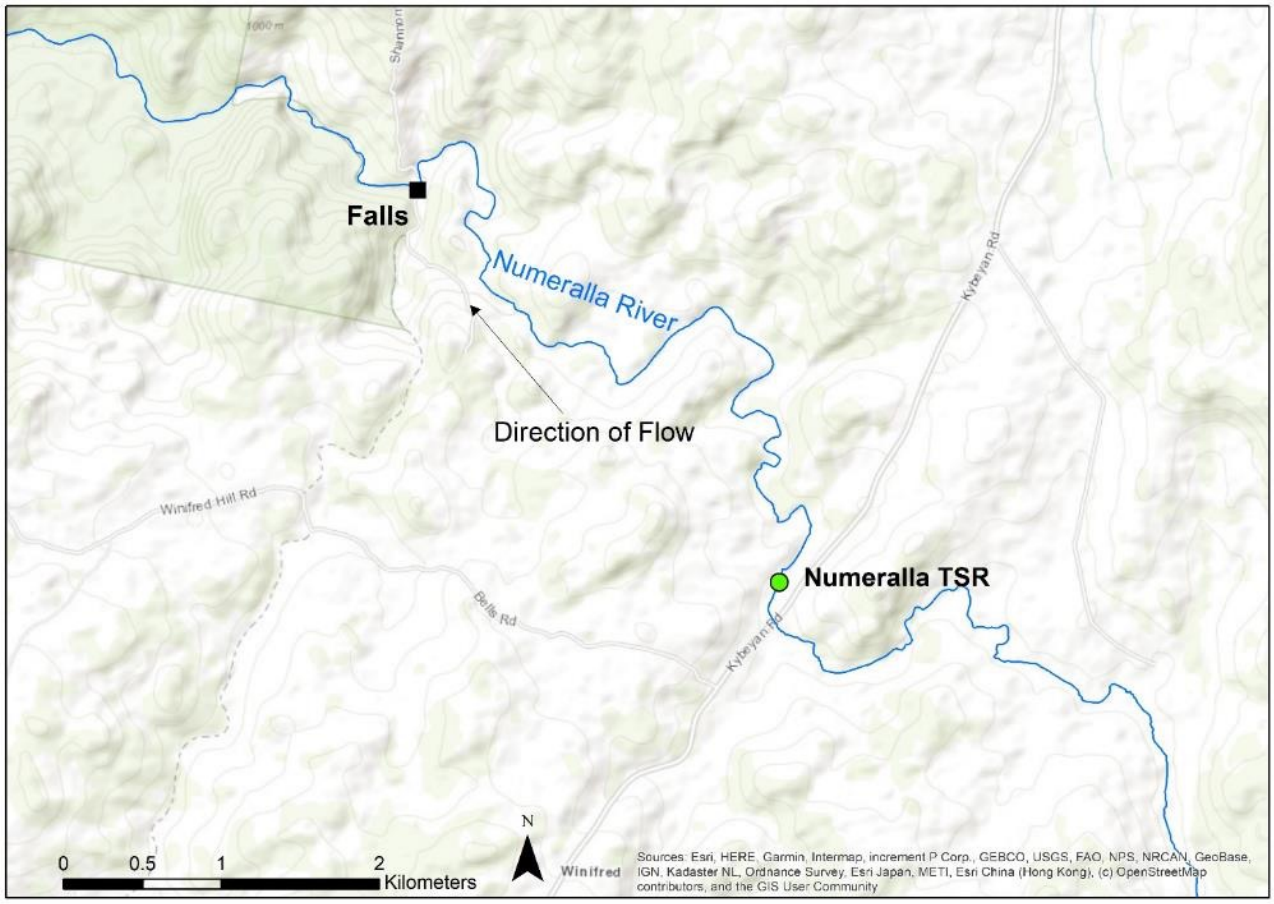

Figure I15. The Numeralla TSR site on the Numeralla River

Strike-a-light River

At the time of assessment, the Rayners Fire Trail site exhibited very low flow conditions, with limited connectivity between isolated pools and riffles. Portions of the river were dry, while other sections displayed subsurface flow. Although some pools reached depths of approximately 2 metres, they were small and offered negligible refuge habitat.

The site featured good-quality cobble riffle substrate and bedrock in pools. However, due to the lack of consistent surface flow and overall poor water security, the site is not currently suitable for species reintroduction efforts. Further investigation could be undertaken in lower sections of Strike-a-light River to find more water permanency.

Figure I16. The Strike-a-light River site - Rayners Fire Trail

Figure I16. The Strike-a-light River site - Rayners Fire Trail – dry section

Doubtful Creek

Doubtful Creek has been identified as a potential site for the reintroduction of Macquarie Perch, though it was not included in the 2024/25 Catchment surveys. Located in the Murrumbidgee Catchment, it lies in the headwaters of the Tumut River. The creek is approximately 20 km in total length and features suitable habitat, with natural fish barriers near its confluence with the Tumut River. Upstream of these barriers, there is a 15 km reach that could serve as a potential stocking and reintroduction site. Sampling undertaken in the upper reaches at Grey Mare Fire Trail in 2016 failed to detect any trout, however further surveys are required to identify the upstream extent of the trout distribution and where they barrier to their upstream movement is located.

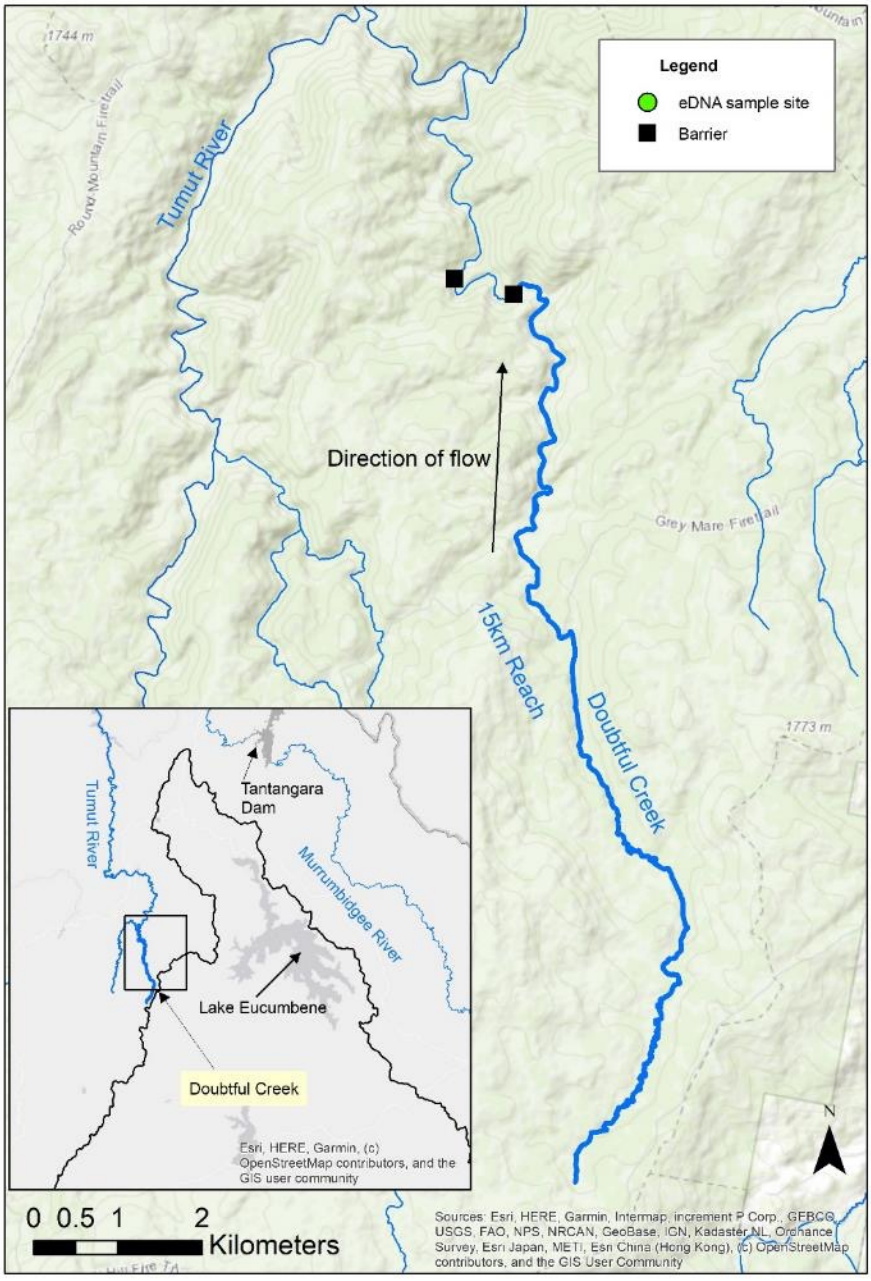

Figure I17. Location of Doubtful Creek.

Figure I18. Potential trout barrier, Doubtful Creek barrier

Figure I19. Example of Doubtful Creek stream habitat

Tantangara Creek

Tantangara Creek has also been identified as a potential site for the reintroduction of Macquarie Perch, though it was not included in the 2024/25 Catchment surveys. A 15.4 km stretch between two barriers has been highlighted as an area warranting further investigation. This section of Tantangara Creek is downstream of the known Stocky Galaxias habitat and is known to hold a high population of self-recruiting both brown and rainbow trout.

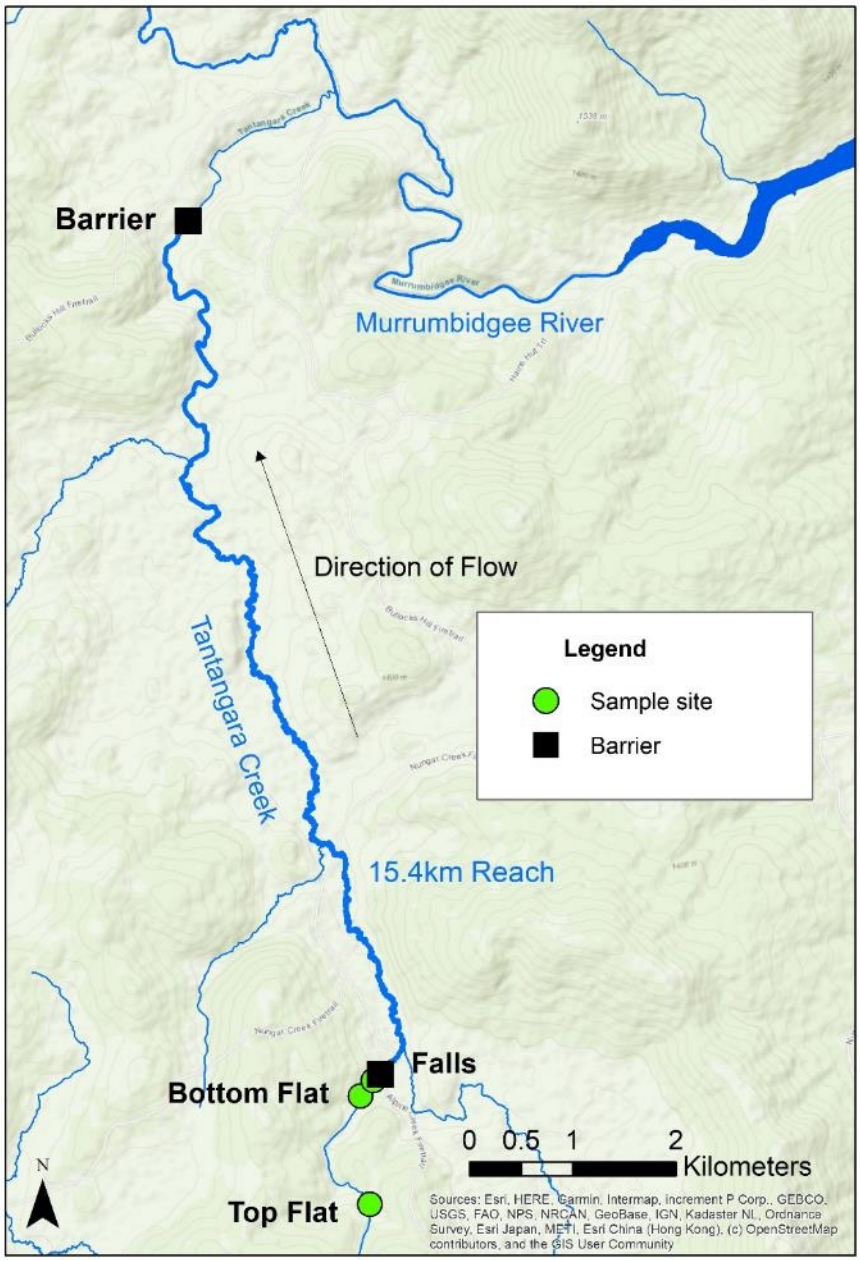

Figure I20. Location of Tantangara Creek.

Appendix J

Using eDNA to detect redfin perch (*Perca fluviatilis*) and Macquarie perch (*Macquaria australasica*) in the Murrumbidgee River

Department of Primary Industries and Regional Development

Using eDNA to detect redfin perch (Perca fluviatilis) and Macquarie perch (Macquaria australasica) in the upper Murrumbidgee River

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Background

The Snowy Mountains Hydro-electric Scheme was designed to generate hydroelectricity and divert water westward for irrigation. This changed the natural flow of rivers such as the Snowy, Eucumbene, Murrumbidgee, and their tributaries through an interconnected system of dams, tunnels, and aqueducts (Snowy Hydro Limited). The Snowy 2.0 project expands the Scheme to increase the electricity generation capacity. While this will deliver substantial energy benefits, there is the potential for widespread ecological consequences, particularly to the endangered Macquarie perch (*Macquaria australasica).* The connection of Talbingo Reservoir (where redfin perch have been recorded) and Tantangara Reservoir (where redfin perch have not been recorded) could allow the introduced redfin perch (*Perca fluviatilis*) to encroach on Macquire perch habitat if planned controls fail. Redfin perch pose a risk to Macquarie perch because it may consume their eggs and larvae as well as spread epizootic haematopoietic necrosis (EHN) virus (NSW DPI).

As part of the NSW and Commonwealth approvals for Snowy 2.0, Snowy Hydro is required to prepare and implement a Threatened Fish Management Plan. This plan includes a range of conservation measures for Macquarie Perch and Stocky Galaxias. One of these is habitat surveys to identify suitable receiving sites for establishing insurance populations through either stocking or translocation of Macquarie Perch. This study is one component of this activity.

To maximise the chance of these new populations establishing, it is important that these sites are free of redfin perch to ensure the translocated individuals have the best chance of becoming established. This project uses environmental DNA (eDNA) to evaluate potential translocation sites by determining if either species is present. Detection of redfin perch would indicate that a site may be unsuitable for translocation. Detection of Macquarie perch would prompt further investigation to assess whether translocating additional individuals could enhance genetic diversity, reduce inbreeding and increase effective population size (Pavlova et al., 2024). In this study, species-specific qPCR assays were used to test for the presence of Macquarie perch and redfin perch at 14 sites in tributaries of the upper Murrumbidgee River. There is currently no evidence that either species are present in the sampling locations.

Methods

Sample Collection

NSW DPI Habitat and Threatened Species staff identified 14 priority sites (Figure 1 and Appendices 1–2) for sample collection between September 2024 and February 2025. At the time of sampling, water was flowing at all sites at typical levels. Samples were collected by DPIRD threatened species managers using a Smith-Root eDNA Sampling Backpack or the Smith-Root Citizen Scientist Sampler and 5 µm self-preserving filters. All sampling was conducted on the bank of the waterways and water was filtered in situ using eight filters targeting a volume of 2.0 L per filter. Eight filters were chosen given this minimised the chances of false negatives (Duncan et al., 2024). In addition, eight filters were used by a previous study that detected redfin perch in a different river system when the species had also been detected by concurrent conventional monitoring (Bylemans et al., 2016). An equipment control containing 1 L of bottled spring water was filtered at the beginning of each site to check for contaminating Macquarie perch or redfin perch DNA at the time of sample filtration. At the completion of sampling a total of 112 samples were filtered. Filters were refrigerated at 4°C before sending to the Narrandera Fisheries Centre (NFC) for processing where they were stored at 4°C until eDNA extraction. Filters were extracted within 1–5 months of collection.

Environmental DNA Extraction

Environmental DNA was extracted from the filters using a PureLink Genomic DNA Mini Kit with a modified protocol (Wilkes Walburn et al., 2022). An extraction control was included with each site to check for contamination that may have occurred at the time of extraction. The extracted DNA was expected to contain PCR inhibitors given this is a common occurrence across many NSW river systems. Therefore, the eDNA was purified using a OneStepTM PCR Inhibitor Removal Kit from Zymo Research following the manufacturer's protocol.

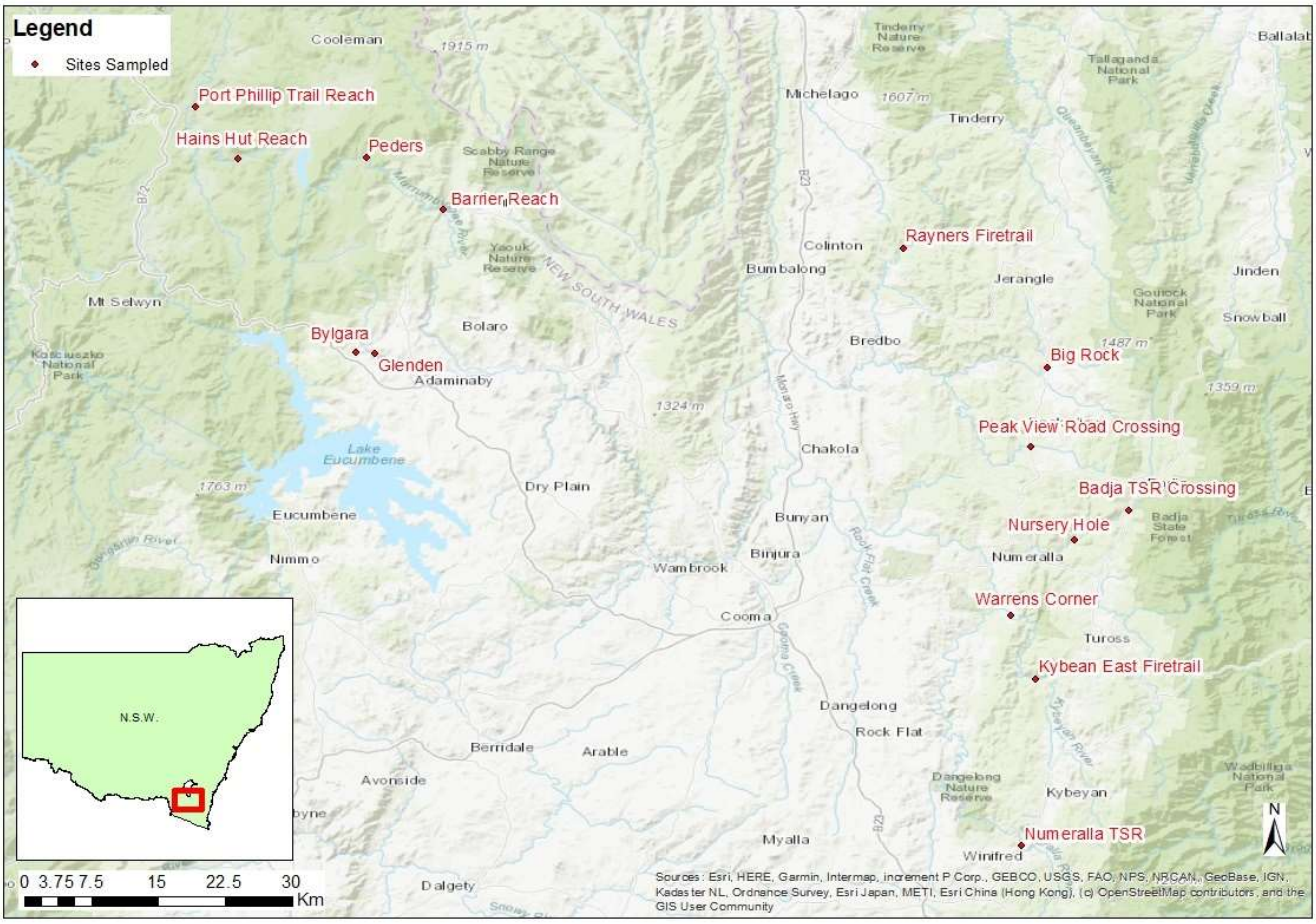

Figure 1. The sampling locations for the 14 sites in the upper Murrumbidgee River.

qPCR analysis

Redfin perch and Macquarie perch DNA was targeted using previously developed species-specific eDNA assays validated for each species (Furlan & Gleeson, 2016; Piggott, 2017). The redfin perch assay targeted a 92 bp fragment of the 12SrRNA while the Macquarie perch assay targeted a 127 bp fragment of the cyt-b gene.

For each eDNA sample, six qPCR replicates were run for each species to increase the chance of detecting the target species. Each qPCR plate contained three positive controls consisting of 10^{-6} ng μl^{-1} synthetic redfin perch 12S rRNA sequence or Macquarie perch cyt-b sequence, each containing an eight-base-pair (bp) pair reverse complement sequence to facilitate detection of any contamination of field samples with the positive control via Sanger sequencing. Each plate also contained six replicate samples of the equipment control, extraction control, and negative qPCR control to ensure no contamination occurred during the extraction or qPCR set-up stage. In addition, a generic eDNA assay targeting plants, algae and bacteria was run in a duplex with the redfin perch and Macquarie perch assays (Zhu et al., 2024)**.** This assay was included in the qPCR reaction mix with sample to ensure there were no errors made during sample collection, extraction, or qPCR to help avoid false negative results. The assay also allowed the identification of potential qPCR inhibition (i.e., any substances in the water such as tannins that can interfere with the qPCR reaction) that may still be present despite treating the samples for inhibition.

Results and Discussion

All positive controls amplified as expected and the generic plant assay successfully amplified in every sample and qPCR replicate, although amplification was delayed by approximately 2–3 cycles at some sites. No contamination of the target species was detected in any equipment controls, extraction controls, or negative qPCR controls. Neither redfin perch nor Macquarie perch were detected in any of the eDNA samples (Table 1). Although these species were not expected at the sampling locations, it was important to confirm that the negative results were not due to residual PCR inhibition. To assess this, we tested eDNA extracts from two sites with the longest amplification delay in the generic assay—Haines Hut Beach and Peak View Road Crossing. Synthetic redfin perch DNA was spiked into these extracts at four dilution levels (1:10, 1:100, 1:1,000, and 1:10,000), and qPCR was rerun to check for consistent ~3.3 cycle increases between dilutions (De Brauwer M et al., 2022). The observed results matched the expected amplification pattern, indicating that PCR inhibition was not affecting detection at these sites. We therefore concluded that inhibition was unlikely to be a significant issue at the other sites as well. As a result, the risk of false negatives was considered low, and the absence of detection was most likely due to the species being genuinely absent, or present at concentrations below the assay's detection threshold.

Despite the best sampling and laboratory efforts, the risk of false negatives is rarely zero. Occupancy modelling indicates that common species can often be detected with high certainty using 15 or fewer samples and minimal qPCR replication. In contrast, rare species typically require a much greater sampling effort. For instance, if the likelihood of capturing eDNA in the filter samples at the site is just 5%—a plausible scenario for extremely rare taxa—achieving a 90% detection confidence could require between 45 and 90 samples per site. As eDNA detectability improves, the number of samples needed to ensure reliable identification correspondingly decreases (Erickson et al., 2019). Nevertheless, false negatives are also a recognised limitation of conventional fish sampling methods. For example, a study comparing electrofishing, fyke netting, gill netting and eDNA revealed that the eDNA method was able to detect Macquarie perch at more sites than any of the physical capture methods (Piggott et al., 2021). Similarly, eDNA methods detected redfin perch at a higher rate to electrofishing, unbaited traps and fyke netting (Bylemans et al., 2016; Hinlo et al., 2017). This suggests that using eDNA to continue to search for these species in the upper Murrumbidgee River area is warranted.

Table 1. Results of the redfin perch and Macquarie perch eDNA assay analysis of 14 sites (see full details in Appendix 1). [±]The downstream latitude and longitude.

Site Name	Rive/creek name	Sampling date	Generic assay (% of replicates that amplified)	Redfin perch positive qPCR replicates	Macquarie perch positive qPCR replicates
Badja TSR Crossing	Big Badja River	17-Sep-24	100	0	0
Barrier Reach	Murrumbidgee River	14-Jan-25	100	0	0
Big Rock	Bredbo River	16-Jan-25	100	0	0
Bulgannia (Bylgara)	Goorudee Rivulet	16-Jan-25	100	0	0
Glenden	Goorudee Rivulet	17-Jan-25	100	0	0
Haines Hut Reach	Murrumbidgee River	14-Jan-25	100	0	0
Kybeyan East Firetrail		18-Sep-24	100	0	0
Numerella TSR		16-Sep-24	100	0	0
Nursery Hole		17-Sep-24	100	0	0
Peak View Road Crossing	Cowra Creek	16-Jan-25	100	0	0
Peders	Murrumbidgee River	12-Feb-25	100	0	0
Port Phillip Trail Reach	Murrumbidgee River	13-Jan-25	100	0	0
Rayners Firetrail	Strike-a-Light River	15-Jan-25	100	0	0
Warrens Corner	Kybean River	13-Feb-25	100	0	0

Conclusion and recommendations

This study found no evidence of redfin perch or Macquarie perch at any of the 14 surveyed sites in the upper Murrumbidgee region using a sensitive and validated qPCR-based eDNA assays. The sampling strategy followed current NSW DPIRD protocols, providing 48 detection opportunities per site, and was appropriate for detecting species at low abundance. Notwithstanding the possibility of false negative results, the results do suggest that neither species is currently established at the sampled sites, though continued surveillance is recommended to monitor potential future incursions.

Environmental DNA offers a powerful, non-invasive approach for detection of threatened species as well as the early detection of invasive species such as redfin perch, particularly in cases where traditional sampling methods may fail to detect rare or low-density populations. Given its demonstrated sensitivity, we recommend that eDNA surveys continue to be incorporated into routine monitoring programs—ideally timed to coincide with the spawning season to increase detection probability. Future surveys could focus on areas near previous detections and upstream reaches to identify potential invasion fronts. If eDNA is detected, targeted conventional sampling can help assess population size and inform management actions. We would be pleased to support the design of an expanded eDNA surveillance strategy, including potential refinements to assay design and sampling effort to further enhance detection reliability.

Appendix 1: Sampling locations and site information for the eDNA survey for redfin perch and Macquarie perch.

Site Name	Waterway	Sampling Date	US Latitude	US Longitude	DS Latitude	DS Longitude	Sampling Method	Weather	Wind
Badja TSR Crossing		17/09/2024	-36.1212	149.4908	-36.1209	149.4893	Citizen Scientist Sampler	Sunny	Slight
Barrier Reach	Murrumbidgee River	14/01/2025	-35.8173	148.7979	-35.8183	148.7996	eDNA backpack	Not recorded	Not recorded
Big Rock	Bredbo River	16/01/2025	-35.9761	149.4083	-35.9778	149.4069	eDNA backpack	Not recorded	Not recorded
Bulgannia (Bylgara)	Goorudee Rivulet	16/01/2025	-35.9630	148.7086	-35.9627	148.7107	eDNA backpack	Not recorded	Not recorded
Glenden	Goorudee Rivulet	17/01/2025	-35.9628	148.7291	-35.9641	148.7304	eDNA backpack	Not recorded	Not recorded
Haines Hut Reach	Murrumbidgee River	14/01/2025	-35.7683	148.5910	-35.7682	148.5925	eDNA backpack	Not recorded	Not recorded
Kybeyan East Firetrail		18/09/2024	-36.2907	149.3962	-36.2907	149.3951	Citizen Scientist Sampler	Sunny	Slight
Numerella TSR		16/09/2024	-36.4609	149.3802	-36.4592	149.3810	Citizen Scientist Sampler	Not recorded	Not recorded
Nursery Hole		17/09/2024	-36.1509	149.4348	-36.1513	149.4336	Citizen Scientist Sampler	Sunny	Slight
Peak View Road Crossing	Cowra Creek	16/01/2025	-36.0577	149.3917	-36.0573	149.3902	eDNA backpack	Not recorded	Not recorded
Peders	Murrumbidgee River	12/02/2025	-35.7670	148.7215	-35.7664	148.7234	eDNA backpack	Cloudy	Still
Port Phillip Trail Reach	Murrumbidgee River	13/01/2025	-35.6998	148.5509	-35.7160	148.5502	eDNA backpack	Not recorded	Not recorded
Rayners Firetrail	Strike-a-Light River	15/01/2025	-35.8569	149.2607	-35.8581	149.2617	eDNA backpack	Not recorded	Not recorded
Warrens Corner	Kybean River	13/02/2025	-36.2271	149.3703	-36.2251	149.3717	eDNA backpack	Cloudy	Windy

Appendix 2: Water quality details for the sampling locations.

Site Name	WQ Depth (m)	Time (24hr)	Water temp (°C)	pH.	D.O. (mg/L)	Conductivity (mS/cm)	Turbidity (NTU)
Badja TSR Crossing	0.2	15:50:00	12.67	Not recorded	9.96	0.03	0.00
Barrier Reach	0.2	Not recorded	24.57	Not recorded	7.95	0.04	3.47
Big Rock	0.2	Not recorded	19.80	Not recorded	7.87	0.07	20.50
Bulgannia (Bylgara)	0.2	Not recorded	22.73	Not recorded	8.58	0.06	11.93
Glenden	0.2	Not recorded	17.36	Not recorded	8.84	0.06	62.00
Haines Hut Reach	0.2	Not recorded	19.71	Not recorded	8.33	0.02	7.10
Kybeyan East Firetrail	0.2	11:08:00	11.66	Not recorded	10.18	0.05	0.00
Numerella TSR	1.0	Not recorded	10.60	Not recorded	9.78	0.04	0.00
Nursery Hole	0.2	12:15:00	12.62	Not recorded	10.14	0.05	0.00
Peak View Road Crossing	0.2	Not recorded	20.54	6.42	6.72	0.10	9.14
Peders	0.2	Not recorded	22.80	6.30	7.97	0.03	1.90
Port Phillip Trail Reach	0.2	Not recorded	23.29	7.07	7.77	0.03	3.62
Rayners Firetrail	0.2	Not recorded	24.32	Not working	17.31	0.18	16.40
Warrens Corner	0.3	Not recorded	20.40	7.01	5.55	0.10	33.20

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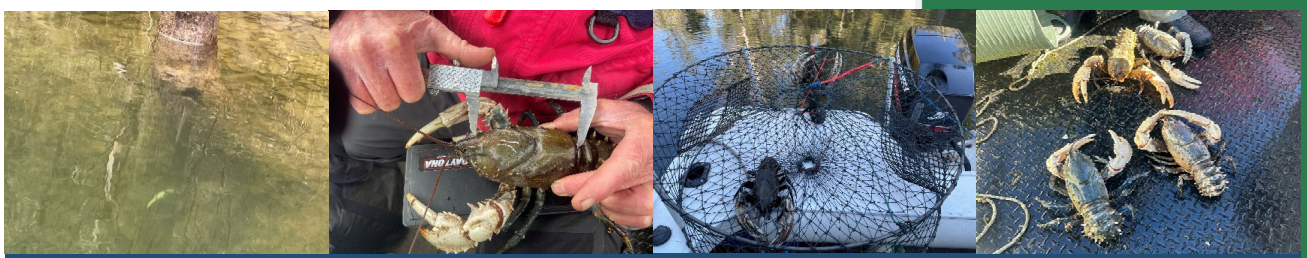
Appendix K

Murray Crayfish Monitoring Results

The status of Murray Crayfish in Talbingo Reservoir, Yarrangobilly River and Wallace Creek in June 2025

Sylvia Zukowski & Matt Jacobs

Report to Snowy Hydro Limited



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Disclaimer

Although reasonable care has been taken in preparing the information contained in this publication, neither NGT, nor Snowy Hydro accept any responsibility or liability for any losses of whatever kind arising from the interpretation or use of the information set out in this publication.

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Background

Murray Crayfish *Euastacus armatus* (von Martens 1866) is one of 53 described species within the genus *Euastacus*. This genus contains high levels of cryptic diversity (Austin, Whiterod et al. 2021) however, *E. armatus* is the most widely distributed with an estimated extent of occurrence >150,000 km^2. The species is endemic to Australia and is the second largest freshwater crayfish worldwide, with a maximum documented occipital carapace length of 174 mm. It is long-lived (~28 years), slow-growing (K = 0.0933), late-maturing (~8–9 years) and has low fecundity (up to 2000 eggs per mature female each breeding event) (Gilligan, Rolls et al. 2007, Furse and Coughran 2011). It spawns annually and utilises a winter-spring brooder strategy (Morison 1988, Gilligan, Rolls et al. 2007).

Murray Crayfish prefer relatively cool, oxygenated (dissolved oxygen (DO) concentrations >2 mg L^{-1}) water with physical structure (Geddes, Musgrove et al. 1993, McCarthy 2005, Gilligan, Rolls et al. 2007). Freshwater crayfish are considered intolerant to pollutants and pesticides, yet no thresholds have been defined for Murray Crayfish (e.g., Gilligan, Rolls et al. 2007). It is capable of short-term emersion to avoid adverse conditions, although mortality can result from extended periods out of the water (McKinnon 1995).

Murray Crayfish is an iconic species endemic and once widespread in the waterways of the southern Murray-Darling Basin (MDB). This species has experienced substantial declines in range and abundance over the second half of the twentieth century (Gilligan, Rolls et al. 2007, Furse and Coughran 2011). Recent population decline across sections of its range (McCarthy, Zukowski et al. 2014, Noble and Fulton 2017, Whiterod, Zukowski et al. 2018) indicate that the species is experiencing a declining trend in population status, fostering concerns over its long-term sustainability. Murray crayfish has been listed as a vulnerable species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Date effective 05-Mar-2025). Murray Crayfish is considered *threatened* in Victoria under the *Flora and Fauna Guarantee Act 1988*, *vulnerable* in NSW (*Fisheries Management Act 1994*)

and the ACT (*Nature Conservation Act 1980*) and protected in South Australia under the *Fisheries Management Act 2007*.

In response to species decline, there has been dedicated research and monitoring focusing on the following:

- sustainability of recreational fishing (Zukowski, Curtis et al. 2011, Zukowski, Watts et al. 2012, Zukowski, Whiterod et al. 2013),
- the impacts of extreme hypoxic blackwater (King, Tonkin et al. 2012, McCarthy, Zukowski et al. 2014, Whiterod, Zukowski et al. 2018),
- habitat degradation (Noble and Fulton 2017),
- a comprehensive genetic assessment (Whiterod, Zukowski et al. 2017),
- the development of a stochastic population model to provide a framework to address management and conservation scenarios (Todd, Whiterod et al. 2018, Whiterod, Todd et al. 2020), and
- Murray crayfish conservation genomics analysis (paper in prep.).

In addition, translocations undertaken over five years on the Murray River, near Echuca, have resulted in the establishment of a translocation method (Whiterod, Asmus et al. 2021) and assessment of conservation translocation feasibility for the entire genus (*Euastacus*) has been undertaken, with specific reference to priority 2019-20 bushfire-impacted species (Zukowski, Whiterod et al. 2021).

This collaborative research and monitoring has improved the wider understanding of the species and facilitated effective conservation management. It has also emphasised the requirement for research and monitoring to conserve known populations of this threatened species, particularly for populations with potential to be impacted by disturbance.

The species was historically abundant in the region of the Tumut River, which is artificially impounded by Talbingo Reservoir (Gilligan, Rolls et al. 2007). Whilst a flow specialist, Murray Crayfish has persisted following the construction of the reservoir and the species is protected from recreational fishing in the reservoir. The population has been shown to be genetically distinct from a broad, interbreeding lowland population across the wider Murray-Murrumbidgee region (Whiterod, Zukowski et al. 2017). Targeted annual surveys within Talbingo and Blowering Reservoirs during the period 2008–2010 provided the first

assessment of the status of the species in these reservoirs (Zukowski, Whiterod et al. 2013). In Talbingo Reservoir, Zukowski *et al*. (2013) demonstrated a healthy population with a 1:1 sex ratio, and good population structure (including regular recruitment and long-term survival). Whilst sampling of a single site in 2013 in Talbingo Reservoir (NSW DPI, unpublished data) demonstrated a similar abundance, a considerable reduction in catch was observed in 2018 surveys (Cardno 2019), raising concern about the status of the species in the reservoir.

In the winter of 2019, 2020, 2021, 2022, 2023 and 2024 surveys were undertaken to resolve the status of Murray Crayfish populations in Talbingo Reservoir to better inform considerations for the species in the Snowy 2.0 project. Fourteen sites were sampled within the reservoir (7 existing sites previously surveyed and 7 new sites) at which 19, 14, 18, 33, 6 and 21 individuals were recorded, respectively. (Zukowski and Whiterod 2019, Zukowski, Whiterod et al. 2020, Zukowski and Whiterod 2022, Zukowski and Whiterod 2023, Zukowski and Whiterod 2024, Zukowski and Whiterod 2024). This project used a repeat spatial monitoring design in 2025 to determine and compare the numbers of Murray Crayfish one, two, three, four, five and six years on from the 2019, 2020, 2021, 2022, 2023 and 2024 surveys, respectively, and determine presence of Murray Crayfish within Talbingo Reservoir in 2025. In 2025, an additional two locations within the area to be impacted by Future Generation were also sampled.

In February 2023, January 2024, and June 2024, additional surveys targeting Murray Crayfish were undertaken to determine the status of Murray Crayfish populations in Yarrangobilly River (3 sites) and Wallace Creek (2 sites) to further inform considerations for the species in the Snowy 2.0 project. During this sampling, two crayfish were sampled in 2023, one in Yarrangobilly River and one in Wallace Creek and one Murray Crayfish was sampled in Wallace Creek in January 2024 and no Murray Crayfish were sampled in June 2024. Six Murray crayfish were previously detected at two sites (one in Yarrangobilly River and five in Wallace Creek) during Environmental Impact Statement (EIS) surveys. Backpack electrofishing was selected for the survey method as it is a very effective technique for collecting crayfish in a variety of freshwater habitats, and is particularly effective for shallow, slow flowing streams and for drawing crayfish out from sources of instream cover (e.g., logs, boulders). It is restricted to use in shallow (<1.25 m) water with low turbidity and a

conductivity of 10–1500 µS cm^{-1}. In June 2025, the sites were again sampled, and results outlined in this report.

Project objectives

The specific objectives of this project were to:

- Undertake a comprehensive repeat survey in 2025 of sites surveyed in 2019/2020/2021/2022/2023/2024 in Talbingo Reservoir.
- Translocate any Murray Crayfish sampled at sites 9, 10, 11 and 14 into another section of Talbingo Reservoir less likely to be affected by works.
- Undertake a repeat survey of Murray Crayfish in the Yarrangobilly River and Wallace Creek.
- Record habitat (physical structure, aquatic vegetation, water depth and location (GPS coordinates) for each net deployment and site-based water quality parameters).
- Collect data on population abundance and demographics (length, weight, sex ratio, reproductive stages of individuals).
- Consider (a) the spatial trend in abundance and demographics, and (b) presence in southern areas of Talbingo Reservoir, Yarrangobilly River and Wallace Creek.

Field surveys (Talbingo Reservoir)

Study region

Talbingo Reservoir (Figure 1) occurs within and adjacent to the Kosciuszko National Park just south of Tumut in the Murrumbidgee Valley on the Tumut River, south-eastern Australia. The reservoir, completed in 1970, creates a head storage for the operation of the Snowy Hydro Tumut 3 hydroelectric pump-storage project. Water released from the reservoir is used to supply irrigation and industry, hydro-power and environmental flows. The reservoir is also used for recreational activities including waterskiing, sailing, boating, and fishing. It is primarily fed by releases from Tumut 2 power station tailrace at the southern end of the reservoir. Other waterways provide additional inflows, including Tumut and Yarrangobilly Rivers, and Long, Honeysuckle, Plain and Middle Creeks. The study region was severely affected by bushfires in January 2020.

Figure 1. Talbingo Reservoir location (left), images of reservoir (top middle and right) and works associated with Snowy 2.0 project (bottom middle and right).

Survey sites

The targeted surveys of Murray Crayfish in Talbingo Reservoir were undertaken 2nd to 16th June 2025. Repeat sampling of the 14 sites surveyed in 2019, 2020, 2021, 2022, 2023 and 2024 was undertaken to allow spatial comparison (Table 1 and Figure 2). The seven existing sites (sites 1–7) of Zukowski et al. (2013), including site 3 – Honeysuckle, also sampled previously (NSW DPI, unpublished data; and Cardno 2019), and seven additional sites (sites 8–14) were sampled to assess areas that may be subjected to disturbance from Snowy 2.0 Main Works. An additional two sites were also sampled to investigate the presence of crayfish in two Future Generation sites where substrate additions were planned which could impact crayfish at these sites. Particular attention was given to the Yarrangobilly River and Middle Creek arms of Talbingo Reservoir (Figure 2).

Table 1. Summary of sites sampled across Talbingo Reservoir in 2025.

Site no.	Site description	Date sampled	(Zone 55)	
			Latitude	Longitude
1	Adjacent to car park	13/6/2025	-35.62940	148.30534
2	Near swimming area	13/6/2025	-35.63425	148.29387
3	Honeysuckle Creek arm	12/6/2025	-35.68451	148.29282
4	Landers Creek arm	12/6/2025	-35.65421	148.32961
5	Lick Hole Creek arm	11/6/2025	-35.70437	148.33427
6	Long Creek arm/Cascade Bay	11/6/2025	-35.74113	148.32155
7	O'Hares Campground (Sue City)	10/6/2025	-35.81193	148.36365
8	Plain Creek arm	10/6/2025	-35.75841	148.34213
9	Opposite Tumut and Yarrangobilly rivers	9/6/2025	-35.75852	148.35837
10	Middle Creek arm	5/6/2025	-35.76043	148.37302
11	Yarrangobilly River upstream	5/6/2025	-35.77102	148.37379
12	Yarrangobilly River middle	4/6/2025	-35.77266	148.37862
13	Yarrangobilly River bottom	4/6/2025	-35.77411	148.38280
14	Open site at rivers junction	9/6/2025	-35.75714	148.35378
FG1	Future Generation 1	6/6/2025	-35.76932	148.37556
FG2	Future Generation 2	6/6/2025	-35.77145	148.37555

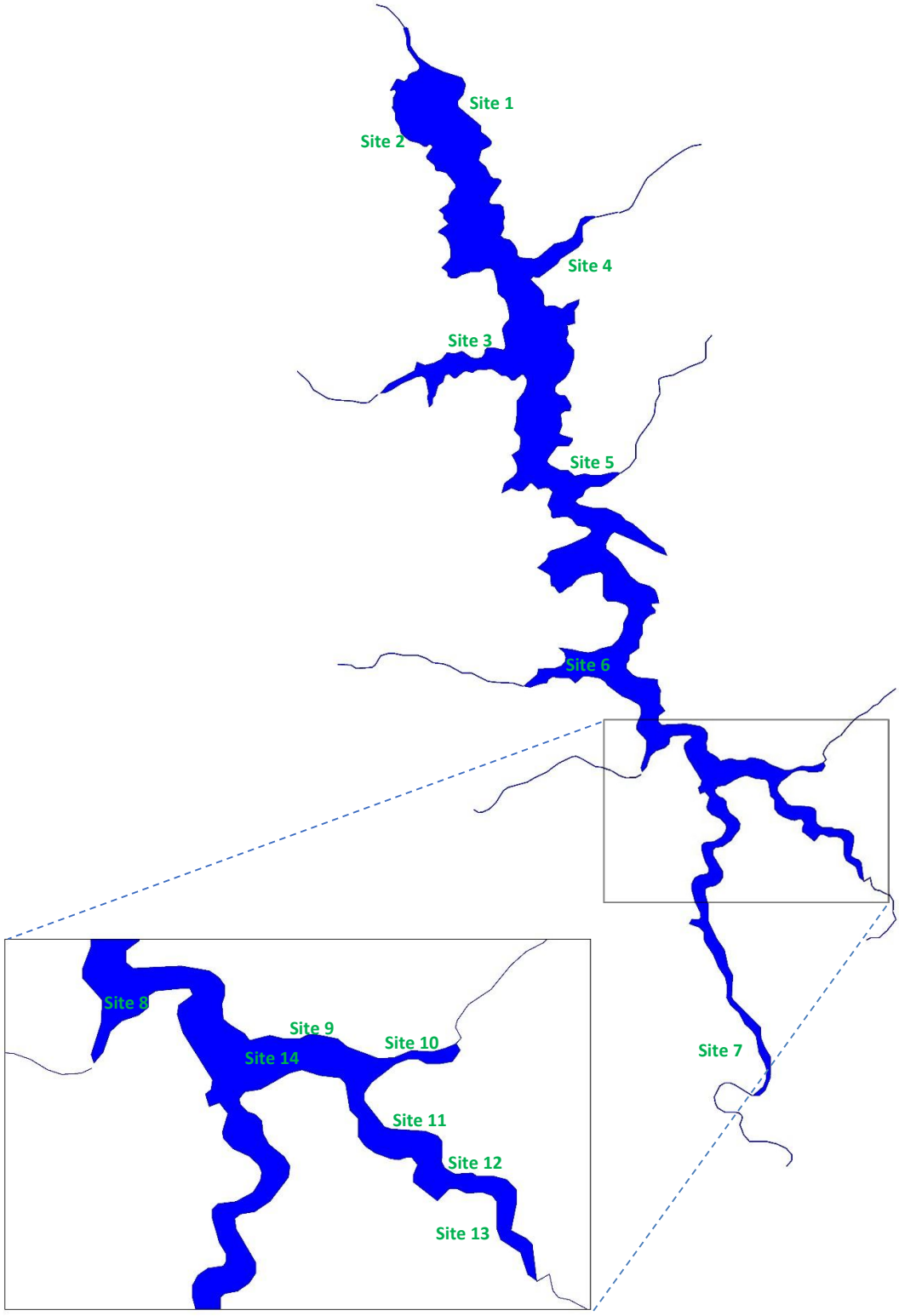


Figure 2. Sites sampled across Talbingo in the present study.

Survey methods

In Talbingo Reservoir, the field survey employed hoop and Munyana nets (Figure 3) to maximise the probability of detection. The standardised hoop net sampling protocol was employed at each site (sites 1–14 and FG1-2), with 20 replicate single hoop nets (700 mm diameter with a mesh size of 13 mm) baited with approximately 300 g of ox liver set and checked hourly (and deployed at the same location) for a total of three hours (60 hoop net hauls per site) during daytime hours (0800–1700) (Zukowski, Whiterod et al. 2013, McCarthy, Zukowski et al. 2014, Whiterod and Zukowski 2017, Whiterod, Zukowski et al. 2018).

Munyana nets, a type of commercially available crab net (Munyana net, Wishart, Queensland: 60 mm mesh, two 0.76 m diameter steel hoops and two 0.18 m × 0.12 m openings), were used in addition to hoop nets at all sites to increase the rate of capture (see McCarthy 2005). At each of these sites, nets were baited with approximately 300 g of ox liver and set overnight. This type of method is designed to have greater retention of crayfish unlike hoop nets from which crayfish can enter and exit.

For each net, location (latitude and longitude), time set and retrieved, sampling level (in metres above sea level, mAHD, to account for variation in reservoir level), water depth, and habitat descriptors was recorded. Water quality parameters (water temperature, pH, dissolved oxygen concentration and electrical conductivity) (HANNA HI98194 multiprobe) and percentage cover of submerged aquatic vegetation were recorded at each site.

Data collection

Sampled Murray Crayfish were sexed, weighed (W, in g) using waterproof scales (A&D weighting, Tokyo, Japan) and occipital carapace length (OCL, measured from the rear of the eye socket to the middle of the rear of the carapace, to the nearest 0.1 mm) was measured using Vernier calipers (Kinchrome, Scoresby, Victoria, Australia). The stage of maturity (stages 1-3: following Turvey and Merrick 1997) was recorded for females as was the presence of eggs. Additionally, each crayfish was marked using a Uni PAINT PX-20 marker (Mitsubishi Pencil Co. Ltd, Milton Keynes, UK: see Ramalho, McClain et al. 2010) to identify potential recaptures (during sampling events) before being returned to the water at the point of capture. These marks persist for months (potentially until the next moult which occurs annually in adult crayfish) and have been employed successfully for a medium-term

mark-recapture study on the species (Zukowski, Asmus et al. 2018). Note Murray Crayfish sampled at sites 9, 10, 11 and 14 were relocated to site 8 during 2025 surveys.

Figure 3. Munyana (top) and hoop (bottom) nets with Murray Crayfish sampled from Talbingo Reservoir.

In addition to this current report, the following data is maintained in an Excel spreadsheet.

- Data on surveys completed (date, method);
- Descriptive information (GPS location, sampling level and water depth, bank habitat) for each hoop and Munyana net deployment;
- Number of individuals caught; and
- Demographic information (length, weight, sex and life stage) for all sampled crayfish.

Results (Talbingo Reservoir)

Catch summary

In total, 21 Murray Crayfish (7 females, 14 males) were sampled from 960 hoop net retrievals (1 crayfish) and 82 Munyana net retrievals (20 crayfish) in Talbingo Reservoir during June 2025 surveys. Most Murray Crayfish sampled appeared in good health with no obvious deformities, disease, or parasite infestations apparent (Figure 4). Seven females were recorded, and all were sexually mature. Of the sexually mature females, four were carrying eggs (i.e. berried). Individuals were recorded from eight sites during the present survey (Table 2, Figures 5 and 6), compared to records from eight sites in 2024, three sites in 2023, eight sites in 2022 and five sites in 2021.

Table 2. Summary of Murray Crayfish sampled during 2025 surveys at 14 sites in Talbingo Reservoir and two FG Impact Sites (Occipital Carapace Length (OCL)); (Net type H=Hoop net, M=Munyana net).

Date	Site	Net type	Net No.	Latitude	Longitude	Depth (m)	Sex	Length mm (OCL)	Weight (g)	Crayfish notes
13/06/2025	1	M	5	-35.63276	148.30823	4	M	92	469	
13/06/2025	1	M	4	-35.62985	148.30522	7.4	M	81	228	
13/06/2025	1	M	4	-35.62985	148.30522	7.4	M	101	481	
13/06/2025	1	M	3	-35.63106	148.30502	8.1	F	133	983	Berried
13/06/2025	1	M	3	-35.63106	148.30502	8.1	M	122	928	
13/06/2025	1	M	3	-35.63106	148.30502	8.1	M	131	1028	
13/06/2025	1	M	3	-35.63106	148.30502	8.1	F	122	709	Berried
13/06/2025	1	M	2	-35.63232	148.30679	7	F	79	269	Berried
13/06/2025	1	M	1	-35.63234	148.30768	10	M	136	1148	
13/06/2025	1	M	1	-35.63234	148.30768	10	M	91.5	442	
12/06/2025	4	M	3	-35.65275	148.33246	5	F	131	962	
12/06/2025	4	M	5	-35.65319	148.32945	9	M	133	1125	
10/06/2025	5	M	4	-35.70244	148.33614	10	M	110	590	Missing L claw and 3 legs
10/06/2025	5	M	4	-35.70244	148.33614	10	F	111	772	Berried
10/06/2025	5	M	3	-35.70237	148.33707	10	M	131	995	
10/06/2025	8	M	3	-35.76128	148.34122	6	M	103	411	No claws
10/06/2025	8	H	11	-35.76110	148.34125	10	M	91	528	
9/06/2025	9	M	4	-35.75908	148.36226	4	M	101	631	#3. Relocated to site 8
5/06/2025	11	M	2	-35.77202	148.37582	8	M	137	694	#4. Broken R claw. Relocated to site 8
9/06/2025	14	M	2	-35.75897	148.35686	4.5	F	129	978	#2. Relocated to site 8
6/06/2025	FG1	M	3	-35.76919	148.37561	4	F	129	763	#1. Relocated to site 8

Figure 4. Murray Crayfish captured in Talbingo Reservoir in June 2025 including berried females (Top left and Bottom left) and a Yabby (Middle Left).

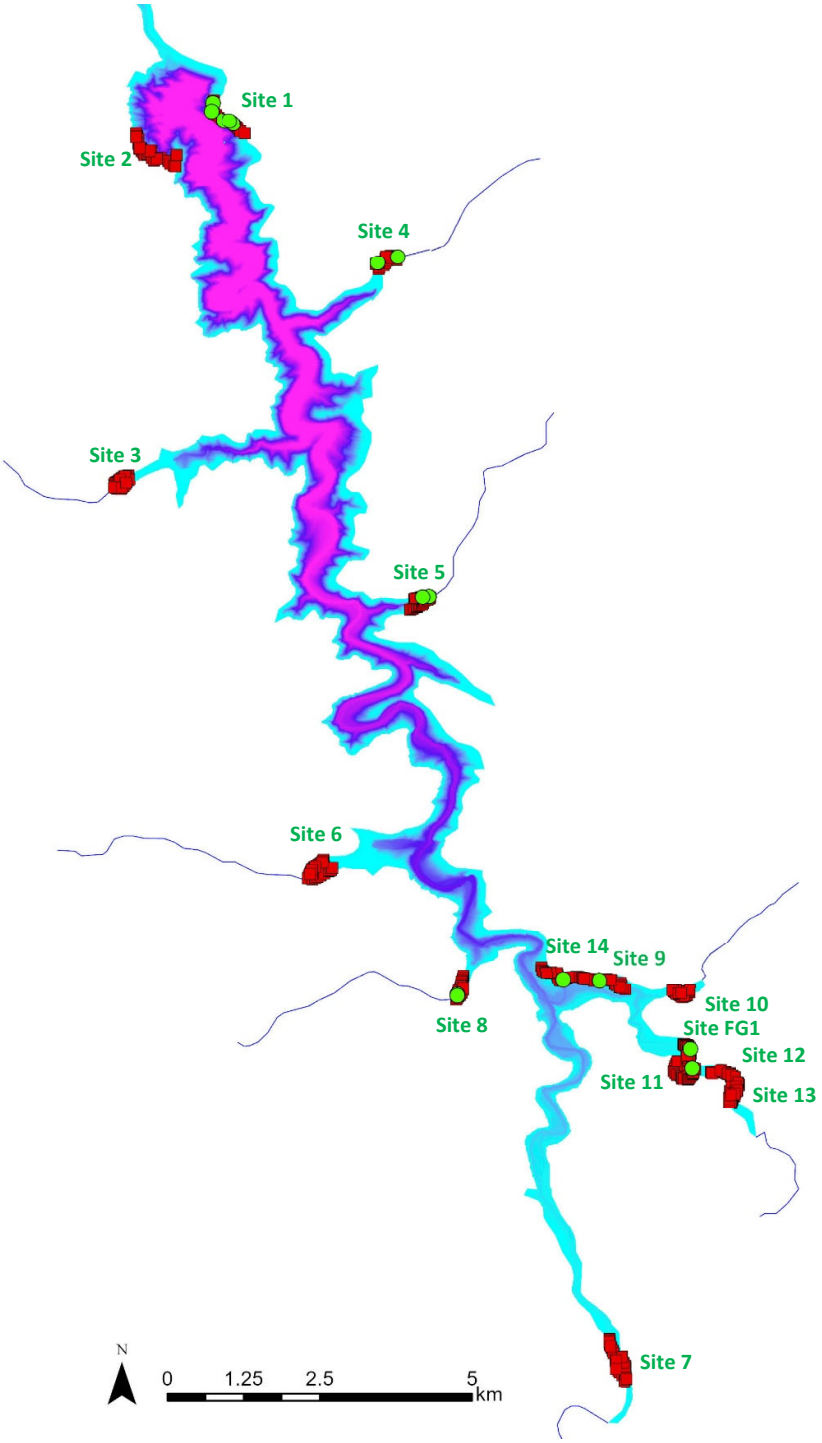


Figure 5. Individual net deployments (red circles) and captured crayfish locations (green circles) in Talbingo Reservoir June 2025. The bathymetry of the reservoir is also shown, with shallower (<20 m) areas indicated in light blue.

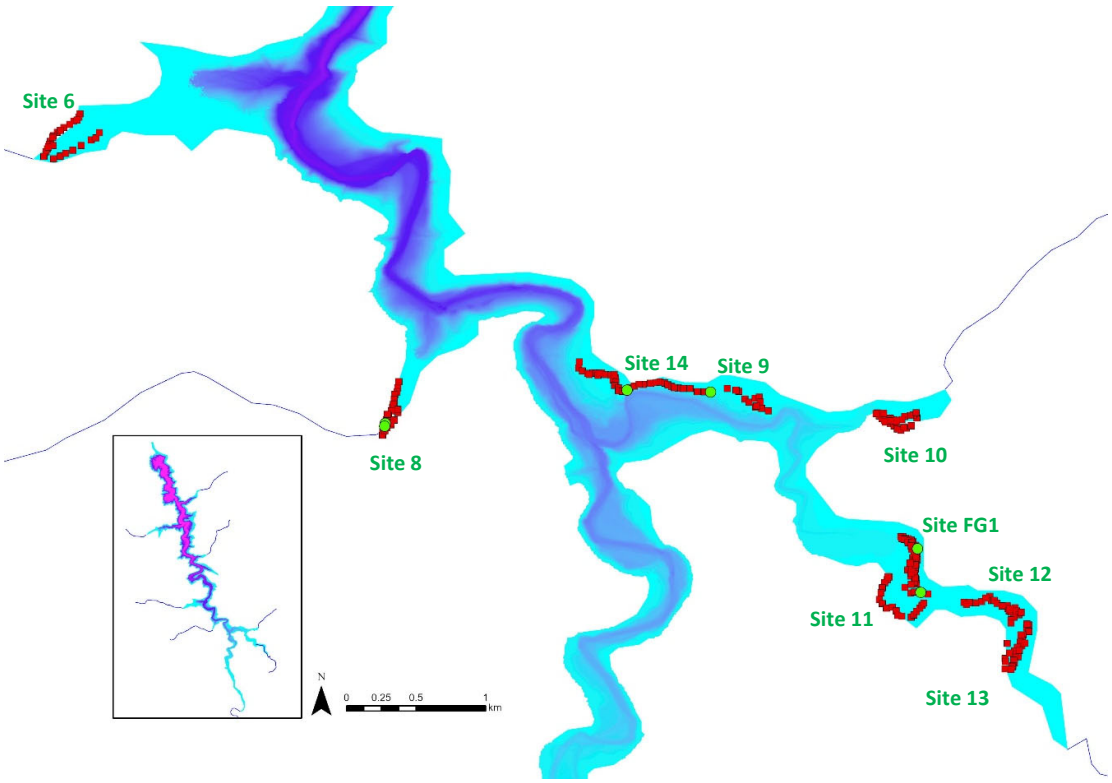


Figure 6. Close up map of the locations of net deployments and crayfish captures in the southern section Talbingo Reservoir in 2025. The shallower (<20 m) areas indicated in light blue.

Changes over time

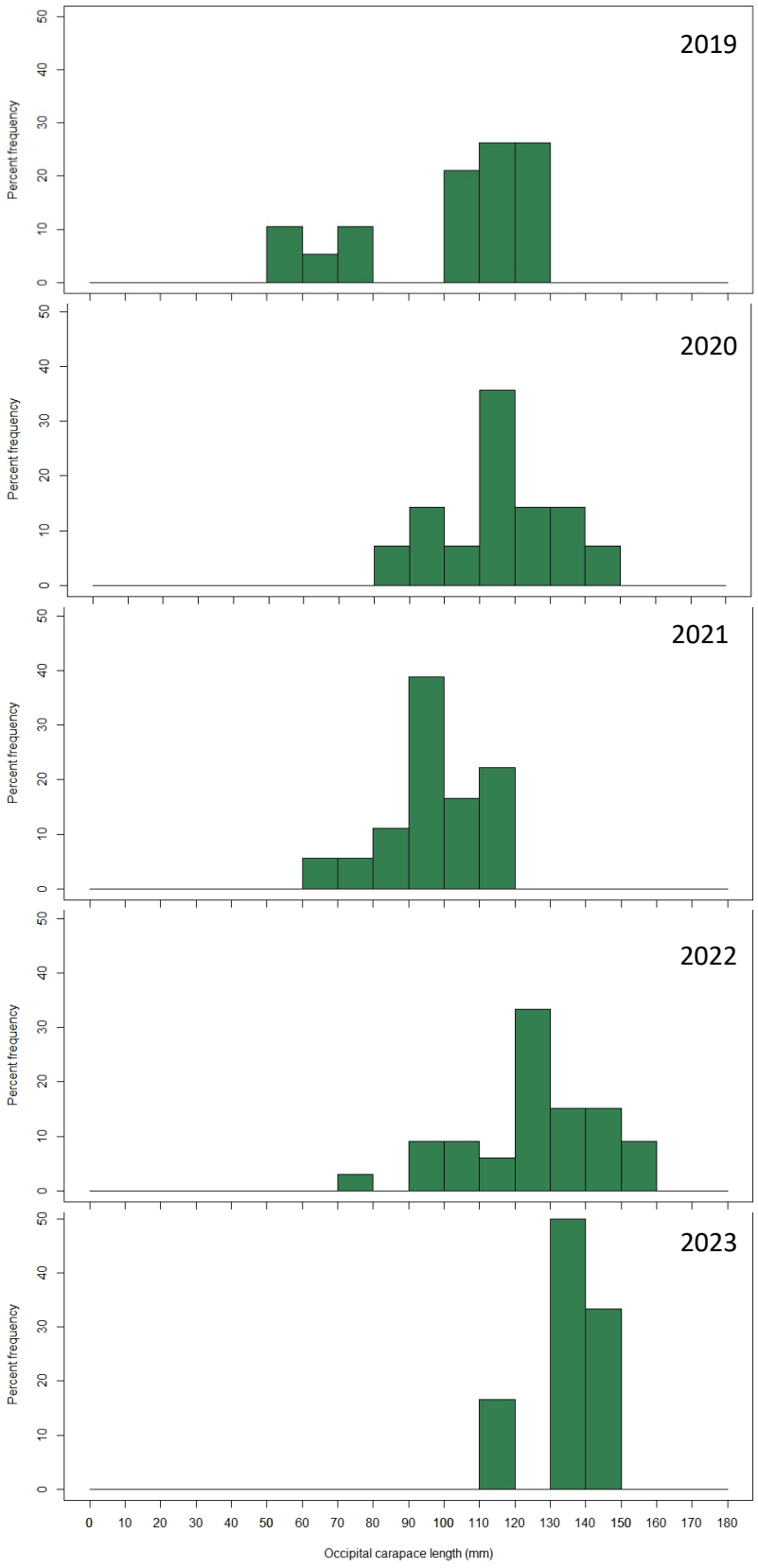
In total, 21 Murray Crayfish (7 females, 14 males) were sampled in Talbingo Reservoir during the June 2025 surveys. For comparison, 19, 14, 18, 33, 6 and 21 individuals were recorded during the 2019, 2020, 2021, 2022, 2023 and 2024 sampling, respectively, and a total of 188 individuals (95 females (13 berried), 93 males) were recorded over the three years of sampling between 2008 and 2010 (Table 3; Table 4). Murray Crayfish were detected at eight sites (sites 1, 4, 5, 8, 9, 11, 14 and FG1) during the 2025 sampling. In comparison, Murray Crayfish were detected in eight sites in 2024, three sites in 2023, eight sites in 2022, five sites in 2021, six sites in 2020 and eleven sites in 2019.

Table 3. Summary of Murray Crayfish numbers across the 14 sampled sites and 2 FG sites (2025 only) from combined 2008–2010 (Zukowski et al 2013) data, 2019, 2020, 2021, 2022, 2023, 2024 and 2025 survey data. HN=Hoop Net, MN=Munyana Net.

Site	2008–2010 HN	2019 HN	2019 MN	2019 Total	2020 HN	2020 MN	2020 Total	2021 HN	2021 MN	2021 Total	2022 HN	2022 MN	2022 Total	2023 HN	2023 MN	2023 Total	2024 HN	2024 MN	2024 Total	2025 HN	2025 MN	2025 Total
1	19	3		3	1	1	2	1	7	8	2	5	7	1		1	1	4	5		10	10
2	3	1		1								2	2									
3	13	1		1	1	2	3										1		1			
4	73							1	1	2		1	1					1	1		2	2
5	47				1		1										1	4	5		3	3
6	12		1	1								4	4		3	3						
7	21							1		1								1	1			
8			3	3	2		2	1	5	6	2	4	6					2	2	1	1	2
9		2	3	5	1	1	2		1	1		1	1		2	2		2	2		1	1
10		1		1																		
11		1		1								1	1								1	1
12			1	1																		
13			1	1																		
14			1	1	2	2	4					11	11					4	4		1	1
FG1	Not sampled in previous years																				1	1
FG2	Not sampled in previous years																					
TOTAL	**188**			**19**			**14**			**18**			**33**			**6**			**21**			**21**

Length structure

In June 2025, all sampled Murray Crayfish were adults and ranged from 79 to 137 mm OCL, and 228 to 1148 g (Figure 7). All sampled individuals, apart from five, were above 100 mm OCL in size in 2025. All the Murray crayfish sampled in 2024 were above 88 mm OCL with 19 of the 21 individuals over 100 mm OCL in size. All the Murray Crayfish sampled in 2023 were above 120 OCL in size. Larger Murray Crayfish were mainly found in 2022, and the majority of smaller individuals were sampled in 2019 (Figure 7).


2019
2020
2021
2022
2023
Percent frequency
0
10
20
30
40
50
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Occipital carapace length (mm)

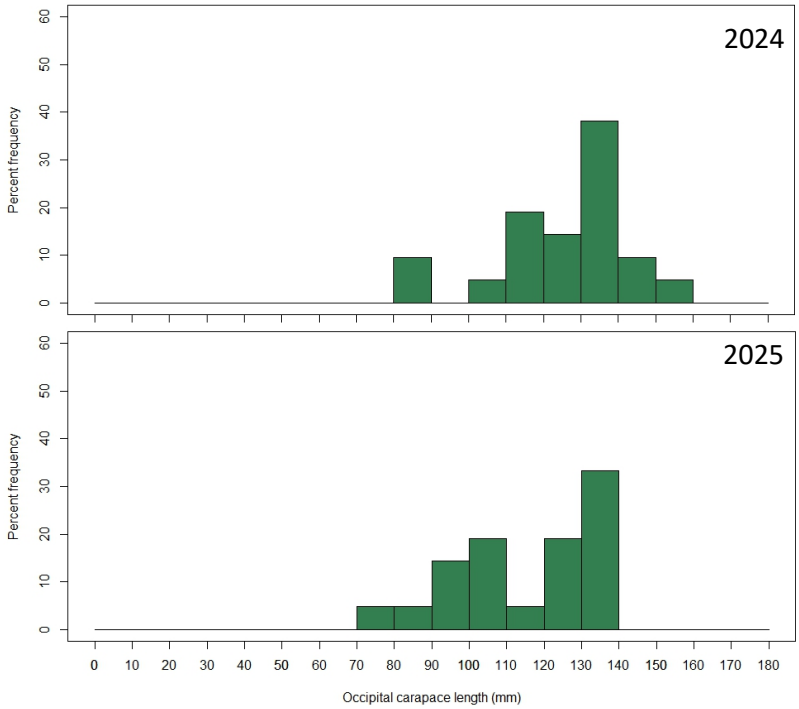


Figure 7. Length structure of Murray Crayfish in Talbingo Reservoir in 2019, 2020, 2021 2022, 2023, 2024 and 2025 top to bottom, respectively.

Habitat and Site Characteristics

Nets were deployed at depths between 1.5 – 16m (525.7 to 540.9 mAHD) with Murray Crayfish recorded at depths between 4 – 10 m (Table 4). Of the sampled crayfish, only one was found using hoop nets with the remaining twenty individuals detected in Munyana nets (Table 4). Meso-habitat varied between sites and included irregular bank, matted bank, smooth bank and mid-channel. Murray Crayfish were sampled in areas with irregular bank, matted bank and mid-channel (Table 4). The percentage presence of aquatic vegetation was slightly higher in comparison to that found in 2024, 2023, 2022, 2021 and 2020 sampling throughout most of the reservoir. At the time of 2025 sampling, the majority of sites had submerged aquatic vegetation present in low concentrations (≤20% cover), however sites 3, 6 and 12 recorded aquatic vegetation of over 50% (Table 5). Aquatic vegetation was a mixture of Canadian Pondweed *Elodea canadensis*, *Potamogeton* sp. and *Chara* sp..

Table 4. Summary of net type, sampling level and water depth and meso-habitat present where Murray Crayfish were captured in June 2025.

Site	Net type	Net no.	Sampling level (mAHD)	Water depth (m)	Meso-habitat	No. of crayfish
1	M	1	530.098	10	Matted Bank	2
1	M	2	533.098	7	Irregular bank	1
1	M	3	532.098	8	Irregular bank	4
1	M	4	532.698	7.4	Irregular bank	2
1	M	5	536.098	4	Irregular bank	1
4	M	3	536.034	5	Mid Channel	1
4	M	5	532.034	9	Irregular bank	1
5	M	3	531.742	10	Irregular bank	1
5	M	4	531.742	10	Matted bank	2
8	H	11	535.745	6	Matted bank	1
8	M	3	531.745	10	Matted bank	1
9	M	4	537.667	4	Irregular bank	1
11	M	2	533.303	8	Irregular bank	1
14	M	2	537.167	4.5	Irregular bank	1
FG1	M	3	536.947	4	Irregular bank	1

Water Quality

Water quality parameters varied across the 16 sites (Table 5). Salinity (EC) was relatively fresh throughout the reservoir and ranged from 22 µScm^{-1} (Site 7) to 51 µScm^{-1} (Site 13). This was similar to EC noted in 2019 (25–76 µScm^{-1}), 2020 (27–80 µScm^{-1}), 2021 (30 –56 µScm^{-1}), 2022 (24–58 µScm^{-1}), 2023 (26–40 µScm^{-1}) and 2024 (20–40 µScm^{-1}). Water temperature ranged between 10.72 and 12.08 ^{o}C and was like water temperature sampled in 2024 (9.4—11.6^{o}C), 2023 (8.14—10.19^{o}C) and 2022 (7.60–12.98°C), where surveys were also undertaken in June. Water temperature was lower than that sampled in 2021 (11.5–15.8°C), reflecting the later sampling time in the year in 2021, and slightly higher than that found in 2019 (4.15–11.82°C) and 2020 (4.4–10°C). The pH was generally near neutral in 2025 with a range of 6.81 – 7.45. The pH was similar in 2024 (6.78 – 7.62), 2023 (6.01 to 7.03), 2022 (6.11–7.18) and in 2021 (6.13–7.21). In 2020, an alkaline pH above 8 was found at all sites (8.05–8.53) and a mostly slightly acidic pH found in 2019 (6.35–7.09). Dissolved oxygen concentrations (measured during the day) (8.78 – 12.34 mgL^{-1}) were higher than those sampled in 2024 (6.8—8.2 mgL^{-1}), 2023 (7.3–8.9 mgL^{-1}) and 2022 (5.4–8.6 mgL^{-1}) and similar to those sampled in previous years (2019 >11 mgL^{-1}, 2020 >10 mgL^{-1}).

Table 5. Summary of water quality parameters and percentage submerged aquatic vegetation cover at the 14 sampled sites and 2 Future Generation sites in Talbingo Reservoir in June 2025.

Site	Temp (°C)	pH	EC (μScm^{-1})	DO (mgL^{-1})	Submerged aquatic vegetation cover %
1	11.57	7.11	26	11.5	0
2	11.68	6.81	26	11.61	0
3	11.56	7.42	27	11.54	80
4	11.68	7.3	26	11.27	10
5	11.89	7.42	26	11.76	10
6	11.7	7.45	27	10.25	40
7	10.72	7.15	22	11.06	25
8	11.7	7.08	27	11.74	20
9	11.61	7.37	30	11.34	15
10	11.8	7.11	36	9.21	5
11	11.75	7.2	38	9.42	10
12	12.08	6.93	40	8.78	50
13	10.88	7.12	51	8.83	25
14	11.73	7.45	28	12.34	15
FG1	11.72	7.25	38	10.46	5
FG2	11.54	7.18	40	10.68	0

Field surveys (Yarrangobilly River and Wallace Creek)

The Yarrangobilly River, located in south New South Wales, flows in a general southwest direction. The river commences at an elevation of 1490 m near Kennedy Ridge and flows into Talbingo Reservoir (573 m), downstream of Lobs Hole. The Yarrangobilly River drops approximately 935 m over its 50 km course. Wallace Creek, a major channel that flows into Yarrangobilly River in New South Wales starts at an elevation of 271 m and drops to an elevation of 157 m. Flows into Wallace Creek and Yarrangobilly River are generally year-round with higher flows occurring during late winter and early spring.

Survey sites

Five sites in total were sampled in the Yarrangobilly River (n=3) and Wallace Creek (n=2) (Table 6, Figure 8) in June 2025. Sites were chosen based on previous sampling, accessibility, and available Murray Crayfish habitat. Sites are labelled as YR1-3, WC1-2. These sites were previously known as 1A, YR1, TR-18-232 (Yarrangobilly River), 2B, 2A/TR-18-231 (Wallace Creek), respectively. One Murray Crayfish was sampled in Wallace Creek (WC1) in 2024 Jan, and two Murray Crayfish were sampled in February 2023, one in WC2 and one in YC1. Six Murray crayfish were previously detected at two sites (YR2 (n=1), and 2A/TR-18-231 (n=5)) in Yarrangobilly River and Wallace Creek, respectively, during the Environmental Impact Statement (EIS) surveys.

Table 6. Summary of sites sampled in Yarrangobilly River and Wallace Creek and Volts and Hz used at each site during backpack electrofishing in June 2025.

Site	Date	Start Latitude	Start Longitude	End Latitude	End Longitude	Volts	Hz
YR1	03/06/2025	-35.7823	148.3868	-35.784	148.3880	500	75
YR2	03/06/2025	-35.7847	148.3947	-35.7860	148.3960	500	75
YR3	03/06/2025	-35.7924	148.4038	-35.7940	148.4040	500	60
WC1	03/06/2025	-35.7932	148.4137	-35.7943	148.4153	500	60
WC2	03/06/2025	-35.7920	148.4119	-35.7928	148.4132	500	60

Figure 8. Three sites sampled across Yarrangobilly River and Wallace Creek. Top left site WC1, Top right site WC2, bottom row YR3.

Survey methods

In the Yarrangobilly River and Wallace Creek, field surveys employed backpack electrofishing methodology due to the shallow and flowing nature of the water body (Figure 8), to maximise the probability of detection. Standard operating procedures (Mossop and Whiterod 2018) were utilised as follows: Backpack electrofishing uses a pulsed DC current to attract and temporarily immobilise crayfish which were then collected by fibreglass dip nets. Surveys used a Smith Root LR24 backpack electrofishing unit (output settings range from 50-990 volts, 40 amps peak current, pulses from 1-120 Hz and maximum continuous power output of 400 watts). Low settings were first used, then gradually increased to ensure a satisfactory catch rate while minimising potential injury to fauna.

Electrofishing was conducted with one operator (wearing the electrofisher) accompanied by one netter (carrying fibreglass-handled dip nets). The team moved in an upstream direction to avoid working in disturbed, stirred up water. Periodically the electrofisher was engaged

to stun crayfish, then disengaged when fauna was spotted and subsequently netted. Each site covered 8 x 150 seconds of 'on time'.

For each site, the location (longitude and latitude), start time, water depth, and habitat descriptors was recorded. Water quality parameters (water temperature, pH, dissolved oxygen concentration and electrical conductivity) (HANNA HI98194 Multiprobe) and percentage cover of submerged aquatic vegetation was recorded at each site.

Data collection

If detected, sampled Murray Crayfish were sexed, weighed (W, in g) using waterproof scales (A&D weighting, Tokyo, Japan) and occipital carapace length (OCL, measured from the rear of the eye socket to the middle of the rear of the carapace, to the nearest 0.1 mm) was measured using Vernier calipers (Kinchrome, Scoresby, Victoria, Australia). The stage of maturity (stages 1-3: following Turvey and Merrick 1997) was recorded for females as was the presence of eggs. Additionally, each crayfish was marked using a Uni PAINT PX-20 marker (Mitsubishi Pencil Co. Ltd, Milton Keynes, UK: see Ramalho, McClain et al. 2010) to identify potential recaptures (during sampling event) before being returned to the water at the point of capture. These marks persist for months (potentially until the next moult which occurs annually in adult crayfish) and have been employed successfully for a medium-term mark-recapture study on the species (Zukowski, Asmus et al. 2018).

Figure 9. Backpack electrofishing used to sample for Murray Crayfish in Yarrangobilly River and Wallace Creek.

Results (Yarrangobilly River and Wallace Creek)

Catch summary

No Murray Crayfish were sampled during the backpack electrofishing in June 2025. One Murray Crayfish, approximately 100 mm OCL was observed at YR2 but was too far into bank habitat to sample. Bycatch including Brown Trout, Rainbow Trout and Redfin Perch were sampled during backpack electrofishing surveys.

Water Quality and site characteristics

Water quality in 2025 was different to that sampled during warmer months in 2024 and 2023 most likely due to the different time of year at sampling (Table 7). The pH sampled in 2025 was slightly acidic (6.42-6.58) and different to 2024 where the water was slightly alkaline. The water was fresh with 28-32 μScm^{-1}, and dissolved oxygen relatively high (7.18-7.68 mgL^{-1}). Water quality was suitable for Murray Crayfish at the sampled site except for the pH which was slightly acidic and would be more suitable ≥7. There was a lack of submerged aquatic vegetation at the sites, with rock, boulder and bedrock making up most of the instream substrate. Sedimentation and silt were noted at the sites similar to that observed in 2024 and 2023. Flow past the Yarrangobilly gauging station was lower on the sampling day (3 June 2025) (0.577 m^3/s) compared to previous sampling occasions (June 2024; 0.9 m^3/s, January 2024; 1.9 m^3/s, February 2023; 1.5 m^3/s).

Table 7. Summary of water quality parameters and percentage submerged aquatic vegetation cover at Yarrangobilly River and Wallace Creek in June 2025.

Site	Temp (°C)	pH	EC (μScm^{-1})	DO (mgL^{-1})	Depth (m)	Submerged aquatic vegetation cover %
YR1	10.9	6.52	28	7.18	0.1-0.2	0
YR2	10.9	6.58	28	7.20	0.1-0.3	0
YR3	10.9	6.53	28	7.68	0.1-0.2	0
WC1	10.9	6.45	32	7.21	0.1-0.3	1
WC2	10.9	6.42	32	7.30	0.1-0.3	1

Discussion

The present survey provided an assessment of the status of the Murray Crayfish population in Talbingo Reservoir and in Yarrangobilly River and Wallace Creek in June 2025.

Talbingo Reservoir

By utilising the same monitoring design over the past seven years, a robust and comparative assessment has been undertaken of the ongoing presence of the species in the reservoir and of key metrics (abundance, length structure, evidence of recruitment) of Murray Crayfish as well as assessments of the habitat and water quality parameters associated with Murray Crayfish. In 2025, Murray Crayfish found at sites 9, 10, 11 and 14 and the FG sites were moved to site 8 to remove them from possible impact sites.

Murray Crayfish were found in low numbers (n=21) during the June 2025 survey in Talbingo Reservoir, the same number of individuals as was sampled in 2024, however numbers were higher than that sampled in 2023 where only six individuals were sampled. Prior to 2023, the number of Murray Crayfish sampled in the reservoir had increased over the past three years with 14, 18 and 33 individuals sampled from 2020 to 2022, respectively. Although these numbers were significantly lower than those sampled from 2008 to 2010 (n=188), the increase in numbers was a positive indication that Murray Crayfish were persisting at a sustainable rate in the reservoir.

In 2025 Murray Crayfish were sampled at eight sites, with only one individual sampled at site 14, one of the future disturbance impact sites, where four individuals were sampled in 2024, and the most crayfish were found in 2022, despite no crayfish being found here in 2023. In 2025, seven females were recorded and all were sexually mature, as well as 14 male crayfish, the opposite of the 14 females and 7 males recorded in 2024. Of the sexually mature female crayfish in 2025, four were berried with bright red healthy eggs which is a positive sign of ongoing reproduction occurring in Talbingo Reservoir. In comparison eight berried females were sampled in 2024, three in 2023, fourteen in 2022, eight during 2021 and five in 2019 and 2020. Two Juvenile-sized crayfish (< 85 mm OCL) were sampled in 2025, however the female at 79 mm was berried showing early maturation and the male at 81 mm being close to maturation. This is compared to 2024 where no juvenile crayfish were sampled with all individuals being mature (> 85 mm OCL). Although juveniles less than 50 mm OCL are rarely

sampled in crayfish surveys, individuals between 50 to 120 mm OCL are frequently sampled. Thus, the ongoing survival of juveniles and recruitment in the reservoir is uncertain.

Measured water quality parameters including low electrical conductivity and water temperature were suitable for Murray Crayfish at the time of sampling. Dissolved oxygen concentrations (measured during the day) were above 6.5 mgL^{-1} at all sites in 2025. The pH was found to be slightly acidic at two sites, however, was overall more neutral in 2025 than 2024 where four sites were slightly acidic. Levels of pH at or below 7 could cause problems for calcification, molting, growth and reproduction (e.g., Haddaway, Mortimer et al. 2013, Beaune, Sellier et al. 2018).

The microhabitat characteristics in which Murray Crayfish were found in 2025 included physical structure such as irregular banks, matted banks and mid-channel. These habitats provide shelter and refuge and are near clay banks which are believed to be necessary for burrowing (Gilligan, Rolls et al. 2007, Zukowski 2012, Noble and Fulton 2017). Just as in 2024, Murray Crayfish were only sampled in water depths ≤10 m which is deeper than that found in 2023 (8 m) but shallower than found in previous years (< 13 m). This depth may reflect the preferred depth and habitat as guided by environmental parameters such as dissolved oxygen levels, proximity to available burrows, habitat availability and food source availability.

In 2025, as in the previous four years, the majority of Murray Crayfish were sampled in Munyana nets (n=20) with only one individual sampled in a hoop net. Interestingly, in 2019 and 2020 similar numbers of crayfish were captured using both methods. However, since 2021, using Munyana nets has shown to have higher sampling rates.

Yarrangobilly River and Wallace Creek

Murray Crayfish were surveyed using the backpack electrofishing methodology in Yarrangobilly River and Wallace Creek in June 2025 during lower flows than in previous sampling events. Decreased flow and water levels led to better visibility during the current sampling. Electrofishing for Murray Crayfish at Yarrangobilly River and Wallace Creek is recommended below 1.5 m^3/s for future events to ensure best conditions and maximum sampling success. Increased sedimentation and silt at sites decreased visibility during January 2024, June 2024 and this sampling event.

No Murray Crayfish were sampled in June 2025. All sampled sites had good water quality despite the slightly acidic pH and flows suitable for Murray Crayfish, however, increased sedimentation and silt were observed indicating that habitat conditions were not optimal for the species. High numbers of trout and presence of redfin detected during past surveys could also be contributing to the low numbers of Murray Crayfish found. Predation by these fish species is likely a common occurrence.

Ongoing annual monitoring of the five sites is recommended through backpack electrofishing, following the methodology described in this report. Further, eDNA analysis as part of the monitoring could test for the presence of Murray Crayfish at each of the sites if no crayfish are detected in future monitoring events. The past presence of Murray Crayfish at these sites demonstrates that that the species have persisted in these sites following the bushfires, albeit in low numbers, and populations may increase with time without further disturbance.

Conclusion

The number of Murray Crayfish sampled in 2025 was the same as 2024 and higher than 2023, however it is lower than historical surveys. The presence of berried females provides a positive indication of ongoing species recruitment and anticipated persistence in Talbingo Reservoir. The continued use of a robust repeat sampling methodology, as outlined in this report, allows the comparison of numbers of Murray Crayfish over time and space and allows for the detection of the presence of individuals throughout Talbingo Reservoir, including within the potential impact area associated with Snowy 2.0. The continued low numbers of individuals detected during more recent surveys, combined with and the lack of juvenile crayfish records, highlights the importance of ongoing habitat and water quality management for the long-term viability of the remaining population in Talbingo Reservoir, and the wider distribution of the species in general. Ongoing monitoring and translocations to boost declining populations remain an essential component in the conservation management of this species.

In June 2025, the third round of backpack electrofishing surveys targeting Murray Crayfish were undertaken to determine the status of Murray Crayfish populations in the Yarrangobilly

River and Wallace Creek. One Murray Crayfish was observed but no Murray Crayfish were sampled, however previously low numbers have been detected. The inclusion of these sites in annual monitoring can be challenging due to variable river heights and flow, however, it is important when considering changes in the status of the overall population over time and space.

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