Snowy 2.0 Macquarie perch monitoring in the upper Murrumbidgee catchment 2024

Mark Lintermans

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Bush Heritage and Murray Darling Basin Authority Native Fish Recovery Strategy have kindly provided access to Macquarie Perch sampling data for 3 sites (Site 2, 6 and 8) collected for the Upper Murrumbidgee Recovery Reach.

Sampling was conducted under NSW Fisheries Scientific Collection Permit No. FP 23/108 and University of Canberra ethics approval AEC 10389

This research was conducted on Ngarigo and Ngambri country.

Cover photo: Sampling site 3 (Bolaro) 27/02/2024: scene of the Platypus attack! (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) 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, 2024). 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*. submitted).

Tantangara Dam diverts 90–99 percent of flow 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, 2024; Pavlova *et al.* submitted). 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) 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 first year of the Macquarie perch Monitoring Plan (MPMP).

Hydrological conditions in 2023-24

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 February to April 2024 sampling period were approximately 45–360 ML/day (Figure 1) with sampling delayed or avoided on high flow days.

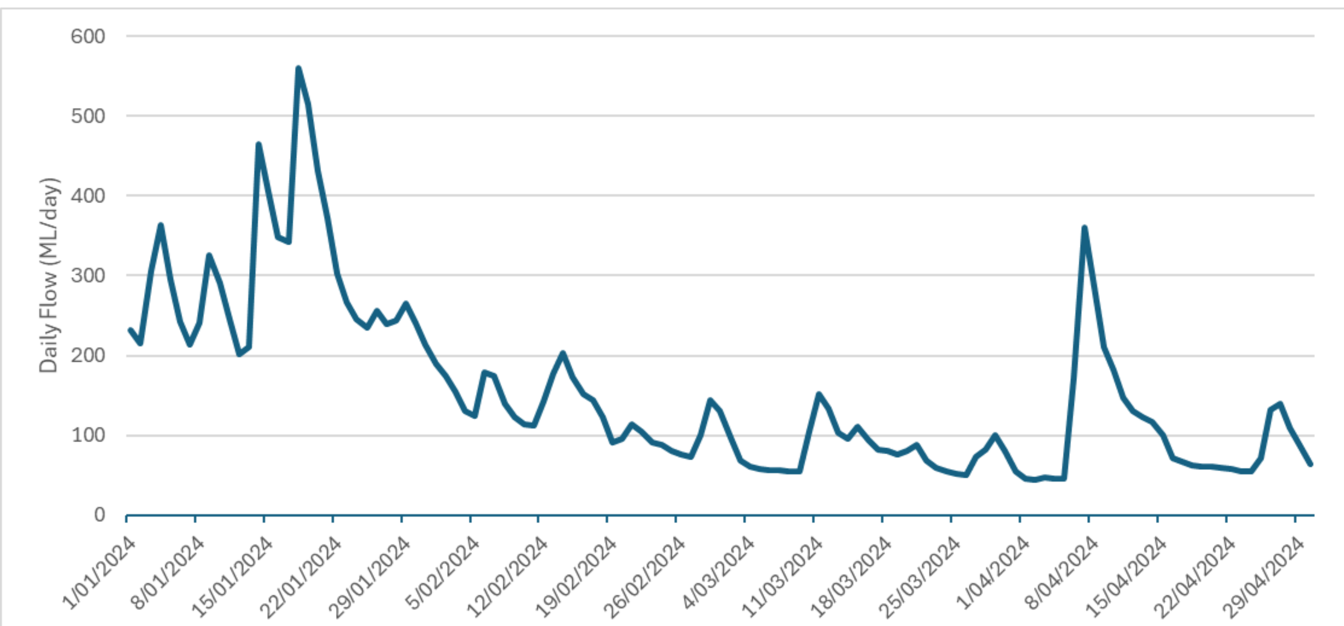

Figure 1. Mean daily discharge in the Murrumbidgee River at Yaouk No. 2 gauge during sampling season from 1/01/2024 to 30/04/2024. Flow data from Water NSW.

Methods

Site selection

Following consultation with South East Local Land Services staff, a total of six sites were selected for sampling on the Murrumbidgee River with all sites sampled between 26/02/2024 and 22/04/2024 (Figures 2 and 3) (Table 1) (Appendix 1). 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).

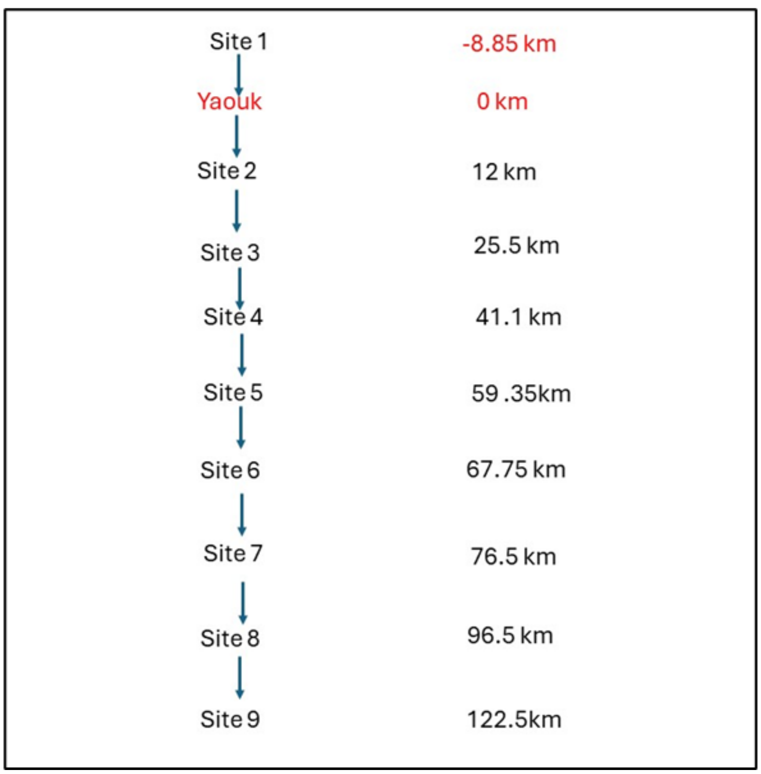

Figure 2. Conceptual diagram of the 2024 site layout and river lengths in the Murrumbidgee River. A reference point (Yaouk Bridge) is included (modified from Lintermans 2023b).

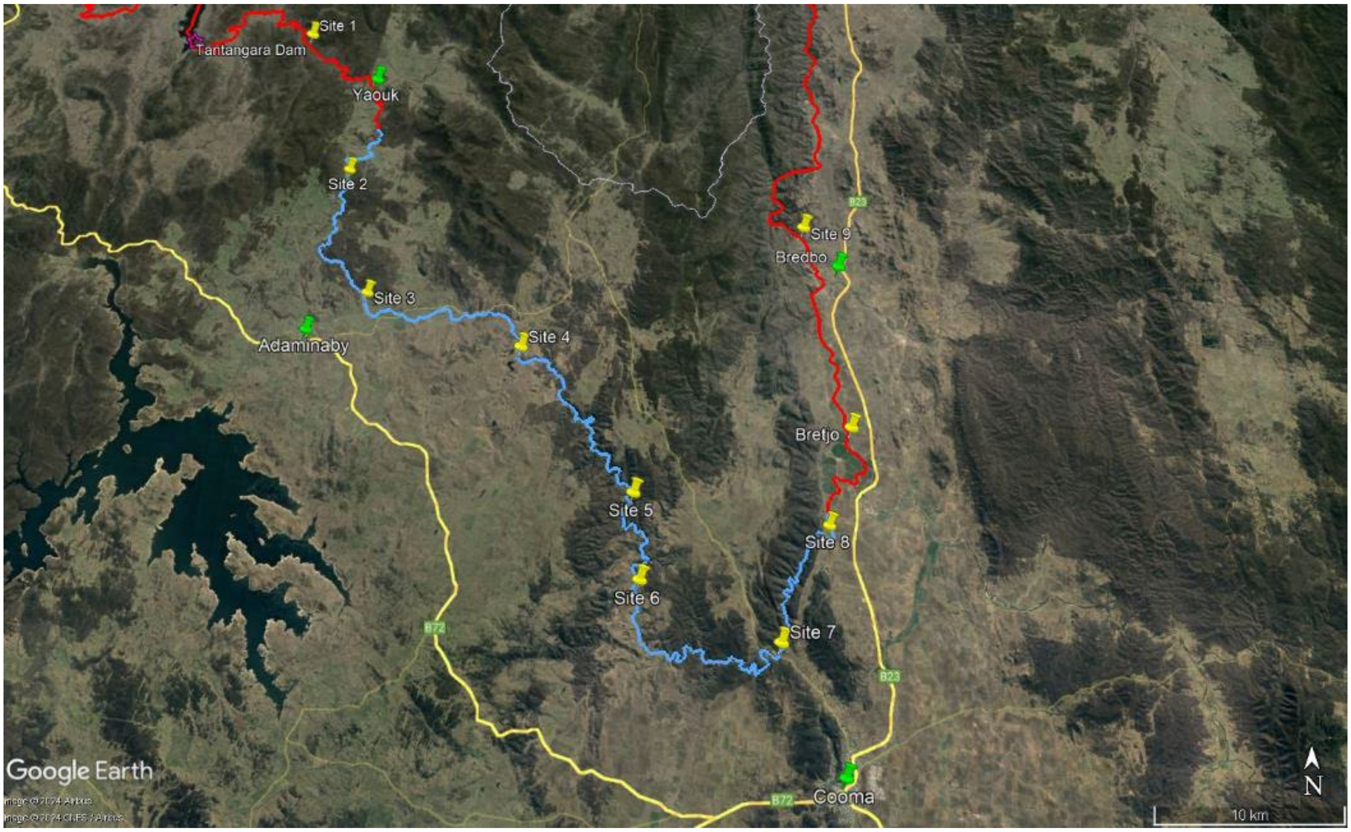

Figure 3. Location of sites sampled in 2024 on the Murrumbidgee River. yellow pins indicate sampling sites; green pins are locality names.

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 2024.

Site/Reach name	Site No.	Core or fringe distribution	Date sampled	Latitude	Longitude	Elevation (m ASL)
Numeralla Junction to Bredbo Falls (reach)	9	Fringe	21/03/2024	-35.79280	148.74973	700
Murrells Crossing	8	Core	12/03/2024	-35.89308	148.79030	720
Mittagang Crossing	7	Core	19/03/2024	-35.96891	148.81262	745
Kissops Flat	6	Core	29/02/2024	-36.00746	148.92119	774
Middle Dry Plains (reach)	5	Core	22/04/2024	-36.09190	148.99870	820
Alum Creek (reach)	4	Core	9/04/2024	-36.16775	149.04325	940
Bolaro (reach)	3	Core	13/03/2024	-36.17025	149.09114	986
Below Yaouk (reach)	2	Core	27/02/2024	-36.10801	149.12303	1030
Upstream Yaouk (reach)	1	Fringe	14/03/2024	-35.930500	149.11742	1160

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. Three of these seven sites were sampled as part of a separate Macquarie perch investigation in 2024 (Lintermans 2024), with the data included in the current report as they will be part of ongoing suite of sites to be sampled in the Snowy 2.0 Monitoring program (Lintermans *et al.* 2022). These three 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, 2024) with another site (Site 5) for which long-term data exists (Lintermans 2016, 2024). 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 DPI (Fisheries).

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; DCCEEW 2024). 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.

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 the first 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 2024 monitoring program for Macquarie perch in the upper Murrumbidgee in Feb-April 2024 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: fyke nets and unweighted gill nets (Table 3). Gill nets were not used at Site 1 as a result of reduced hand functionality after a Platypus spurring the previous night. Sampling was conducted from late February to late April, with the final sampling trip delayed slightly by rainfall, and associated site access constraints and elevated flows (see Figure 1).

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 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 retrieved between 07:30 and ~08:30 hrs the following morning, giving a ~16-hour soak time.

Figure 4. A gill-net set at Site 3, Murrumbidgee River 2024. (photo Mark Lintermans).

Figure 5. Retrieving a single-winged fyke net set at Murrells Crossing (Site 8), 2023.

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 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). 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 by titration with a Visocolor HE SA 10 kit; turbidity was measured with a turbidity tube. Water quality was unremarkable at all sites (Appendix 3).

Site suitability

Seven of the nine sites sampled are established fish monitoring sites that have been previously sampled. Sites 1 and 9 are new fish sampling sites, and while Site 9 was suitable for ongoing inclusion in the monitoring program, Site 1 proved challenging to access a suitable length of contiguous stream to allow adequate separation of nets. The landholder is keen for the site to be included in the long-term sampling program, and alternative access options are proposed in 2024 to facilitate broader sampling in future years. Prior to the 2025 sampling program, these access modifications need to be confirmed.

Results and Discussion

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

Overall sampling results

A total of 269 individuals of seven species of finfish were sampled with the native Macquarie perch the most abundant species followed by the alien Carp *Cyprinus carpio*, then Goldfish *Carassius auratus* (Table 4). No other species recorded had an abundance >8 individuals. The only other native species captured were Mountain galaxias *Galaxias olidus* and cod sp. *Maccullochella* spp. (Figure 6). The cod could not be accurately identified to species as both Murray Cod and Trout Cod M. *macquariensis* have been stocked into the upper Murrumbidgee since the 1980s (Koehn *et al*. 2013; Lintermans 2023b), with these species now hybridising (Couch *et al*. 2016).

Figure 6. A small *Maccullochella* sp, from site 9 (photo Hugh Allan).

Table 4. Snowy 2.0 Macquarie perch Monitoring: Fish and non-target animals captured (or observed) in 2024.

Common name	Macq perch	Mountain galaxias	Cod spp	Rainbow trout	Brown trout	Carp	Goldfish	***Total fish***	Long neck turtle	F/water prawn	Yabby	Platypus	Water rat
Sites													
1	-	-	-	-	1	-		1	-	-	-	1	-
2	51	-	-	1	-	-	-	52	-	-	-	6	-
3	4	2	-	-	3	-	-	9	-	-	7	9 (1)	obs
4	7	5	-	-	-	-	-	12	-	-	-	obs	-
5	36	1	-	2	-	-	-	39	-	1	-	2	obs
6	75	-	-	-	-	2	-	77	2	14	1	1	-
7	6	-	-	-	-	6	1	13	1	54	11	-	-
8	14		-	-	-	2	-	16	12 (1)	84		1	obs
9	3	-	1	-	-	28	18	50	3	62	4	-	obs
TOTAL	**196**	**8**	**1**	**3**	**4**	**38**	**19**	**269**	**18 (1)**	**215**	**23**	**20 (1) +**	**Obs 4 sites**

In addition to Carp and Goldfish another two alien species were captured, Rainbow Trout *Oncorhyncus mykiss,* and Brown Trout *Salmo trutta*, both at similar abundances. Macquarie perch were by far the most abundant fish species recorded in 2024 (Figures 7-8). Of the other native species, Mountain Galaxias was recorded at three sites, and *Maccullochella* spp at one. The alien species Carp was recorded at four sites, all in the lower section of the recruitment reach or below it, with the remaining alien species recorded at two sites (Table 4).

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

Abundance and distribution

Macquarie perch were in high abundance with 196 individuals captured, and were recorded at eight of the nine sites on the Murrumbidgee River, including all of the core sites and one of the fringe sites. The only fringe site where the species was absent was at the most upstream site upstream of Yaouk (Table 4) where the species is known to be absent (Lintermans 2023b, 2024). 2024 was the first sampling of Site 5 in the middle of the recruitment reach, with this site not part of the 2019–23 recruitment monitoring (Lintermans 2023b), however it returned good numbers of Macquarie perch. A lower-upper recruitment reach site (Site 4, downstream of Bolaro) had not been previously sampled but Macquarie perch were caught, but in relatively low abundance. Similarly, another site in the lower-upper of the recruitment reach (Site 3) also returned low numbers of Macquarie perch, with only four individuals captured. Macquarie perch abundance at Site 3 appears variable between years with previous samplings of this site in 2021 and 2022 returning 32 and 7 individuals respectively (Lintermans 2023b). Abundance in the downstream end of the recruitment reach was low in 2024, with Site 8 recording amongst the lowest abundances at this site on record (14 individuals). This is a reference site that was sampled each year in 2019-2023 with the annual mean catch across these years of 27 individuals, with good abundances in years of higher or average flow and low abundances during drought years (2019, 2020) — 2024 was not a drought year (Lintermans 2023b). Site 7 in the downstream portion of the recruitment reach also recorded low abundance, but this is normal for this site with sampling in 2019 and 2023 recording 0 and 3 individuals respectively (Lintermans 2023b).

The abundance of age 1+ individuals in 2024 was low, as has been regularly found in past sampling (Lintermans 2023b). The failure to produce young-of-year at several sites in 2023 is an obvious explanation for low age 1+ abundance in 2024 at such sites (e.g. Site 2), but 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 multiple Macquarie perch individuals at the most downstream site in the study (Numeralla Junction to Bredbo Falls reach: Site 9) was unexpected. While single individuals are occasionally collected between Angle Crossing (the ACT/NSW southern border) and the Numeralla River junction, catches of multiple individuals in a single night's sampling are rare (Lintermans 2016; Beitzel *et al*. 2019; Lintermans 2023b, unpubl. data; ACT Government unpubl.data). 2024 was the first sampling of Site 9, and although the site and adjacent reaches were significantly impacted by sand, Macquarie perch were still present.

Figure 7. Macquarie perch young-of-year from Site 4 (Photo Hugh Allan).

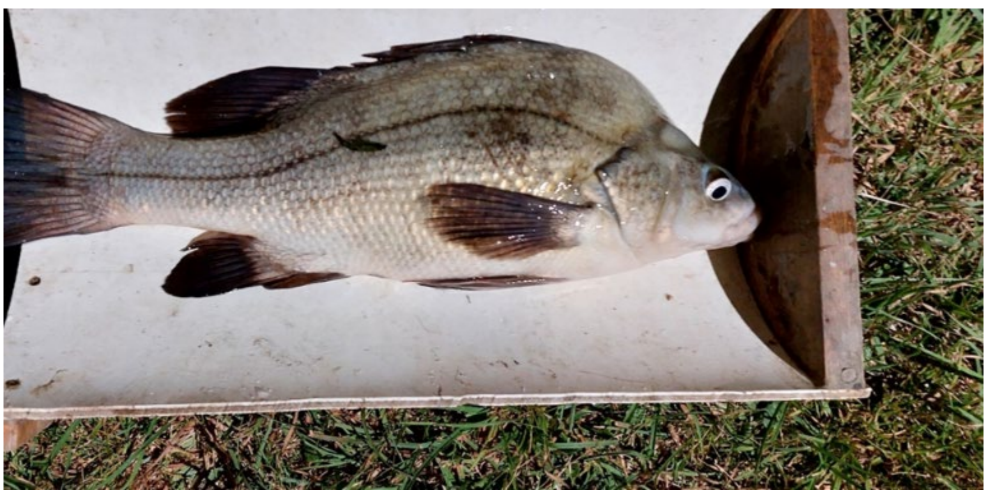

Figure 8. A large Macquarie perch (396 mm TL) captured in a gill net at Site 2. (photo Mark Lintermans).

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. However, the combined abundance of Macquarie perch sampled in 2024 was the second highest on record for the Murrumbidgee River, fractionally behind the 197 caught in 2021 (from a sampling of five sites) (Lintermans 2021, 2023b). Highest Macquarie perch abundance was from Site 6, followed by Sites 2 and 5 (Table 4). Abundance at Site 6 in the current sampling was exceptional, surpassing catches of 53 and 55 in 1998 and 1999 respectively where a similar sampling methodology was used (gill nets and fyke nets) but sampling intensity with fyke nets was lower (10 nets instead of the current 12) (Lintermans 2016). The number of individuals at this site from fyke nets (69) in 2024 is more than double the 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. Abundance at Site 2 was second only to the 2021 result (109 individuals) for this site in sampling since 2020, and approximates the abundance captured in 1998 (50) and 1999 (65) (noting that lower fyke net numbers were used in 1998 and 1999 (Lintermans 2016). 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).

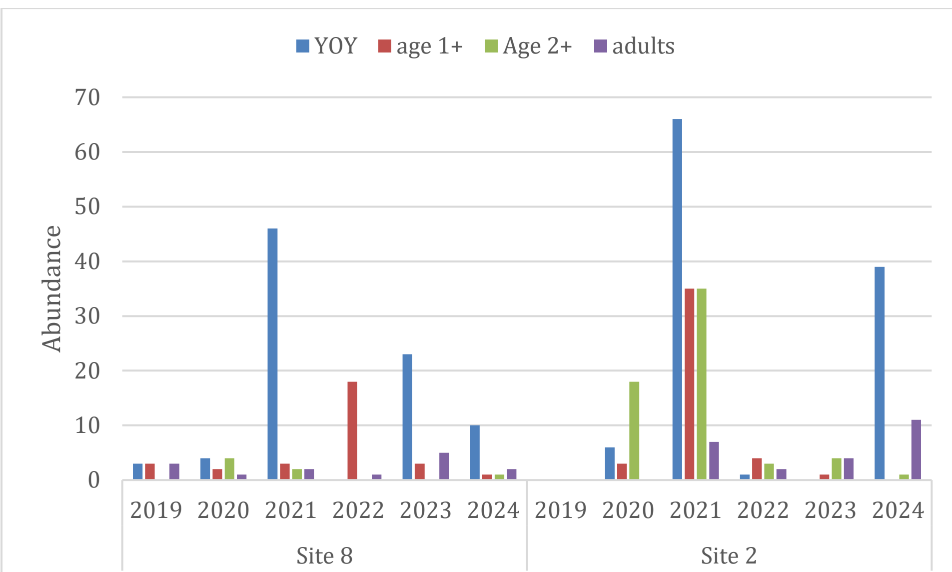

Figure 9. Captures by year of Macquarie perch (all age classes) in fyke nets at sites 8 and 2 between 2019 and 2024.

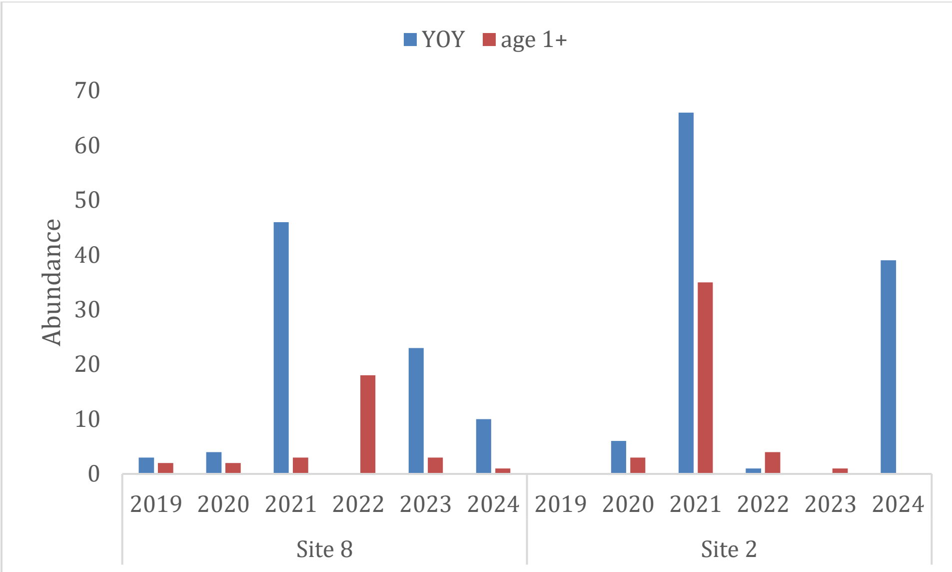

Figure 10. Captures by year of Macquarie perch young-of-year (YOY) and age 1+ in fyke nets at sites 8 and 9 between 2019 and 2024.

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. The high abundance of young-of-year at Site 2 in 2024 suggest that high age 1+ abundance will be apparent in 2025, and as a long-lived species (Tonkin *et al*. 2018; Lintermans 2023a) the absence of two consecutive years of recruitment whilst undesirable, is not of great concern for the population as a whole.

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.* submitted). 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. Monitoring in future years will help to clarify the occurrence and severity of any recruitment shadow. The downstream sub-reach is more secure with higher N_e, greater (though still impoverished) genetic diversity, and some connectivity apparent (Pavlova *et al*. submitted).

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 5). Young-of-year comprised 80 % of all Macquarie perch captured in 2024, with age 1+ comprising 7 % and medium to large adults 11 % (Table 5).

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 seven sites where Macquarie perch were caught in 2024 after successful spawning in 2023. 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.

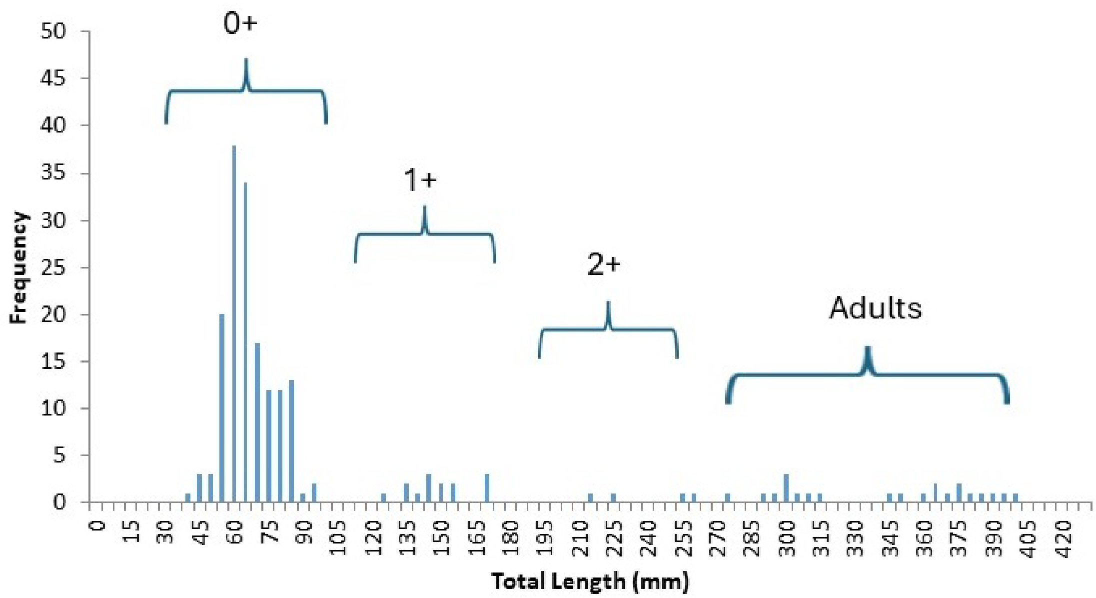

Figure 11. Length frequency of Macquarie perch captured from the upper Murrumbidgee River in 2024. Annotations above bars indicate age classes (years of age) of fish.

Table 5. Estimated age composition (based on total length) of Macquarie perch captured from upper Murrumbidgee River in 2024.

Site	YOY (<100 mm)	Age 1+ (100-170 mm)	Subadults/ small adults (195-~260 mm)	Medium adults (261-350 mm)	Large adults (>350 mm)
2	39		1	6	5
3	2	1			1
4	7				
5	34			2	
6	61	8	1	3	2
7	2	2			2
8	10	1	1	1	1
9	1	2			
TOTAL	**156**	**14**	**3**	**12**	**11**

Condition

Fulton's condition factor (K) for Macquarie perch varied from 0.793–1.860 (mean = 1.328, sd = 0.201, n = 194) (Figures 12 and 13). As the total Macquarie perch catch was dominated by young-of-year fish, unsurprisingly the distribution of K values for the combined catch closely resembles that for just young-of-year (Figure 12).

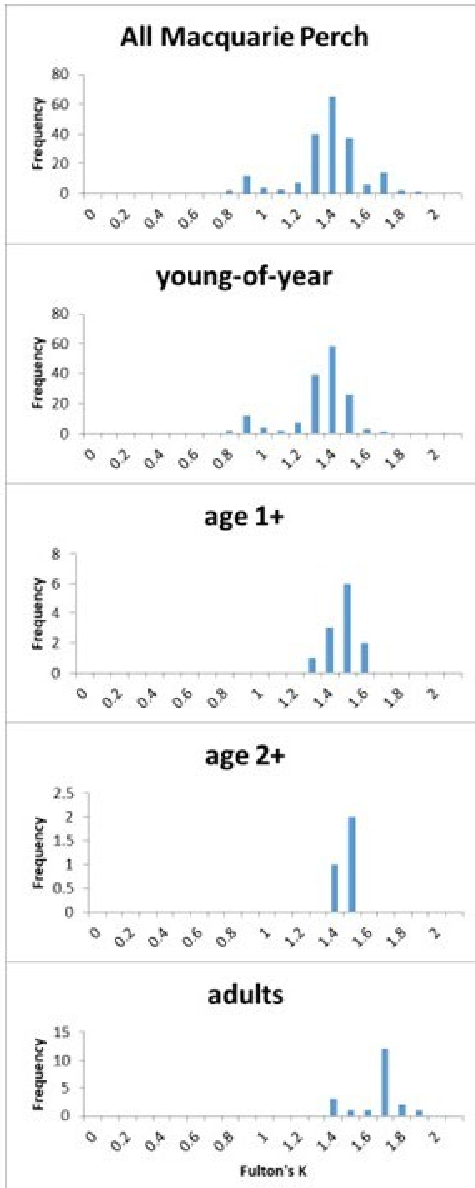

Figure 12. Histogram of Fulton's condition factor (K) of Macquarie perch for all fish combined (all sites) and for young-of-year, age 1+, age 2+, and adults (large and small combined).

Age classes older than young-of-year tended to have higher K values (Figure 13) with all K values <1.29 being young-of-year fish and 97 of the lowest 107 values being young-of-year. (Figure 13).

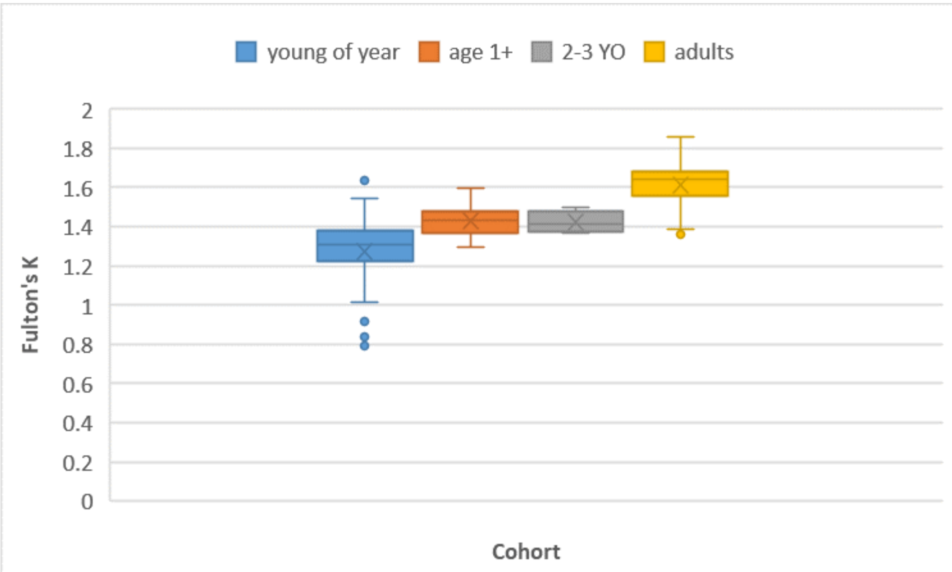

Figure 13. Range, median, and upper and lower quartiles for Fulton's condition factor (K) of Macquarie perch (all sites combined) for young-of-year, age 1+, age 2-3, and adults (large and small combined).

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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). It might be expected that maturing individuals might differ in Fulton's K to immature individuals without developing gonads. The clearly lower values in Fulton's K for most young-of-year Macquarie perch and the outliers evident in Figure 13 is potentially related to the vagaries of weighing small live fish on a mobile platform (i.e. a small boat). With fish weights of small young-of-year of between 0.6 and 3 g, variations in fish 'wetness' (i.e. external water after being transferred live from a holding bucket) can have significant effects on K. Condition is commonly measured on euthanised individuals to enable accurate comparisons (Archdeacon and Dunnum 2024), but this is unacceptable for the current Macquarie perch study of a highly threatened species. Therefore, 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. The condition of sub-adult and adult Macquarie perch should be measured in future monitoring programs so that trajectory of fish condition at sites and sub-reaches can be monitored, but further investigation is required for comparing changes in body condition of small individuals.

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 Sites 3 and 4 but was present on Macquarie perch from all other sites (Table 6). 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). *Lernaea* prevalence was low or absent on the most upstream and some middle reach sites (Sites 2–5) and highest at the lower-mid and lower sites (Sites 6–9). The mean *Lernaea* intensity on Macquarie perch in the Murrumbidgee River was ≤2 at all but one site (Site 7), with most fish having a single lesion or worm (Table 6). Sixty-seven and Seventy-one percent of Macquarie perch at Sites 7 and 8 respectively had evidence of *Lernaea* infection with up to 6 lesions or parasites detected on a single fish (Table 6). 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 Carp, Goldfish and Brown trout (Table 7) with all but one affected individual found in downstream sites (Sites 7 and 9). No Rainbow trout or cod spp were recorded with *Lernaea* in the current sampling but these species have recorded *Lernaea* in previous years (Lintermans 2022, 2023b; 2024).

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 2023b, 2024).

Table 6. Prevalence (number and percentage) and intensity of *Lernaea* infection on Macquarie perch by sampling site where Macquarie perch were captured in 2024.

2024	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**
Total No. Macquarie perch captured	*0*	51	4	7	36	75	6	14	3
Prevalence (*No. fish with lesions/worms*)		3 (6%)	0	0	3 (8%)	44 (59%)	4 (67%)	10 (71%)	2 (67%)
Mean load (*No. lesions/ worms per affected fish*)		1.33			1	1.48	3.5	1.73	2
Max load (*lesions/worms per fish*)		2			1	3	6	6	2
Individual Load (Lesion/worm count on individuals)		1, 1, 2,			1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2; 2;,2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2. 2, 2, 2, 3	6, 5, 1, 2	1, 1, 1, 1, 1, 1, 1, 3, 3, 6	2, 2

Table 7. 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	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**
Carp (total no. caught)							5		28
No. Carp with lesions/worms							3 (60%)		4 (4%)
Mean No. lesions/worms per affected Carp							2		1
Goldfish (total no. caught)							1		18
No. Goldfish with lesions/worms							1 (100%)		4 (22%)
Mean No. lesions/worms per affected Goldfish							3		1
Brown trout (total no. caught)			2						
No. Brown trout with lesions/worms			1 (50%)						
Mean No. lesions/worms per affected Brown trout			1						

MPMP Objective 6 - Threat status

The rapid, visual assessment of potential threats did not reveal any critical new threats to Macquarie perch at any site, but there are some existing and continuing threats in play. Uncontrolled stock 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 (Figure 14). Bank degradation results in sedimentation of the stream which has impacts on stream depth and spawning site integrity. Controlling stock 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 and erect riparian fencing along the Murrumbidgee mainstem would be of benefit.

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 discovery 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 there has been significant removal of alien riparian species at several sites within the recruitment reach as a result of coordinated willow control in recent years (Lintermans 2023b).

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. Targeted eDNA sampling in the upper Murrumbidgee by NSW DPI (Fisheries) in early-mid 2023 also failed to detect any Redfin (NSW DPI unpubl. data), but there have been confirmed reports in 2019 further downstream in the reach between Angle Crossing and approximately Michelago (Beitzel *et al*. 2019). 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.

Figure 14. Bank degradation from stock access at several sites. (photos Mark Lintermans).

Trigger Action Response Plan (TARP) trigger evaluation

Of the six identified TARP triggers, items B, C, and D require baseline or trend data to determine if 'decline' has occurred. As this is the first monitoring year completed for Macquarie perch at several sites it is not possible to ascertain whether such declines have occurred, or triggers are met. Trigger E can only be assessed when genetic samples collected from the monitoring program are analyzed. However, a baseline now exists for the genetic parameters of the upper Murrumbidgee Macquarie perch population (Pavolva *et al.* submitted). Trigger A has been previously addressed in this report, and there has been no significant fire since 2019-20, and no drought. Consequently, the 2024 monitoring found there were no threats or other triggers to require TARP intervention.

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

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). 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.

Conclusion and recommendations

The 2024 Snowy 2.0 Macquarie perch monitoring found there were no threats or other triggers to require TARP intervention. The abundance of Macquarie perch in the sampling program is at a record high, although it must be acknowledged that 2024 is the first dedicated monitoring conducted under the Snowy 2.0 monitoring program. The resumption of good recruitment of young-of-year at a number of sites in 2024 (Lintermans 2024; this report) is encouraging, and it remains to be seen how this young-of-year abundance translates to age 1+ abundance in 2025.

Recommendations

- The Snowy 2.0 monitoring program should be repeated in 2025 using the same sites and methodology. Further investigation of available access at Site 1 is required to enable better spacing of nets. If this enhanced access is not available, the site may have to be moved slightly downstream where better access is available.
- 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.

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Appendix 1. Photos of field sampling sites in 2024.

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	14/03/2024
Site name	Site 1

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	A	Rock	A
Boulder	A	Timber	O
Cobble	A	Undercuts	-
Pebble	A	Leaf litter	A
Gravel	O	Macrophytes	R
Sand	O		
Mud/silt	A		
Plants		**Mesohabitat**	
Native trees	A	Pool	A
Exotic trees	R	Run	O
Native shrubs	A	Riffle	O
Exotic shrubs	-	Rapid	-
Riparian grass	O	Backwater	F
Floating macrophytes	-	Velocity (still, slow. mod, fast)	slow
Emergent macrophytes	R	Avg depth (m)	1.1
Submerged macrophytes	O	Max depth (m)	2.1
Filamentous algae	O	Avg width (m)	42
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

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

Habitat sheet	
Date	27/02/2024
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	O	Max depth (m)	2.7
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	13/03/2024
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)	1.2
Submerged macrophytes	F	Max depth (m)	2.6
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	*9/04/2024*
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	*22/04/2024*		
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)*	***2.0***
Filamentous algae	***-***	*Avg width (m)*	***20***
Suspended algae	***O***		
Biofilms	***A***		

Appendix 2 (cont). Site habitat descriptors

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

Habitat sheet	
Date	27/02/2024
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)	1.5
Submerged macrophytes	F	Max depth (m)	5.4
Filamentous algae	R	Avg width (m)	35
Suspended algae	A		
Biofilms	F		

Appendix 2 (cont). Site habitat descriptors.

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

Habitat sheet	
Date	18/03/2024
Site name	Site 7

Habitat element	Score	Habitat element	Score
Substrate		**Cover**	
Bedrock	-	Rock	F
Boulder	A	Timber	F
Cobble	A	Undercuts	-
Pebble	F	Leaf litter	A
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	R
Exotic shrubs	F	Rapid	-
Riparian grass	F	Backwater	-
Floating macrophytes	-	Velocity (still, slow. mod, fast)	Slow
Emergent macrophytes	A	Avg depth (m)	2.5
Submerged macrophytes	A	Max depth (m)	4.2
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	12/03/2024
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	O	Run	O
Native shrubs	A	Riffle	O
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)	2.6
Filamentous algae	R	Avg width (m)	24
Suspended algae	A		
Biofilms	A		

Appendix 2 (cont). Site habitat descriptors.

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

Habitat sheet	
Date	21/03/2024
Site name	Site 9

Habitat element	Score	**Habitat element**	Score
Substrate		**Cover**	
Bedrock	A	Rock	F
Boulder	O	Timber	F
Cobble	O	Undercuts	-
Pebble	F	Leaf litter	F
Gravel	A	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	R
Riparian grass	A	Backwater	-
Floating macrophytes	--	Velocity (still, slow. mod, fast)	mod
Emergent macrophytes	R	Avg depth (m)	1.0
Submerged macrophytes	O	Max depth (m)	2.0
Filamentous algae	O	Avg width (m)	41
Suspended algae	A		
Biofilms	A		

Appendix 3: Water quality parameters at each site

(pH, conductivity, water temperature, turbidity and dissolved oxygen). Note that at Sites 2 and 5 faulty equipment prevented accurate measurement of most parameters.

Site	Date sampled	Time measured	pH	Cond. (uS/cm)	Water temp (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
Site 1	14/03/2024	16:15	7	20	20.0	<9	8.4
Site 2	27/02/2024	14:25	*	*	22.5	<9	*
Site 3	13/03/2024	10:20	7	30	19.8	<9	7.2
Site 4	9/04/2024	10:50	7	-	-	9	10.0
Site 5	22/04/2024	10:30	7	50	15.1	<9	9.4
Site 6	29/02/2024	16:50	*	*	23.6	<9	*
Site 7	19/03/2024	10:00	7	80	19.6	<9	7.9
Site 8	21/03/2024	19:10	7	100	23.5	<9	7.8
Site 9	12/03/2024	18:37	7	190	19.8	11	8.5