When do endangered Macquarie perch spawn in the upper Murrumbidgee River?

Department of Climate Change, Energy, the Environment and Water

NSW GOVERNMENT

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the Traditional Custodians of the lands where we work and live.

We pay our respects to Elders past, present and emerging.

This resource may contain images or names of deceased persons in photographs or historical content.

This document should be cited as: Campbell D, McGrath N, Wilson E and Lintermans M (2025) *Spawning period of endangered Macquarie perch in the upper Murrumbidgee River*, Department of Climate Change, Energy, the Environment and Water, NSW Government.

Artist and designer Nikita Ridgeway from Aboriginal design agency Boss Lady Creative Designs created the People and Community symbol.

Cover photo: Settling drift nets below a riffle for Macquarie perch eggs and larvae, Kissops Flat. Dale Campbell/DCCEEW

Published by:
Environment and Heritage
Department of Climate Change,
Energy, the Environment and Water
Locked Bag 5022, Parramatta NSW 2124
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment and Heritage enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email info@environment.nsw.gov.au
Website www.environment.nsw.gov.au

ISBN 978-1-76186-274-8
EH 2026/0248 July 2026

Find out more at:

environment.nsw.gov.au

Contents

List of tables

List of figures

Acknowledgements

We thank Paul Humphries of Charles Sturt University, Albury, for providing lab access for this project. We also thank university staff members Paul Humphries, Nicole McCasker and John Trethewie for fish larval identification assistance, and John Trethewie for taking high-quality microscope images of larval fish.

We thank the landholders and managers of the properties we sampled (Killarney, Bolaro Station, Kissops Flat, Murrells Crossing) for their interest and for facilitating access.

We thank Paul Doyle, Ray Matthews and Hayden Smith for fieldwork assistance, and Deanna Duffy, from Charles Sturt University's Spatial Data Analysis Network research unit, for creating the site map in this report.

Sampling was conducted under NSW Department of Industries and Regional Development Fisheries Scientific Collection Permit no. FP23/108 and University of Canberra Animal Ethics Committee approval AEC 14148.

This research was conducted on Ngarigo Country.

Introduction

Macquarie perch (*Macquaria australasica*) is a moderately sized, deep-bodied, freshwater percichthyid fish found in south-eastern Australia. It occurs in both the inland drainage of the Murray–Darling Basin as well as the coastal drainages of the Shoalhaven and Hawkesbury-Nepean catchments in New South Wales (Faulks et al. 2010; Pavlova et al. 2017; Lintermans 2023a). It is now considered that the 3 morphologically distinct and geographically disjunct forms occurring 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 Murray–Darling Basin, the species attains a maximum length of 550 mm (total length) and a maximum weight of 3.5 kg; however, individuals larger than 400 mm total length or 1 kg are uncommon (Harris and Rowland 1996; Lintermans 2023a). Length at maturity is variable, with females generally maturing at approximately 250 mm total length and males at 150 to 200 mm total length (Cadwallader and Rogan 1977; Appleford et al. 1998; Lintermans 2023a; Lintermans et al. 2019). The remaining coastal taxa (Hawkesbury-Nepean and Shoalhaven) are smaller, generally not exceeding 180 mm length (Harris and Rowland 1996; Knight and Bruce 2010; Gilligan and Bruce 2019).

Macquarie perch were one of the first fish species formally listed as nationally threatened. Macquarie perch (including all inland and coastal forms) are currently listed as endangered internationally, nationally and in all the states and territories in which the species occurs (Ingram et al. 2000; Lintermans et al. 2019; Lintermans 2023a).

The upper Murrumbidgee River contains one of only a handful of remaining large, self-sustaining natural populations (Lintermans 2024a, 2024b; Pavlova et al. 2024), with the species declining noticeably in the Murrumbidgee River in the Australian Capital Territory since the mid-1980s, when catch rates dropped by approximately 95% (Lintermans 2002). Major threats to the species include habitat modification, sedimentation, barriers to fish passage, cold-water discharge, highly modified flows and interaction with alien species (Ingram et al. 2000; Lintermans 2012, 2023a; Commonwealth of Australia 2018).

Macquarie perch can form significant populations in impoundments but are truly a riverine fish that can only breed in flowing waters (Cadwallader and Rogan 1977; Tonkin et al. 2017; Lintermans 2023a). Males are reported to reach sexual maturity at 2 years of age, and females at 3 years (Lintermans 2023a). Macquarie perch tend to spend most of their time in deep holes and move to spawn. Macquarie perch are known to undertake a synchronised upstream spawning migration from impoundments to tributary streams in spring (Wharton 1968; Cadwallader and Rogan 1977; Douglas 2002; Lintermans et al. 2013; Tonkin et al. 2018), but the occurrence, extent and direction of spawning migration is less certain in riverine ecosystems (Koster et al. 2014). Research in the upper Murrumbidgee River around Cooma has found the species moving both up and downstream to spawn (Prue Haantjens unpublished).

Macquarie perch spawning is known to occur from October to December, with increasing water temperatures and late spring to early summer flows acting as cues to commence spawning (Cadwallader and Rogan 1977; Tonkin et al. 2010, 2015; Broadhurst et al. 2017, 2019). Macquarie perch require shallow cobble or gravel riffle areas for breeding (Wharton 1968; Kearns et al. 2012), with water depths of 20 to 90–cm and water velocity of 0.3 to 0.6–metres per second. Low silt and coarse spawning substrates are critical for egg development.

When spawning, females remain close to the substrate, usually in groups of 2 or 4, accompanied by 1 or 2 males (Cadwallader and Rogan 1977; Tonkin et al. 2010, 2015). Wharton (1973) and Cadwallader and Rogan (1977) estimated fecundity to be 30,000 eggs per kg of mature female. A large female Macquarie perch may produce up to 100,000 eggs (Cadwallader and Rogan 1977; Appleford et al. 1998). Cadwallader and Rogan (1977) and Wharton (1973) measured the diameter of unfertilised eggs as 2 mm, and the diameter of fertilised, water-hardened eggs as 4 mm.

Macquarie perch eggs typically hatch after 10 to 18 days at water temperatures between 15 and 17 °C. Hatching commences 13 days after fertilisation and is completed by 18 days after fertilisation at water temperatures of 11 to 18 °C (Wharton 1973). Gooley (1986) noted that hatching commenced more quickly in higher water temperatures (10 to 11 days at 15 to 17 °C and 5 to 6 days at 18 to 20 °C). Newly hatched larvae range from 4.5 to 7 mm in total length.

After absorbing their yolk sac, Macquarie perch larvae commence feeding on small aquatic organisms such as microinvertebrates and macroinvertebrates. Juvenile Macquarie perch measuring 10 to 30 mm have been recorded in high abundance in pools.

Macquarie perch have been particularly problematic to breed in captivity, requiring flowing water, and have typically relied on the collection of wild broodstock (Ingram et al. 1994; Farrington et al. 2014). This highlights the importance of maintaining the wild population and natural spawning and recruitment, as broodstock is still largely collected from wild populations.

Research has demonstrated that the upper Murrumbidgee population regularly breeds and recruits along an approximately 95 km ‘recruitment reach’, from just downstream of Yaouk to below Cooma (Lintermans 2023b). The Murrumbidgee recruitment reach has a limited number, distribution and abundance of alien fish species such as carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*). This, along with the reach’s relatively small extent, habitat quality, and reliable recruitment, makes it the best Macquarie perch population in New South Wales and one of national significance (Lintermans 2022, 2023b). These qualities also provide a haven for the species from the impacts of some introduced fish (Woinarski et al. 2023). The species 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).

There are 2 types of flow release from Tantangara Dam, environmental flows and riparian releases. Environmental flows come from the Snowy Montane Rivers Increased Flows allocation. These releases are designed to support ecological objectives. Riparian releases are made when environmental flow and tributary flows equal a flow rate below 32 ML/day at Mittagang Crossing, the aim is to target a minimum of 32 ML/day for domestic water supply (Pendlebury et al. 1997; Snowy Scientific Committee 2010).

The riparian releases are much smaller in volume (annual average of 2.8 GL between 1993 and 2009 (Snowy Scientific Committee 2010)), whereas annual environmental releases have ranged from 3.1 to 44.7 GL since 2011–12, with an annual average of 24.14 GL (Snowy Hydro data is available via Snowy Hydro annual water reports). Environmental flows are designed using a natural flow-scaling approach, with higher peaks in late winter and spring to partially mimic natural flow. Environmental flows can experience low or no flow periods, pending allocation. Environmental releases are limited by both the existing regulatory framework (the Snowy Water Inquiry Outcomes Implementation Deed) and existing dam outlet infrastructure. The Snowy Scientific Committee (2010) considered the flows insufficient to support natural values and threatened species. Historic average annual inflows at Tantangara Dam prior to its construction were around 300 GL (Pendlebury et al. 1997), so the average annual environmental releases since 2011–12 are around 8% of natural pre-impoundment flows. Allocation is often insufficient to provide a release every day of the year, with a variable flow regime resulting in prolonged periods of zero-flow day releases from the dam.

Under the current licence and Snowy Water Inquiries Implementation Outcomes Deed arrangements, environmental flows are designed up to 15 months in advance and cannot be adaptively managed. Since 2013–14 a partial natural flow-scaling approach has been used to mimic a snow melt river, with the addition of higher peaks in late winter/spring, and low flow periods pending allocation (Reinfelds et al. 2013).

A critical knowledge need for managing Macquarie perch in the upper Murrumbidgee recruitment reach is around the location of spawning sites and the timing of when the species spawns in this reach (Lintermans 2023b; Lintermans et al. 2024). This knowledge is essential to improve the timing and quantum of environmental water releases from Tantangara Dam, with Macquarie perch a key environmental asset in this river reach upstream of the Numeralla River junction (NSW DCCEEW 2024).

Currently, there is limited 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 and UMR06 in Bylemans et al. 2017). A pilot study undertaken in 2023 (Lintermans et al. 2024) was unsuccessful in determining when Macquarie perch are breeding in the upper Murrumbidgee, with no Macquarie perch larvae or eggs found. This result may reflect the limited sites and number of riffles sampled, limited sampling events, and high flows and storm runoff in the catchment resulting in very large volumes of organic debris accumulating in drift nets.

As a benthic spawning species with no parental care, high flows when eggs or newly hatched larvae are on the ground can result in washout of nests or damage to fragile

larvae (Tonkin et al. 2009, 2010, 2015). Eggs and newly hatched larvae are susceptible to higher flows, which may hinder the persistence and recovery of the upper Murrumbidgee Macquarie perch population. However, given the Macquarie perch's spawning requirement for clean riffles to allow adhesion of its demersal fertilised eggs, environmental releases at the right time could be beneficial to reduce sediment in riffles immediately prior to the commencement of the spawning period. Maintaining sufficient flows for the duration of the incubation period to ensure eggs are not smothered by sedimentation is likely to be an important use of environmental flows to increase the success of recruitment.

This study aims to examine the location and the relationship between flow timing and temperature of successful Macquarie perch spawning.

Methods

Survey sites

Four sites along the upper Murrumbidgee River were sampled for Macquarie perch larvae and eggs (see Figure 1). Survey sites were distributed between Yaouk and downstream of Cooma, NSW, and were sampled 4 times at approximately fortnightly intervals between late October and early December 2024 (Table 1).

The timing of sampling was informed by the previously published collection of eggs at the lower end of the study reach (Murrells Crossing) in late October (Bylemans et al. 2017) and the assumption that timing would be delayed in upper reaches, as water temperatures at Killarney (Yaouk No. 2 gauge) generally exceed 16 °C in late October to early November.

The 4 sampling sites (Killarney, Bolaro Station, Kissops Flat and Murrells Crossing) were selected based on previous knowledge of where Macquarie perch recruitment regularly occurs (Lintermans 2023b, 2024a, b).

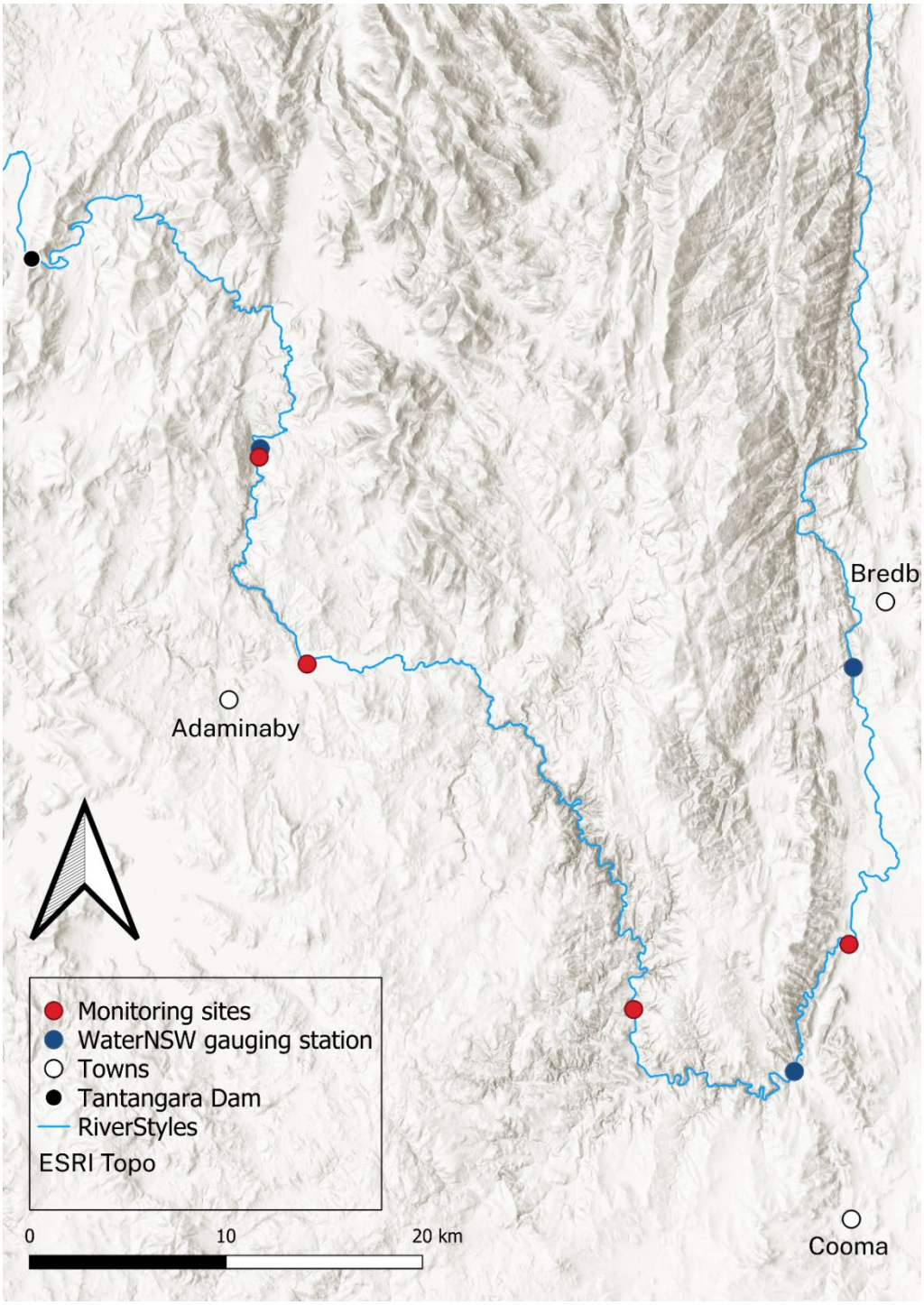

Figure 1 **Location of egg and larval Macquarie perch sampling sites: Killarney, Bolaro Station, Kissops Flat and Murrells Crossing**

Note: Red circles are survey sites, blue circles (Murrumbidgee River at Yaouk No. 2, Mittagang Crossing and upstream of Bredbo Junction) are gauge stations recording flow and temperature at Yaouk.

Table 1 **Sampling dates for the 4 sites in the upper Murrumbidgee River.**

Trip	Killarney	Bolaro Station	Kissops Flat	Murrells Crossing
Trip 1	31/10/2024	30/10/2024	28/10/2024	29/10/2024
Trip 2	7/11/2024	6/11/2024	4/11/2024	5/11/2024
Trip 3	21/11/2024	22/11/2024	N/A	20/11/2024
Trip 4	3/12/2024	3/12/2024	4/12/2024	5/12/2024

Note: Site access to Kissops Flat was not possible during trip 3.

Sample collection

Egg and larval surveys were conducted via the use of wingless drift nets – a well-established method for sampling drifting fish larvae and eggs in Australian freshwater fish (Bylemans et al. 2017; Humphries 2005; Humphries and King 2004; King et al. 2005, 2007; Koehn and Harrington 2006). Nets were secured mid-stream via ropes and stakes, with the opening of the drift nets facing into the flow. Nets were deployed in the afternoon (3:00 pm to 5:30 pm) and collected the next day (8:00 am to 2:00 pm). Each net was fitted with a flow meter (General Oceanics Mechanical Flowmeter model 2030R with 3-inch dia. rotor). Drift nets had a 50 cm opening and were made of 500µ mesh.

Each site had 5 riffles sampled, with 2 nets secured below each riffle in areas of greatest flow (Figure 1). For each site, 4 sampling trips were undertaken. Riffle numbers per site and sampling frequency was increased from the 2023 pilot study to increase the likelihood of collecting eggs and larvae (Lintermans et al. 2024).

Drift nets were washed down to collect samples and to condense any eggs and larvae stuck on the nets. Contents of drift nets were put into storage jars and immediately preserved in 70% ethanol.

Laboratory processing

Preserved samples were subsequently processed in the laboratory with samples wet sieved into different size fractions, which were then examined under stereo microscope for fish larvae and eggs. Larvae and eggs were identified using relevant keys (Serafini and Humphries 2004) and consultation with species experts. Fish larvae total length and eggs (diameter) were measured to the nearest tenth of a millimetre. Eggs were also DNA tested to confirm species.

Results

A total of 185 fish larvae were collected over the 4 larval sampling trips. A total of 3 fish species were collected in larval drift nets: Macquarie perch (*Macquaria australasica*), mountain galaxias (*Galaxias olidus*) and European carp (*Cyprinus carpio*). See Table 2.

Table 2 **Occurrence of larval fish (Macquarie perch, mountain galaxias, carp) and eggs in drift net samples from Killarney, Bolaro Station, Kissops Flat and Murrells Crossing.**

Number	Site	Riffle	Net	Date	Macquarie perch	Mountain galaxias	Carp	Eggs
1	Killarney	5	10	31/10/2024	–	–	–	1
1	Kissops Flat	1	1	28/10/2024	–	1	–	2
1	Kissops Flat	2	3	28/10/2024	–	4	–	--
1	Kissops Flat	4	7	28/10/2024	–	6	–	5
1	Murrells Crossing	1	1	29/10/2024	–	5	60	10
1	Murrells Crossing	1	2	29/10/2024	–	4	43	--
1	Murrells Crossing	2	4	29/10/2024	–	4	4	–
1	Murrells Crossing	3	5	29/10/2024	–	2	5	–
1	Murrells Crossing	4	7	29/10/2024	–	5	–	1
2	Killarney	4	7	7/11/2024	–	-	–	65
2	Kissops Flat	2	3	4/11/2024	–	12	–	--
2	Kissops Flat	2	4	4/11/2024	–	–	–	3
2	Murrells Crossing	2	3	5/11/2024	–	–	–	2
2	Murrells Crossing	4	7	5/11/2024	–	–	–	1
4	Killarney	2	3	3/12/2024	–	2	–	–
4	Killarney	2	4	3/12/2024	–	--	–	1

Number	Site	Riffle	Net	Date	Macquarie perch	Mountain galaxias	Carp	Eggs
4	Bolaro Station	4	8	3/12/2024	–	2	-	-
4	Kissops Flat	4	7	4/12/2024	–	--	1	7
4	Kissops Flat	4	8	4/12/2024	–	1	4	8
4	Murrells Crossing	2	3	5/12/2024	–	–	1	–
4	Murrells Crossing	4	7	5/12/2024	–	–	6	–
4	Murrells Crossing	5	10	5/12/2024	–	–	10	–
–	–	–	–	**Total**	**3**	**48**	**134**	**106**

A total of 3 Macquarie perch larvae were collected from these surveys. Two recently hatched larvae from Murrells Crossing collected on 29 October 2024, riffle 1, net 2 (Figure 2) and one larvae from Kissops Flat collected on 4 November 2024, riffle 2, net 4 (Figure 3).

Macquarie perch eggs typically hatch after 10 to 18 days at water temperatures between 15 to 17 °C. Therefore, the estimated spawning of Macquarie perch larvae was back calculated to mid- to late October.

- Murrells Crossing: 4.9 mm larvae capture date 29 October 2024. Estimated spawn date 11 to 19 October 2024.
- Kissops Flat: 7 mm larvae capture date 4 November 2024. Estimated spawn date 17 to 25 October 2024. This larvae was larger and more mature than the 2 recently hatched larvae collected at Murrells Crossing.

A total of 106 fish eggs were also collected during drift net sampling. Fish eggs ranged in size from 2 to 2.5 mm diameter. A total of 65 eggs were collected from a single drift net at Killarney riffle 4, net 7 on 31 October 2024. Through visual examination of eggs and egg measuring, species identification was determined to be either mountain galaxias or Macquarie perch. Identification was supported by reference to expert opinion. DNA testing of eggs confirmed them as Macquarie perch. Killarney riffle 4 is below a large natural rock barrier that spans the Murrumbidgee River. Eggs were found on the inside and outside of the drift net and were not water-hardened indicating spawning occurred in front of the net the previous night (Figure 4).

European carp larvae were collected from the lower study area at Kissops Flat and Murrells Crossing (see Figures 5 and 6). Mountain galaxias larvae were collected at all 4 study sites (Killarney, Bolaro Station, Kissops Flat and Murrells Crossing). The only galaxias species known in the upper Murrumbidgee catchment downstream of

Tantangara Dam is *Galaxias olidus* (Lintermans 2002, 2023b, 2024b; Raadik 2014); therefore, all collected specimens were considered to be *G. olidus*.

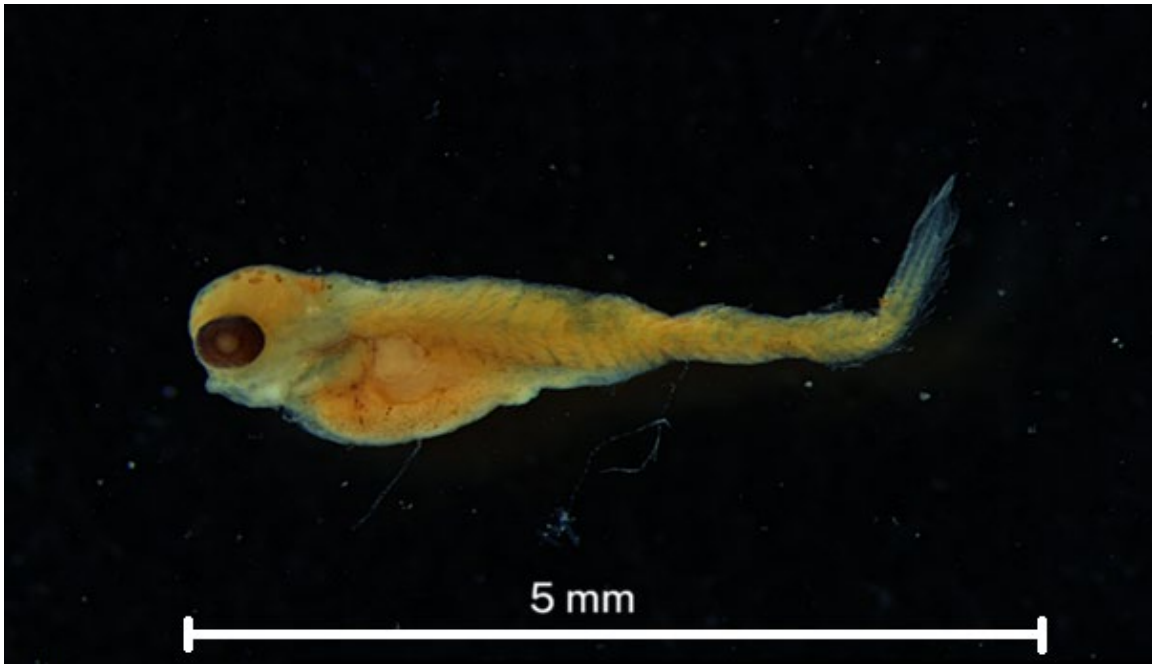

Figure 2 **One of 2 recently hatched Macquarie perch larvae from Murrells Crossing collected from riffle 1, net 2 on 29 October 2024. Photo: John Trethewie/CSU and Dale Campbell/DCCEEW**

Figure 3 **7 mm Macquarie perch larvae from Kissops Flat collected from riffle 2, net 4 on 4 November 2024. Photo: John Trethewie/CSU and Dale Campbell/DCCEEW**

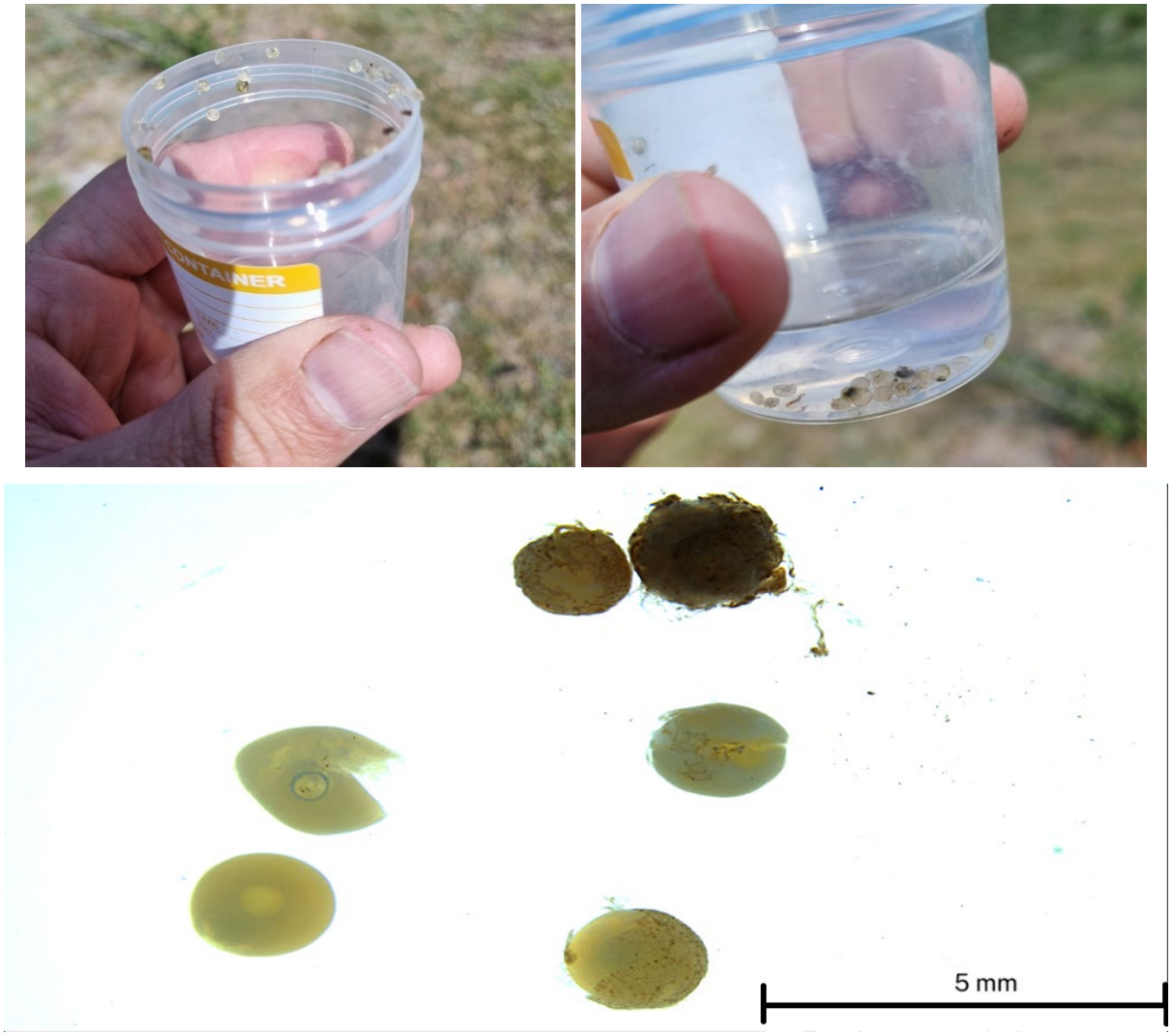

Figure 4 **Subset of 65 fish eggs collected from drift net. Trip 2, Killarney, riffle 4, net 7, 7 November 2024. Eggs ranged in size from 2 to 2.5 mm diameter. DNA confirmed these as Macquarie perch eggs. Top: Macquarie perch eggs picked off net in the field. Bottom: Macquarie perch eggs under a microscope. Photos: John Trethewie/CSU and Dale Campbell/DCCEEW**

Figure 5 **Carp larvae from Murrells Crossing, trip 1, riffle 1, net 2, 29 December 2024. Photo: John Trethewie/CSU and Dale Campbell/DCCEEW**

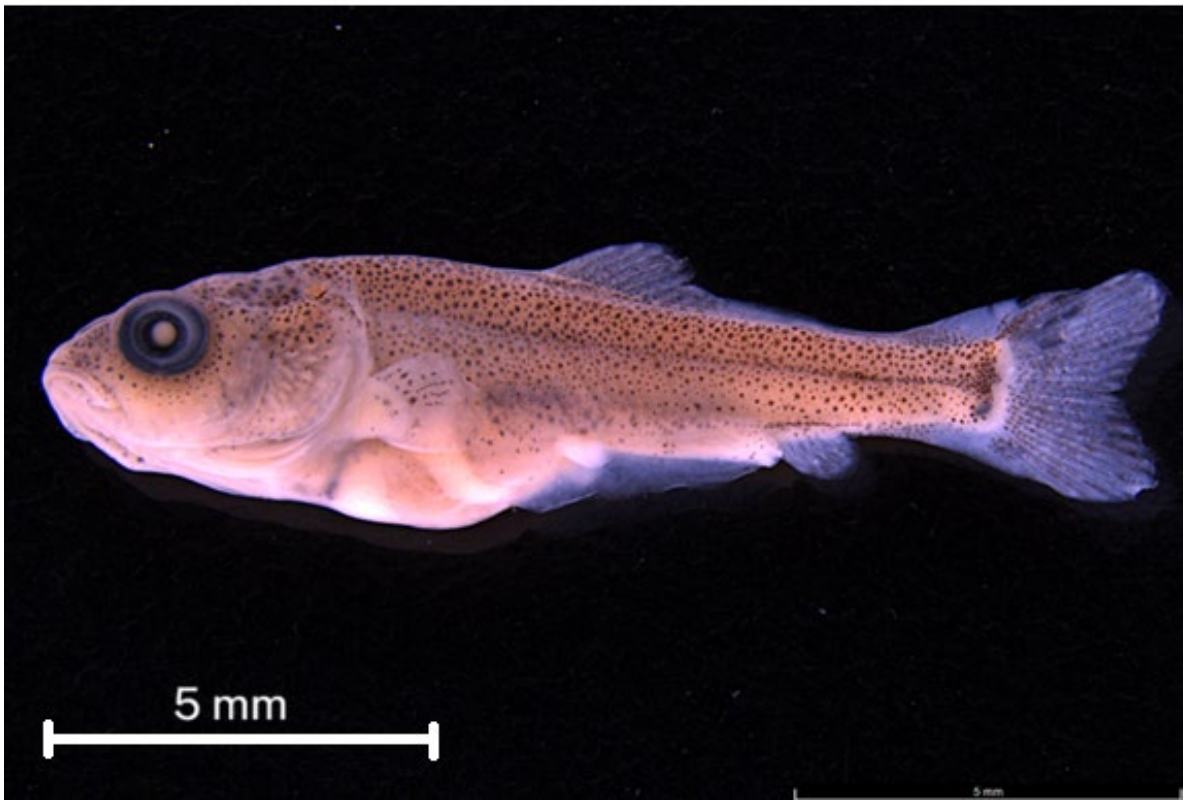

Figure 6 **Juvenile carp from Murrells Crossing, trip 4, riffle 5, net 10, 5 December 2024. Photo: John Trethewie/CSU and Dale Campbell/DCCEEW**

During sampling for another project (Lintermans unpublished), a 22 mm young-of-year Macquarie perch was caught in a fyke net at Kissops Flat on 4 December 2024. Otoliths from this young-of-year Macquarie perch were extracted and sent to Fish Ageing Services Pty Ltd for daily ageing. Results of daily ageing showed the fish was 33 days old and hatched on 1 November 2024. Macquarie perch eggs typically hatch after 10 to 18 days at water temperatures between 15 to 17 °C; therefore, the estimated spawning date of this Macquarie perch larvae was back calculated to 14 to 22 October, which corresponds with the larvae caught at Kissops Flat (7 mm larvae, capture date 4 November 2024, estimated spawn date 17 to 25 October 2024) which further supports estimated spawning time for the species at this site (see Figure 7).

Figure 7 **22 mm total length Macquarie perch caught at Kissops Flat on 4 December 2024. Photo: John Trethewie/CSU and Dale Campbell/DCCEEW**

Discussion

Determining the timing and location of Macquarie perch breeding is crucial for successful conservation and management efforts. Understanding when and where the species spawns allows targeted flow management to aid in movement, spawning, survival and recruitment. Macquarie perch spawning has never been documented in the upper Murrumbidgee River reaches upstream of Mittagang Crossing, with some previously published data available for the Cooma Gorge and Murrells Crossing (Bylemans et al. 2017; van der Meulen et al. 2023).

This study has increased the knowledge of Macquarie perch spawning in these upstream reaches (including Kissops Flat and Killarney), and determined 2 estimated spawning dates, confirming the timing previously published for below Mittagang Crossing (Bylemans et al. 2017; van der Meulen et al. 2023). While only very few Macquarie perch were caught, the findings will help refine sampling strategies in future years and indicate that more riffles should be sampled. Increasing knowledge of the spawning time and spawning areas used by Macquarie perch is vital for the survival and long-term management of perch populations in the upper Murrumbidgee River.

Macquarie perch larvae and/or eggs were found at 3 of the 4 sampling sites during the 2024 breeding season (Killarney, Kissops Flat and Murrells Crossing, not detected at Bolaro Station). While the number of eggs and larvae collected were low, subsequent sampling in March 2025 revealed high abundance of Macquarie perch young-of-year (individuals 50 to100 mm total length) (Lintermans 2025; Lintermans and Campbell 2025), compared to low larval capture. There are 3 possible explanations why no to low abundance of eggs or larvae were sampled at the 4 sampling sites (Lintermans et al. 2024):

1. Macquarie perch spawning did not occur at all in the vicinity of the current monitoring riffles and spawning occurred at the riffles not sampled.
2. Spawning/larval hatch occurred at the sampled sites earlier or later in season.
3. Sampling failed to detect low-level spawning at the sampled sites.

Macquarie perch are highly selective of the riffles in which they spawn (Tonkin et al. 2015; Broadhurst et al. 2017, 2018, 2019). Previous studies have also encountered low detectability of Macquarie perch spawning in the upper Murrumbidgee River. Macquarie perch eggs or larvae were recorded in only 2 of the 6 sites examined by Bylemans et al. (2017), and 2 of 3 riffles in 2020 (van der Muelen et al. 2023). Previously, in the upper Murrumbidgee River, the majority of eggs collected were from a small subset of riffles monitored over several years (Prue Haantjens unpublished). Low detection of Macquarie perch larvae and eggs may simply be due to the fact we have not found the preferred spawning riffles, which accounts for most spawning and recruitment in the different reaches. This riffle selectivity highlights the importance of further work to find preferred spawning riffles if breeding areas are to be protected.

Current study sites range in elevation from approximately 720 m at Murrells Crossing to 1040 m at Killarney. It was expected that attainment of critical temperature thresholds for migration and spawning would be somewhat delayed at upstream sites compared to downstream sites (Lintermans et al. 2024). Understanding breeding in the upper reaches of the Murrumbidgee is important as the higher reaches are more likely to experience the benefits of available environmental flow volumes (<1500 ML/day) such as the riffle and cobble cleaning flows.

The upper Murrumbidgee River flows were low during the study period (daily average from 80 to 260 ML/day at Yaouk No. 2 gauge and 70 to 260 ML/day at Murrells Crossing). Macquarie perch typically spawn when water temperature rises to around 16 °C. At Yaouk, water temperature first reached 16 Con 20 October 2024, with this occurring a week earlier on 13 October 2024 at the more downstream Mittagang Crossing (see Figure 8).

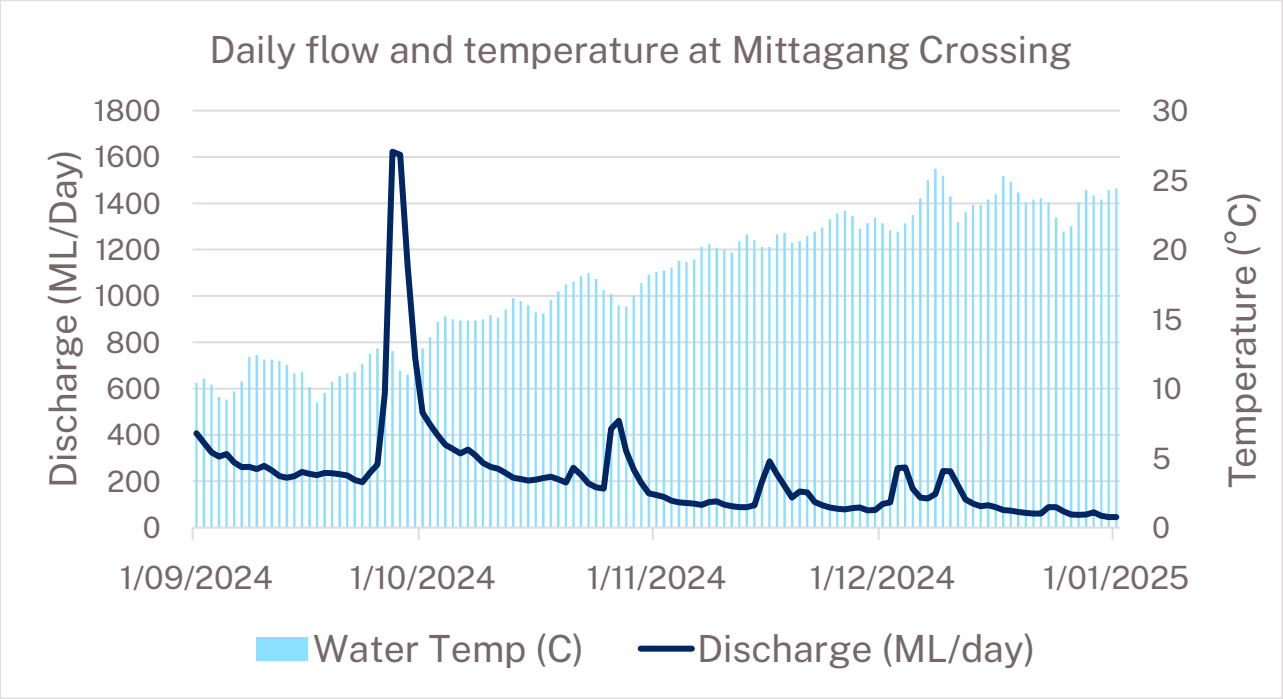

Figure 8 **Daily flow and water temperature in the upper Murrumbidgee River at Yaouk No. 2 station above Killarney, September to December 2024**

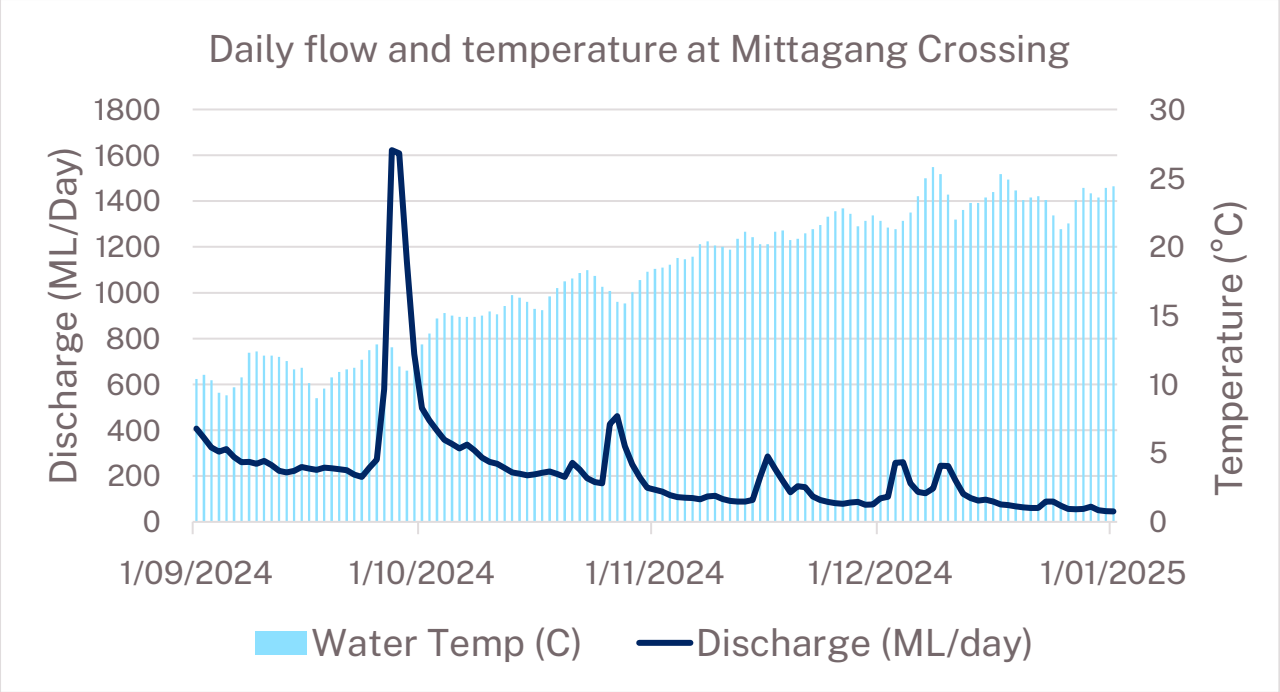

Figure 9 **Daily flow and water temperature in the upper Murrumbidgee River at Mittagang Crossing above Murrells Crossing, September to December 2024**

The 2024 Macquarie perch breeding season was characterised by a warm spring and low river flow. During sampling, Macquarie perch were only detected in early sampling events, suggesting spawning and larval hatching may have already occurred and fish detected were the last of the larvae to hatch for the season. While breeding conditions are generally well understood, there is some variability in the importance of key cues (such as temperature, day length and flow). The deployment of more temperature and flow loggers would aid in determining when suitable conditions for breeding are met in the upper Murrumbidgee River.

Conclusion

Determining the timing and location of Macquarie perch breeding is crucial for successful conservation and management efforts in the upper Murrumbidgee. Understanding the Macquarie perch reproductive cycle allows for targeted environmental flow management to aid in their movement, spawning, survival and recruitment. With continued surveys in future years, together with increasing the number of riffles sampled, the knowledge gained will greatly benefit the remaining Macquarie perch population in the upper Murrumbidgee River.

Recommendations

The need to determine the spawning window for Macquarie perch in the upper Murrumbidgee recruitment reach remains. Without such information there is a real risk that environmental flows may be inappropriately targeted. Determining important spawning sites will also facilitate focused riparian or adjacent land and water management activities to protect and enhance such sites. To identify the Macquarie perch spawning window and priority spawning sites, the following actions are recommended:

1. Sampling is conducted at a larger number of riffles to account for the documented riffle selectivity of the species.
2. Sampling is conducted for an extended period – commencing earlier and repeated at fortnightly intervals to detect spawning. Monitoring should occur from mid-October to early December to cover the known spawning period.
3. Sampling is expanded to include larval fish light trapping. Larval fish light trapping takes advantage of the phototactic behaviour of many aquatic organisms by using a bright light to lure organisms inside. Samples from light trapping also produce a cleaner sample (less organic detritus), requiring less processing time compared to drift netting.
4. The broadscale use of eDNA genetic techniques is explored to build on the work of Bylemans et al. (2017) using concentrations of nuclear and mitochondrial eDNA concentrations over time. The NSW Department of Climate Change, Energy, the Environment and Water is currently developing an eDNA project.
5. The use of double-winged drift nets, which was trialled in 2025, to significantly increase the sampling area of each drift (see Tonkin et al. 2015; van der Muelen et al. 2023).
6. The use of drones and drone surveys to find and observe Macquarie perch at different riffle sites. This will aid in determining which riffles are holding fish and may identify possible spawning areas and help characterise interannual variability in spawning activity.
7. Sampling of both eggs and larvae across a range of high, average, and low flow years so that correlations can be made between spawning and young-of-year recruitment strength to identify the life phase at which failure occurred (i.e. failure to spawn, failure in larval survival, failure in early juvenile survival).
8. Undertaking annual young-of-year surveys in January for the collection of an ageing sample to determine spawn or hatch date. Collection of younger year-on-year samples will allow for more accurate ageing.
9. Deployment of more temperature and depth loggers to see when triggers for spawning are met.

References

Appleford P, Anderson TA and Gooley GJ (1998) 'Reproductive cycle and gonadal development of Macquarie perch, *Macquaria australasica* Cuvier (Percichthyidae), in Lake Dartmouth and tributaries of the Murray- Darling Basin, Victoria, Australia', *Marine and Freshwater Research*, 49:163–169.

Broadhurst BT, Lintermans M, Clear RC and Jekabsons M (2018) *Spawning habitat of Macquarie perch in the Cotter River 2017: Report to Icon Water*, Institute for Applied Ecology, University of Canberra, Canberra.

Broadhurst BT, Lintermans M, Clear RC and Jekabsons M (2019) *Spawning habitat of Macquarie perch in the Cotter River 2018: Report to Icon Water*, Institute for Applied Ecology, University of Canberra, Canberra.

Broadhurst BT, Lintermans M, Clear RC and van der Meulen D (2017) *Spawning movements of Macquarie perch in the Cotter River 2016: Report to Icon Water*, Institute for Applied Ecology, University of Canberra, Canberra.

Bylemans J, Furlan E, Hardy C, McGuffie P, Lintermans M and Gleeson D (2017) 'An environmental DNA (eDNA) based method for monitoring spawning activity: a case study using the endangered Macquarie perch (*Macquaria australasica*)', *Methods in Ecology and Evolution*, 8:646–655.

Cadwallader PL and Rogan PL (1977) 'The Macquarie perch, *Macquaria australasica* (Pisces: Percicthyidae), of Lake Eildon, Victoria', *Australian Journal of Ecology*, 2:409–418.

Commonwealth of Australia (2018), *National Recovery Plan for Macquarie Perch*.

Douglas J (2002) 'Observations on Aspects of Macquarie Perch *Macquaria australasica* (Cuvier) Spawning Natural Recruitment and Selected Population Attributes in Lake Dartmouth and the Mitta Mitta River between 1994 and 1998', *Marine and Freshwater Resources Institute Freshwater Fisheries, Report No. 02/07*.

Farrington LW, Lintermans M and Ebner BC (2014) 'Characterising genetic diversity and effective population size in one reservoir and two riverine populations of the threatened Macquarie perch', *Conservation Genetics*, 15(3):707–716.

Gilligan D and Bruce A (2019) *Macquaria sp. nov. 'Hawkesbury'*, The IUCN Red List of Threatened Species 2019: e.T128972817A128972820,http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T128972817A128972820.en, accessed 14 May 2025.

Harris JH and Rowland SJ (1996) 'Family Percicthyidae: Australian freshwater cods and basses', pp 150–163 in McDowall RM (ed) *Freshwater fishes of south-eastern Australia*, Reed Books, Australia.

Humphries P (2005) 'Spawning time and early life history of Murray cod, *Maccullochella peelii* (Mitchell) in an Australian river', *Environmental Biology of Fishes*, 72(4), pp 393–407, https://doi.org/10.1007/s10641-004-2596-z, accessed 14 May 2025.

Humphries P and King AJ (2004) 'Drifting fish larvae in Murray–Darling Basin rivers: composition, spatial and temporal patterns and distance drifted', in Lintermans M and Phillips B (eds), *Downstream movement of fish in the Murray–Darling Basin: statement, recommendations and supporting papers from a workshop held in Canberra 3–4 June 2003*, pp 51–58), Murray–Darling Basin Commission.

Ingram BA, Rimmer MA and Rowland SJ (1994) 'Induced spawning trials with captive Macquarie perch, Macquaria australasica (Percichthyidae)', *Proceedings of the Linnean Society of New South Wales*, 114 (2):109–116.

Ingram BA, Douglas JW and Lintermans M (2000) 'Threatened fishes of the world: *Macquaria australasica* Cuvier, 1830 (Percichthyidae)', *Environmental Biology of Fishes*, 59(1):68.

Kearns J, Tonkin Z, O'Mahony J and Lyon J (2012) *Identification and protection of key spawning habitats for Macquarie Perch in King Parrot Creek: Black Saturday Victoria 2009 – Natural values fire recovery program*, Department of Sustainability and Environment, Heidelberg, Victoria.

King AJ, Crook DA, Koster WM, Mahoney J and Tonkin Z (2005) 'Comparison of larval fish drift in the Lower Goulburn and mid-Murray Rivers', *Ecological Management and Restoration*, 6(2):136–138.

King AJ, Tonkin Z and Mahoney JM (2007) *Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa Forest*, Report to Murray-Darling Basin Commission.

Knight J and Bruce A (2010) 'Threatened fish profile: 'eastern' Macquarie perch *Macquaria australasica* Cuvier 1830', *Australian Society for Fish Biology Newsletter*, 40,:73–76.

Koehn JD and Harrington DJ (2006) 'Environmental conditions and timing for the spawning of Murray cod (*Maccullochella peelii peelii*) and the endangered trout cod (*Maccullochella macquariensis*) in southeastern Australian rivers', *River Research and Applications*, 22(3):327–342, https://doi.org/10.1002/rra.897, accessed 14 May 2026.

Koster WM, Dawson DR, Morrongiello JR and Crook DA (2014) 'Spawning season movements of Macquarie perch (*Macquaria australasica*) in the Yarra River, Victoria', *Australian Journal of Zoology*, *61*(5):386–394, https://doi.org/http://dx.doi.org/10.1071/ZO13054, accessed 14 May 2025.

Lintermans M (2022) *Macquarie perch recruitment monitoring in the Upper Murrumbidgee River in March 2022*, Consultancy report to South East Local Land Services, Fish Fondler Pty Ltd.

Lintermans M (2002), *Fish in the Upper Murrumbidgee Catchment: A Review of Current Knowledge*, Environment ACT, Canberra, p 92.

Lintermans M (2012) ‘Managing potential impacts of reservoir enlargement on threatened *Macquaria australasica* and *Gadopsis bispinosus* in southeastern Australia’, *Endangered Species Research*, 16(1):1–16.

Lintermans M (2023a) *Fishes of the Murray-Darling Basin*, second edition, Australian River Restoration Centre, Canberra.

Lintermans M (2023b) *Macquarie perch recruitment monitoring in the upper Murrumbidgee and Mongarlowe rivers: March 2023 results, and five-year project review (2019-2023)*, consultancy report to South East Local Land Services, Fish Fondler Pty Ltd.

Lintermans M (2024a) *Recruitment monitoring of Macquarie perch in the upper Murrumbidgee River Recovery Reach in 2024*, consultancy report to Bush Heritage, Fish Fondler Pty Ltd.

Lintermans M (2024b) *Snowy 2.0 Macquarie perch monitoring 2024*, consultancy report to NSW DPI (Fisheries), Fish Fondler Pty Ltd.

Lintermans M (2025) *Snowy 2.0 Macquarie perch monitoring 2025*, consultancy report to NSW DPI (Fisheries), Fish Fondler Pty Ltd.

Lintermans M, Broadhurst B and Clear R (2013), *Assessment of the potential impacts on threatened fish from the construction, filling and operation of the Enlarged Cotter Dam Phase 1 (2010-2012): Final Report*, report to ACTEW Corporation, Institute for Applied Ecology, University of Canberra, Canberra.

Lintermans M and Campbell DR (2025) *Shuffle the Deck: Improving Macquarie perch genetic diversity in the Upper Murrumbidgee River through translocation. 2025 Annual Progress report*, consultancy report to South East Local Land Services, Fish Fondler Pty Ltd.

Lintermans M, Campbell D, Doyle P and Wilson E (2024) *Characterising spawning time for the endangered Macquarie perch in the upper Murrumbidgee River: a pilot study*, consultancy report to NSW Department of Climate Change, Energy, the Environment and Water, Fish Fondler Pty Ltd.

Lintermans M, Pearce L, Tonkin Z, Bruce A and Gilligan D (2019) *Macquaria australasica*, The IUCN Red List of Threatened Species 2019: e.T12581A123378234. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12581A123378234.en, accessed 14 May 2025.

Lutz ML, Sunnucks P, Chapple DG, Gilligan D, Lintermans M and Pavlova A (2022) ‘Strong bidirectional gene flow between fish lineages separated for over 100,000 years’, *Conservation Genetics,* 23 (6):1105–1113.

NSW Department of Climate Change, Energy, the Environment and Water (2024) *Annual environmental water priorities in the Snowy and Snowy montane rivers 2024–25*, DCCEEW website, https://www.environment.nsw.gov.au/topics/water/water-for-the-environment/snowy-and-montane/snowy-and-montane-rivers-environmental-water-priorities-2024-25, accessed 12 May 2025.

Pavlova A, Beheregaray LB, Coleman R, Gilligan DM, Harrisson KA, Ingram BA, Kearns J, Lamb AM, Lintermans M, Lyon J, Nguyen T, Sasaki M, Tonkin Z, Yen JDL and Sunnucks P (2017) 'Severe consequences of habitat fragmentation on genetic diversity of an endangered Australian freshwater fish: a call for assisted gene flow', *Evolutionary Applications*, 10(6):531–550.

Pendlebury P (1997) 'Hydrology report to the upper Murrumbidgee River expert panel', pp 28–45 in Anon (1997) 'Expert Panel Environmental Flow Assessment of the Upper Murrumbidgee River', report prepared for the NSW Environment Protection Authority.

Raadik TA (2014) 'Fifteen from one: a revision of the *Galaxias olidus* Günther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species', *Zootaxa*, 3898:1–198.

Serafini LG and Humphries P (2004) *Preliminary guide to the identification of larvae of fish, with a bibliography of their studies, from the Murray-Darling Basin: Presented at the taxonomy workshop, Lake Hume resort, 10 & 11 February 2004*, Cooperative Research Centre for Freshwater Ecology.

Snowy Scientific Committee (2010) *The adequacy of environmental flows to the upper Murrumbidgee River*, report SSC_4, prepared by the Snowy Scientific Committee for the Water Administration Ministerial Corporation of New South Wales, Canberra.

Tonkin Z, Kearns J, Lyon J, Balcombe SR, King AJ and Bond NR (2017) 'Regional-scale extremes in river discharge and localised spawning stock abundance influence recruitment dynamics of a threatened freshwater fish' *Ecohydrology*, 10(6), p 1842.

Tonkin Z, Kearns J, O'Mahony J and Mahoney J (2015) 'Spatio-temporal spawning patterns of two riverine populations of the threatened Macquarie perch (*Macquaria australasica*)', *Marine and Freshwater Research*, 67(11):1762–1770.

Tonkin Z, Lyon JP, Moloney P, Balcombe SR and Hackett, G (2018) 'Spawning-stock characteristics and migration of a lake-bound population of the endangered Macquarie perch *Macquaria australasica*', *Journal of Fish Biology*, *93*(4):630–640. https://doi.org/10.1111/jfb.13731, accessed 12 May 2025.

Tonkin Z, Lyon J and Pickworth A (2010) 'Spawning behaviour of the endangered Macquarie Perch *Macquaria australasica* in an upland Australian river', *Ecological Management & Restoration*, 11(3):223–226.

Tonkin Z, Lyon J and Pickworth A (2009) *An assessment of the spawning stocks, reproductive behaviour and habitat use of Macquarie perch Macquaria australasica in Lake Dartmouth*, Victoria, Technical Report Series No. 188.

van der Meulen D, Haantjens P, Gilligan D, Jess L and Stocks J (2023) *Macquarie Perch Wild Egg Collection: An assessment of viability of wild egg collection as a non-invasive method to enhance Macquarie perch populations in the upper Murrumbidgee River. Draft Report*, NSW Department of Primary Industries, Batemans Bay Fisheries Centre, Batemans Bay, NSW.

Wharton JCF (1968) ‘Spawning areas of the Macquarie perch *Macquaria australasica* above the Eildon Lake (Victoria)’, *Australian Society for Limnology Newsletter*, 6:11–13.

Wharton JCF (1973) ‘Spawning induction, artificial fertilization and pond culture of the Macquarie perch (Macquaria australasica [Cuvier, 1830])’, *Australian Society for Limnology Bulletin*, 5:43–65.

Woinarski JC, Chapple DG, Garnett ST, Legge SM, Lintermans M and Scheele, BC (2024), ‘Few havens for threatened Australian animal taxa that are highly susceptible to introduced and problematic native species’, *Biodiversity and Conservation*, 33(1):305–331.