# Macquarie Perch – review of existing information, Snowy 2.0

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## Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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**Front cover photo**: (clockwise from top) Murrumbidgee River at junction with Tantangara Creek; Macquarie Perch; alpine plain in snow; Stocky Galaxias (Images: Tarmo A. Raadik).



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# Macquarie Perch – review of existing information, Snowy 2.0

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**Caveat:** This report was completed in July 2021 and consequently does not contain more recent information which may have become available.

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# Figures

# 1 Introduction

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.

The Arthur Rylah Institute for Environmental Research has been engaged by Snowy Hydro to provide specialist advice that can inform the selection of options and preparation of various aquatic Management Plans required as part of the NSW and Commonwealth approvals for the Snowy 2.0 project. This report provides a review of existing information on Macquarie Perch (*Macquaria australasica*).

## 1.1 Relevance to priority conservation actions

Priority actions for Macquarie Perch identified by NSW DPI (2015) that are relevant to this document include:

- *Compile existing information on Macquarie Perch and identify knowledge gaps for the purpose of targeting future research activities (Medium priority).*

A summary of all priority actions for the species is detailed in Appendix A.

# 2 Methods

Here we review and summarise current information on the species description, biology and ecology, threats and recovery actions, and specifics of the study area. Key documents used for this exercise were the National Macquarie Perch Recovery Plan (Commonwealth of Australia 2018); aquatic assessment for the Main Works Environmental Impacts Study (Cardno 2019); Lintermans (2019a) and Cardno (2020). This document reviews existing and unpublished information and provides a summary description of:

- Current understanding of Macquarie Perch biology and ecology.
- Existing knowledge regarding distribution, in particular the mid-Murrumbidgee catchment (upstream of the Australian Capital Territory).
- Key threats to Macquarie Perch populations as a whole and specific to the study area.
- Measures to minimise the impact of the development on Macquarie Perch and their habitat in the mid-Murrumbidgee catchment.

# 3 Description and general ecology

## 3.1 General description

Macquarie Perch is a medium-sized (up to 55 cm length and 3.5 kg weight: NSW DPI 2016), long-lived (up to 30 years: Tonkin et al. 2018) percichthyid fish endemic to the south-eastern reaches of the Murray–Darling Basin and several rivers of the eastern seaboard. Morphological and genetic differences between Murray–Darling Basin and eastern seaboard Macquarie Perch have resulted in a revision of the taxonomic status of the species to recognise the Shoalhaven, Hawkesbury–Nepean, and Murray–Darling Basin as separate species (Faulks et al. 2010; Pavlova et al. 2017).

Macquarie Perch has a deep, laterally compressed body with adults having a pronounced lateral line down the side of their body (Figure 1). Body colour varies from bluish grey, dark brown or black-grey with some individuals being noticeably mottled, particularly juveniles. The eyes are large and silvery-white with prominent pores around the eyes and on the spout. The tail is rounded. The mouth is large, and the upper jaw slightly overhangs the lower jaw (Figure 1).

## 3.2 General ecology

The following ecological information relates only to the Murray–Darling species.

Macquarie Perch is primarily a riverine fish; however, populations have been maintained in some reservoirs where they have access to suitable inflowing riverine habitat for spawning (Cadwallader 1981; Appleford et al. 1998; Lintermans 2012; Broadhurst et al. 2013). Macquarie Perch prefer clear water and deep, rocky holes with extensive cover in the form of aquatic vegetation, large boulders, debris and overhanging banks, and is found in both river and lake habitats, especially in the upper reaches of rivers and their tributaries (NSW DPI 2016). Macquarie Perch is an active predator of macroinvertebrates and has a relatively large, linear, along-shore diel range, which suggests that it is unlikely to inhabit small and discontinuous pools of water (Ebner et al. 2011).

The species is iteroparous, with both sexes reaching full maturation at 3+ years of age, and reproductive maturity is age-dependent rather than size-dependent (Appleford et al. 1998), although some males have been reported to mature as young as ages 1+ and 117 mm length (Appleford et al. 1998; Douglas 2002; Lintermans 2012). Fecundity of Macquarie Perch is estimated at 32,000 eggs per kilogram of fish (Wharton 1973). The species spawn over stones and gravel in shallow, flowing parts of streams and rivers during spring and early summer (October–December) when water temperatures exceed 16 °C (Cadwallader and Rogan 1977; Appleford et al. 1998; Douglas 2002; Tonkin et al. 2010; Tonkin et al. 2018).

**Figure 1. Adult Macquarie Perch *Macquaria australasica* (image: Jarod Lyon)**

# 4 Distribution

Macquarie Perch was once widespread and abundant, supporting a popular recreational fishery, however, the species underwent major declines in abundance and distribution from 1920 to the 1960s (Trueman 2011; Figure 2). In the Murray–Darling Basin, Macquarie Perch have been reduced to a series of fragmented, small, and often isolated populations occurring in suboptimal habitats (Lintermans 2007; Riches et al. 2016; DELWP unpublished data). Some populations have established and remain within impoundments where they still have access to suitable riverine spawning habitat, or have been re-established, both within and outside their natural range, by stocking and translocations (Commonwealth of Australia 2018; Figure 2). These translocated populations of Macquarie Perch represent important sources for populations given they contain important genetic diversity no longer present in the remaining remnant populations (Pavlova et al., 2017). Macquarie Perch has approximately 12–18 known populations, primarily in the Murray–Darling Basin but also three translocated populations in coastal systems (Lintermans et al. 2019).

Macquarie Perch were historically widespread in the upper Murrumbidgee catchment, but suffered precipitous declines since the mid-1980s (Lintermans 2002). There are anecdotal reports of them as high up the system as Tantangara Reservoir, where they were relatively abundant after the dam filled in the late 1960s (Trueman 2011; Lintermans 2019a). They are now known to exist as a series of scattered self-sustaining sub-populations in the upper Murrumbidgee (approximately 30.5 km downstream of Tantangara Dam) extending downstream to around Murrells Crossing (approximately 15 km south of Cooma). A targeted survey of 20 sites across 26 sampling events in the upper Murrumbidgee catchment in 1998 and 1999 using multiple sampling methods recorded the species at seven sites (Lintermans 2016). The species core, reproducing distribution is concentrated along approximately 85 km of the Murrumbidgee mainstem between about Yaouk Bridge (approximately 27 km downstream of Tantangara Dam) and Murrells crossing (approximately 15 km downstream of Cooma) with occasional records from another 55 km downstream to Michelago (M. Lintermans, unpublished data).

Individuals are recorded for another 40–50 km downstream of Murrells Crossing but there is no evidence of recruitment (M. Lintermans unpublished data) The population near Yaouk Bridge demonstrates successful recruitment to young-of-year life-stage (YOY) every year (Lintermans 2016, M. Lintermans, unpublished data). Science-based fish sampling records upstream of Yaouk are extremely sparse, as are angling reports. The typically low flow released from Tantangara Reservoir in conjunction with the rocky gorge topography commonly found along this reach suggest that natural instream barriers may limit Macquarie Perch dispersal upstream (M. Lintermans, unpublished data). Similarly, there has been sparse scientific sampling for fish in the main stem of the Murrumbidgee upstream of or in Tantangara Reservoir. Although present in this location in the 1950s, it seems unlikely that Macquarie Perch are currently present as a viable population in or above Tantangara Reservoir (Trueman 2011; Lintermans 2019a).

The species has been functionally extinct in the Murrumbidgee River in the ACT since the mid-1980s (Lintermans 2002) and similarly downstream to Lake Burrinjuck (including the Goodradigbee River) (M. Lintermans, unpublished data). The species has also disappeared from the Goodradigbee River near Lake Burrinjuck where is has not been recorded since the early-mid 1990s (M. Lintermans unpublished data). There also does not seem to be any evidence that there is a self-sustaining population of Macquarie Perch in the Tumut River upstream of Blowering Reservoir (including within Talbingo Reservoir) despite the species historical presence at least until the early 1960s (Trueman 2011).

## 4.1 Stocking activities

Macquarie Perch were stocked in NSW from 1970 to the mid 1980s, when the captive breeding program at Narrandera Fisheries Centre ceased (NSW DPI 2020). In 2011 captive breeding recommenced, and several thousand fish were stocked into the Retreat River; however, the program soon ceased once again. In 2020 renewed attempts at captive breeding commenced (NSW DPI 2020), and 7,500 juvenile Macquarie Perch were bred and successfully released into the Winburndale Dam in early March 2021. Establishing additional Macquarie Perch populations within the species natural range is considered a high priority action in the National recovery plan for Macquarie Perch (Commonwealth of Australia 2018). A stocking and translocation program (> 100,000 fingerlings and sub-adults) in the Ovens River in Victoria, using fish from differing source populations, has resulted in a self-sustaining population, with genetic structure better than remnant populations (Lutz et al. 2021). The success of this project was supported by other rehabilitation actions, including restoring instream habitat (woody debris), planting streamside vegetation, installing fishways to improve fish passage, and removing exotic fish species (i.e. European carp, *Cyprinus carpio*).

Populations of Macquarie Perch have been successfully established in the Retreat River (NSW) where the population appears to be naturally recruiting (although this has yet to be confirmed). Macquarie Perch were stocked into the Talbingo Reservoir in 1995–96 (captively bred in Victoria), and there is an angler report from the upper Tumut in 1998–99, but the species is now presumed extinct in the system (Lintermans 2019a). The species was previously recorded from the upper Numeralla/Badja rivers about 70 years ago, and there are still occasional captures in the lower Numeralla (as recently as 2019, M. Lintermans, unpublished data). The remnant population in the Queanbeyan River ceased breeding in the late 1970s and a subsequent translocation in 1980 relocated adult fish from Googong Reservoir to the river upstream of a waterfall that had prevented access to spawning sites (Lintermans 2013a). This translocation, whilst successful for a number of years now seems to have failed (Lintermans 2013a).

Macquarie Perch have not been stocked previously in the Murrumbidgee River catchment upstream of the ACT, with the recent exception of a genetic rescue stocking of 40 fish in and around Cooma by NSW DPI in November 2020 as part of the ‘Reaching For Recovery’ project in partnership with the Southeast Local Land Services (See Section 8).

# 5 Conservation status

The ongoing declines of the species across its range has resulted in the species being listed as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; the Australian Society for Fish Biology Threatened Fishes List (Lintermans 2019b), the IUCN Red List (Lintermans et al. 2019); the Australian Capital Territory *Nature Conservation Act 2014*, and the New South Wales *Fisheries Management Act 1994*. The Macquarie Perch is also listed as 'threatened' in Victoria under the *Flora and Fauna Guarantee Act 1988* and 'presumed extinct' in South Australia under the *National Parks and Wildlife Act 1972*.

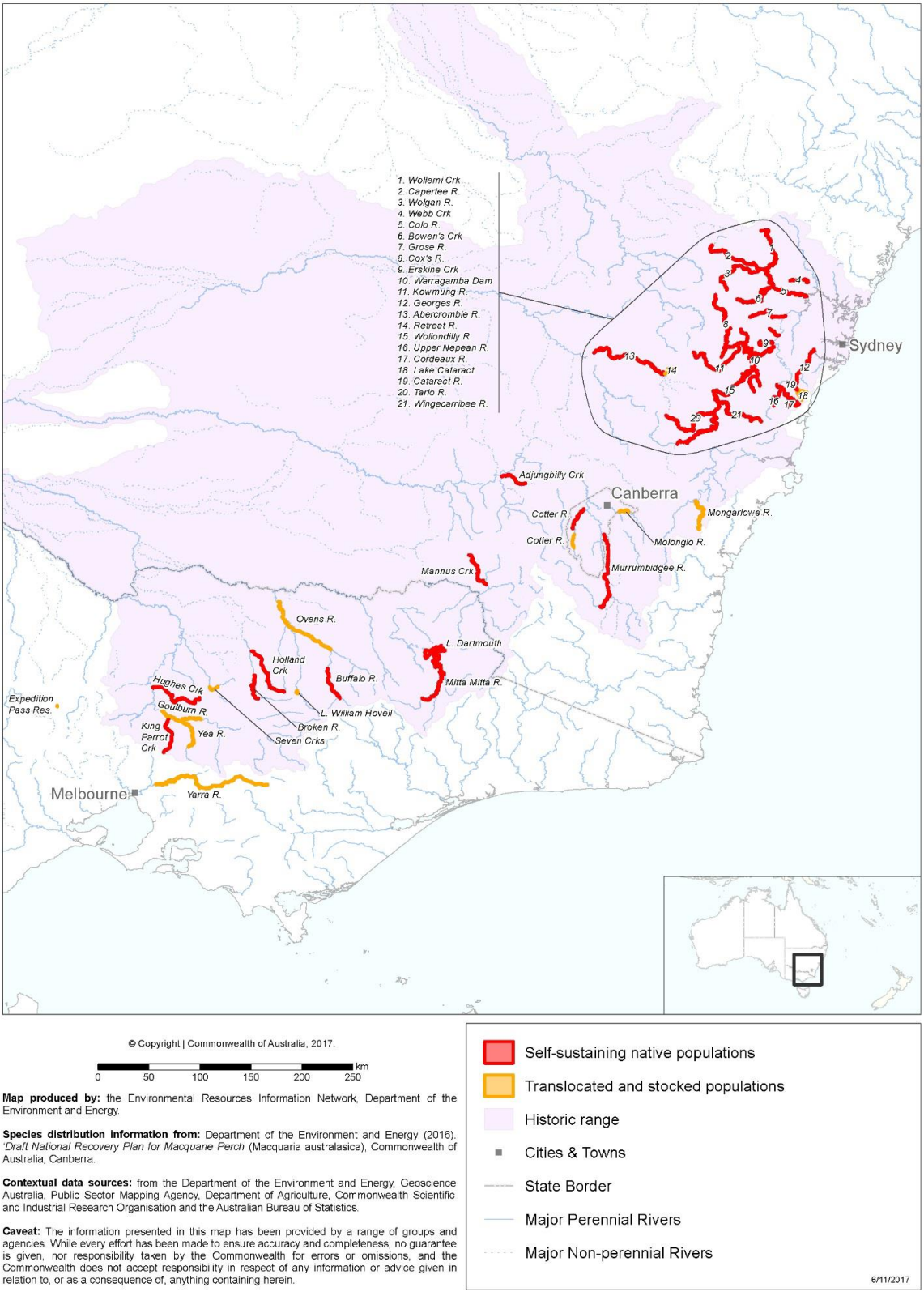


**Figure 2. Current and historical distribution of Macquarie Perch in south-eastern Australia (from the National Recovery Plan for Macquarie Perch, Commonwealth of Australia 2018).**

# 6 Threats

Numerous causes of the decline and future threats to Macquarie Perch populations have been proposed. The initial large-scale decline between 1920 and the 1960s has been attributed to the sedimentation of waterways (from historic mining practices followed by land use change and roading) across southeastern Australia (Cadwallader 1978). Other threats identified as likely drivers of the species decline include:

- De-snagging and riparian degradation.
- Interspecific competition.
- Overfishing.
- Predation and disease transmission by introduced species, particularly Redfin Perch (*Perca fluviatilis*) and the transmission of epizootic haematopoietic necrosis virus (EHNV; see Hick et al. 2019; ACT Government 2018; Commonwealth of Australia 2018).
- The construction of dams acting as barriers to movement and modifying river flows and temperatures downstream (Cadwallader and Rogan 1977; Ingram et al. 2000; Lintermans 2007, 2012; ACT Government 2018; Commonwealth of Australia 2018; Lintermans et al. 2019c; Tonkin 2019).

For small remnant riverine populations which are generally isolated and fragmented, there are additional challenges:

- Loss of and now poor genetic diversity (Pavlova et al. 2017).
- Ongoing threat of episodic events induced by climate change, such as extreme drought (Tonkin et al. 2019) and fire (ACT Government 2018; Legge et al. 2020).

# 7 Recovery actions

Recovery actions for Macquarie Perch are detailed in existing recovery plans (NSW DPI 2015; ACT Government 2018; Commonwealth of Australia 2018) and include actions that incorporate community and stakeholder liaison, compliance/enforcement, habitat protection, habitat rehabilitation, pest control/prevention of population invasion, research/monitoring, stocking/translocation, genetic rescue and survey/mapping (Appendix A). In general these actions are sporadic and rely on opportunistic funding programs (i.e. there is no ongoing funding for these interventions).

The specific critical actions which deal with on-ground activities to directly protect the species can be summarised as follows:

- Control of alien fish (Redfin Perch) – incursion surveillance and removal if found.
- Management of EHNV – biosecurity/sanitation measures to prevent introduction of the virus.
- Provision of environmental water releases below impoundments.
- Search for additional, remnant populations or potential translocation sites.
- Monitoring of population status and trend of existing populations.
- Establishment of new populations to spread extinction risk (wild to wild translocations, or hatchery to wild).
- Captive breeding – improvement of existing captive breeding techniques/approaches and producing captive-bred fish to supplement existing populations or establish new populations.
- Genetic management/rescue – management of population genetic diversity to maximise evolutionary potential.
- Managing sedimentation – preventing sediment input to, or soil disturbance within, the catchment, from roading, mechanical works or feral animals.
- Broader protection of catchment habitat.
- Research into priority knowledge gaps (e.g. spawning sites, spawning movements, genetic diversity, efficacy of environmental water releases).

# 8 Current management

Captive breeding of Macquarie Perch in NSW is currently undertaken at the Narrandera Fisheries Centre (NSW DPI) where new hormone technology is being developed to improve hatchery production of fingerlings to reduce the reliance on capturing ripe broodstock from the wild. The vast majority of Macquarie Perch currently produced in Australia come from Victoria, at the Snobs Creek Hatchery.

Surveys in the past year to obtain population estimates in the Abercrombie River estimates suggest the population is declining with Redfin Perch incursion and predation considered the primary threat. In February 2021, 40 Macquarie Perch from Cataract Dam were translocated into the upper Murrumbidgee River as a direct management action to prevent further loss of genetic diversity for this species (see Pavlova et al. 2017). Netting surveys undertaken in the Upper Murrumbidgee River during 2020 revealed Macquarie Perch had successful spawned with eggs being collected in drift nets. Limited sampling in 2019, 2020 and 2021 aimed at detecting recruitment locations in the upper Murrumbidgee River have documented regular production of young-of-year fish recruitment at several locations within the core range (Lintermans et al. 2010; Lintermans 2019c, 2021).

Extensive research has been undertaken on the population dynamics of Macquarie Perch in the Yarra River, Victoria over the past decade and is particularly important given this translocated population contains genetic diversity no longer present in remnant populations (Pavlova et al. 2017). Long-term monitoring revealed a decreasing trend in the abundance of adult fish (>300 mm in length) which has since been used to facilitate changes to the Victorian Recreational Fishing Guidelines during 2020 which now prohibit Macquarie Perch from being caught in the Yarra River. Similar long-term monitoring programs in Lake Dartmouth, Victoria which is considered the largest and most secure population in this state, have been used to demonstrate the importance of increasing restrictions on recreational catch (i.e., increasing minimum legal size) to protect the population (Hunt et al. 2011).

A review in 2013 identified that Macquarie Perch had the highest numbers of on ground recovery actions for any threatened freshwater fish in Australia (Lintermans 2013b). Over the last 3–5 years the following management interventions/projects have been undertaken for Macquarie Perch in NSW, Vic, and the ACT:

- Captive breeding undertaken intermittently at Narrandera Fisheries Centre (NSW) and Snobs Creek hatchery (Vic). New hormone technology is currently being developed to improve hatchery production of fingerlings to reduce the reliance on capturing ripe broodstock from the wild.
- Reintroductions for conservation and genetic rescue purposes undertaken into Winburndale Dam (Macquarie River catchment) in 2021; Ovens River (Vic) 2011–present); upper Cotter River (2006–2019); Retreat River, upper Murrumbidgee River (2021) others (Lintermans 2017; Todd and Lintermans 2015; Lutz et al. 2021).
- Construction of a population model to guide reintroductions in the ACT (Todd and Lintermans 2015).
- Studies of movement ecology, diet, spawning site characteristics, recruitment in Vic, ACT and NSW (Lintermans 2006; Ebner et al. 2010; Ryan 2010; Broadhurst et al. 2019, 2020; Tonkin 2019, Tonkin et al. 2018, 2019).
- Investigation of wild egg collection to supplement hatchery breeding (NSW).
- Investigations of presence of EHN virus (ACT, NSW) (Whittington 2008; Hick et al. 2019).
- Installation of fishways to improve fish passage (ACT, NSW, Vic) and identification of barriers to spawning migrations (ACT: Broadhurst et al. 2013, 2016).
- Riparian habitat enhancement (NSW, Vic).
- Construction of artificial habitats in Cotter reservoir (Lintermans et al. 2010).
- Completion of national recovery plan and IUCN Red List assessment of species conservation status (Commonwealth of Australia 2018; Lintermans et al. 2019).
- Investigation into recruitment locations in the upper Murrumbidgee River (Lintermans 2019c; Lintermans 2020, 2021).
- Some long-term population monitoring has occurred in impoundment populations (Lake Dartmouth, Vic; Cotter Reservoir ACT (Lintermans et al. 2013; Broadhurst et al. 2020).

- Extensive research on the population dynamics of Macquarie Perch in the Yarra River (Vic). Outcomes from this has been used to facilitate changes to the Victorian Recreational Fishing Guidelines post 2020 where this species is prohibited from being caught in the Yarra River.

Currently there is no long-term ecological monitoring being undertaken targeted particularly at Macquarie Perch on the Murrumbidgee River. There is a single project by Local Land Services gathering recruitment data at 2 sentinel sites on the upper Murrumbidgee River, with some additional sampling to identify other sites where recruitment is occurring (Lintermans 2019c, 2020, 2021). This project ceases in 2023 and there is no funding for long-term or ongoing monitoring (from federal or State sources) allocated post 2023. NSW DPI undertake sporadic sampling in the upper catchment using electrofishing to collect information on fish population structure.

# 9 Key knowledge gaps

Five key knowledge gaps for the species, and the Mid-Murrumbidgee population specifically have been identified.

## 9.1 Distribution and trend of recruiting sub-populations

Whilst Macquarie Perch distribution is largely understood in the mainstem of the mid-Murrumbidgee catchment (downstream of Yaouk), the location and trend of recruiting (i.e., source, not sink) sub-populations is not well known. Some limited investigation of the location of such sub-populations in the Murrumbidgee mainstem is currently underway the resources and spatial/temporal scope of such investigations is not adequate for robust inference (M. Lintermans unpublished). There has been no survey of major Murrumbidgee tributaries apart from the 1998–99 surveys of Lintermans (2016) and identification of remanent tributary populations is important should Redfin Perch invade the Murrumbidgee mainstem. Areas with the potential to contain unidentified populations or that may be suitable for future translocations include upper reaches of the Queanbeyan, Bredbo, Badja, and Kybean rivers and the Murrumbidgee in and upstream of Tantangara Dam.

## 9.2 Captive breeding

Artificial production of fish is a major conservation tool to enable population recovery and expansion, particularly if natural source populations are too small to be harvested without causing an impact. Whilst hatchery programs for Macquarie Perch exist, the production of hatchery-bred fingerlings still relies on the collection of spawning fish from the wild, which is unsustainable in the medium to long term (see Todd and Lintermans 2015).

## 9.3 Population dynamics

Previous monitoring of Macquarie Perch population demography in the mid-Murrumbidgee catchment has demonstrated consistent annual recruitment of young-of-year fish but very little survival to the following year class (age 1+) (M. Lintermans, unpublished data). Such gaps in age 1+ fish are not evident in other nearby populations (e.g. Cotter Reservoir, ACT and Queanbeyan River (Broadhurst et al 2020; Lintermans 2013a). The reasons for such gaps in the population age structure are unknown, and this failure to recruit from YOY to age 1+ severely hampers population recovery.

## 9.4 Genetic diversity and genetic rescue

Some information on Macquarie Perch genetic diversity in the mid-Murrumbidgee is documented (Farrington et al. 2014; Pavlova et al. 2017), but such information was collected from a limited number of sites and a limited number of samples. The efficacy of the recent genetic rescue fish stocking exercise around Cooma in November 2020 is unknown and at present, no follow up monitoring is planned.

## 9.5 Translocation and reintroduction opportunities

There has been no survey of potential reintroduction sites for Macquarie Perch in the mid and upper Murrumbidgee catchment. Broader survey work of tributaries in the would assist in identifying opportunities and constraints for future reintroductions should Redfin Perch colonise the Murrumbidgee mainstem at some point in the future.

# 10 References


ACT Government (2018). *ACT Aquatic and Riparian Conservation Strategy and Action Plans*. Australian Capital Territory Government, Canberra.

Appleford P., Anderson T.A. and Gooley G.J. (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, B.T., Ebner, B.C., Lintermans, M., Thiem, J.D. and Clear, R.C. (2013). Jailbreak: A fishway releases the endangered Macquarie perch from confinement below an anthropogenic barrier. *Marine and Freshwater Research* **64**, 900–908.

Broadhurst, B.T., Clear, R.C. and Lintermans, M. (2016). *Potential barriers to upstream migration of Macquarie Perch to spawning areas in the Cotter River, ACT*. Institute for Applied Ecology, University of Canberra, Canberra.

Broadhurst, B.T., Lintermans, M., Clear, R.C. 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, B.T., Clear, R.C., Fulton, C., Allan, H. and Lintermans, M. (2020). *Enlarged Cotter Reservoir ecological monitoring program*. Technical Report 2020. Centre for Applied Water Science, Institute for Applied Ecology, University of Canberra, Canberra.

Cadwallader, P.L. (1978). Some causes of decline in range and abundance of native fishes in the Murray–Darling River system. *The Proceedings of the Royal Society of Victoria* **90**, 211–224.

Cadwallader, P.L. (1981). Past and present distributions and translocations of Macquarie perch *Macquaria australasica* (Pisces: Percichthyidae), with particular reference to Victoria. *Proceedings of the Royal Society of Victoria* **93**, 23–30.

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

Cardno (2019). *Appendix M.2 Aquatic Ecology Assessment, Snowy 2.0 Main Works.* Prepared for EMM Consulting Pty Ltd. Cardno, St Leonards, NSW.

Cardno (2020). 'Snowy 2.0 – request for information'. Letter with accompanying information from Cardno to EMM Consulting, 12 March 2020, addressing the request for further information from the Department of Planning, Industry and Environment on the Snowy 2.0 Main Works EIS, which relates to the Aquatic Ecology assessment prepared by Cardno and included as Appendix M.2 of the Snowy 2.0 Main Works EIS.

Commonwealth of Australia (2018). National Recovery Plan for Macquarie Perch (*Macquaria australasica*). Available at: https://www.environment.gov.au/system/files/resources/bdee49ef-45da-4eb7-b548-bcfce460a21b/files/recovery-plan-macquarie-perch-2018.pdf

Douglas, J.D. (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. Marine and Freshwater Resources Institute, Department of Natural Resources and Environment, Victoria.

Ebner, B.C., Lintermans, M., Dunford, M. (2011). A reservoir serves as refuge for adults of the endangered Macquarie perch. *Lakes & Reservoirs: Reseach and Management* **16**, 23–33.

Farrington, L.W., Lintermans, M. and Ebner, B.C. (2014). Characterising genetic diversity and effective population size in one reservoir and two riverine populations of the threatened Macquarie perch. *Conservation Genetics* **15**, 707–716.

Faulks, L.K., Gilligan, D.M. and and Beheregaray, L.B. (2010). Evolution and maintenance of divergent lineages in an endangered freshwater fish, *Macquaria australasica*. *Conservation Genetics* **11**, 921–934.

Hick, P., Whittington, R. and Becker, J. (2019). *Assessment of the potential for increased distribution of Epizootic haematopoietic necrosis virus (EHNV) associated with Snowy 2.0.* Consultation to EMM Consulting Pty Ltd for Snowy Hydro Limited. Faculty of Science, the University of Sydney.

Hunt, T., Douglas, J.W., Allen, M.S., Gwinn, D.C., Tonkin, Z., Lyon, J. and Pickworth, A. (2011). Evaluation of population decline and fishing sustainability of the endangered Australian freshwater fish *Macquaria australasica*. *Fisheries Management and Ecology* **18**, 513–520.

Ingram, B.A., Douglas, J.W. and Lintermans, M. (2000). Threatened fishes of the world: *Macquaria australasica* Cuvier, 1830 (Percichthyidae). *Environmental Biology of Fishes* **59**(68), 68.

Legge, S., Woinarski, J., Garnett, S., Nimmo, D., Scheele, B., Lintermans, M., Mitchell, N., Whiterod, N. and Ferris, J. (2020). *Rapid analysis of impacts of the 2019–20 fires on animal species, and prioritisation of species for management response*. Report prepared for the Wildlife and Threatened Species Bushfire Recovery Expert Panel 14 March 2020. Available at https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-animals.

Lintermans, M. (2002). *Fish in the Upper Murrumbidgee Catchment: a review of current knowledge*. Environment ACT, Canberra.

Lintermans, M. (2006). *The re-establishment of endangered Macquarie perch* Macquaria australasica *in the Queanbeyan River, New South Wales, with an examination of dietary overlap with alien trout*. Technical report. CRC for Freshwater Ecology, Canberra.

Lintemans, M. (2007). *Fishes of the Murray–Darling Basin: An Introductory Guide*. Murray–Darling Basin Commission, Canberra.

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

Lintermans, M. (2013a). The rise and fall of a translocated population of the endangered Macquarie perch *Macquaria australasica* in southeastern Australia. *Marine and Freshwater Research* **64**, 838–850.

Lintermans, M. (2013b). A review of on-ground recovery actions for threatened freshwater fish in Australia. *Marine and Freshwater Research* **64**, 775–791.

Lintermans, M. (2016). Finding the needle in the haystack: comparing sampling methods for detecting an endangered freshwater fish. *Marine and Freshwater Research* **67**(11), 1740–1749.

Lintermans, M. (2017). *Research into the establishment of new populations of Macquarie perch, through translocation: Final Report to Icon Water.* Institute for Applied Ecology, University of Canberra, Canberra.

Lintermans, M. (2019a). *A review of fish information from the Upper Murrumbidgee and Upper Tumut catchments*. Consultant's report to EMM Consulting Pty Ltd.

Lintermans, M. (2019b). Conservation Status of Australian Fishes – 2019. *Lateral Lines* [Australian Society for Fish Biology Newsletter] **49**(2), 172–174.

Lintermans, M. (2019c). *Macquarie perch recruitment monitoring in the Mongarlowe and upper Murrumbidgee rivers: March–April 2019*. Report to Southeast Local Land Services. Institute for Applied Ecology, University of Canberra.

Lintermans, M. (2020). *Macquarie perch recruitment monitoring in the Mongarlowe and upper Murrumbidgee rivers in April 2020*. Consultancy Report to South East Local Land Services.

Lintermans, M. (2021). *Macquarie perch recruitment monitoring in the Mongarlowe and upper Murrumbidgee rivers: March-April 2021.* Report to Southeast Local Land Services. Fish Fondler Pty Ltd., Canberra.

Lintermans, M., Broadhurst, B., Thiem, J. D., Ebner, B. C., Wright, D., Clear, R. and Norris, R. H. (2010). *Constructed homes for threatened fishes in the Cotter River catchment: Phase 2 final report.* Report to ACTEW Corporation. Institute for Applied Ecology, University of Canberra, Canberra.

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., 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

Lutz, M.L., Tonkin, Z., Yen, J.D.L., Johnson, G., Ingram, B.A., Sharley, J., Lyon, J., Chapple, D.G., Sunnucks, P. and Pavlova, A. (2021). Using multiple sources during reintroduction of a locally extinct

population benefits survival and reproduction of an endangered freshwater fish. *Evolutionary Applications* **14**(4), 950–964.

NSW DPI (2015). *Priorities Action Statement – Actions for Macquarie Perch*. Available at: https://www.dpi.nsw.gov.au/fishing/species-protection/what-current/endangered-species2/macquarie-perch/priorities-action-statement-actions-for-macquarie-perch (accessed July 2021)

NSW DPI (2016). Macquarie Perch – *Macquaria australasica*). Primefact, NSW Department of Primary Industries, 3rd edn.Available from: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/635257/primefact-9-macquarie-perch-macquaria-australasica-2.pdf (accessed July 2021)

NSW DPI (2020). Fish stocking. Available at: https://www.dpi.nsw.gov.au/fishing/recreational/resources/stocking (accessed February 2020)

Pavlova, A., Beheregaray, L.B., Coleman, R., Gilligan, D., Harrisson, K.A., Ingram, B.A., Kearns, J., Lamb, A.M., Lintermans, M., Lyon, J., Nguyen, T.T.T., Sasaki, M., Tonkin, Z., Yen, J.D.L., 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.

Riches, M., Gilligan, D., Danaher, K. and Pursey, J. (2016). *Fish communities and threatened species distributions of NSW*. NSW Department of Primary Industries (DPI).

Ryan, K.A. (2010). Macquarie perch under pressure: spatial ecology and predation risk upon an endangered fish species in an upland reservoir. Unpublished PhD thesis. Institute for Applied Ecology, University of Canberra.

Todd, C.R. and Lintermans M. (2015). Who do you move: a stochastic population model to guide translocation strategies for an endangered freshwater fish in southeastern Australia. *Ecological Modelling* **311**, 63–72.

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

Tonkin, Z., Lyon, J.P., Moloney, P., Balcombe, S.R. 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.

Tonkin, Z. (2019). From processes to populations: understanding the drivers and dynamics of Macquarie perch *Macquaria australasica* populations. Unpublished PhD thesis, Griffith University, Nathan, Queensland, 4111, Australia.

Tonkin, Z., Sharley, J., Fanson, B., Raymond, S., Ayres, R., Lyon, J., Balcombe, S. and Bond, N. (2019). Climate variability regulates population dynamics of a threatened freshwater fish. *Endangered Species Research* **40**, 257–270.

Trueman, W.T. (2011). *True Tales of the Trout Cod: River histories of the Murray–Darling Basin.* Murray–Darling Basin Authority Publication number 215/11. Murray–Darling Basin Authority, Canberra, ACT, Australia.

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

Whittington, R.J. (2008). *EHNV in Cotter Dam*. Report to ACTEW Corporation. Faculty of Veterinary Science, University of Sydney.

## Appendix A. Management and research actions recommended for Macquarie Perch in NSW in the Priorities Action Statement, and nationally in the National Recovery Plan.

Actions are numbered in the order they appear in the documents, and similar actions from each document are mapped to each other.

| Priorities Action Statement (NSW DPI 2015) | National Recovery Plan for the Macquarie Perch (Commonwealth of Australia, 2018) |
|---|---|
| **Advice to consent and determining authorities**<br>1. Provide information on the distribution of the Macquarie Perch to local councils and determining authorities to ensure appropriate consideration during development assessment processes (High priority). | |
| **Collate and review existing information**<br>2. Compile existing information on Macquarie Perch and identify knowledge gaps for the purpose of targeting future research activities (Medium priority).<br>3. Collate data on the historical distribution of Macquarie Perch including anecdotal and indigenous knowledge (Low priority). | |
| **Community and stakeholder liaison, awareness and education**<br>4. Install signs and/or interpretive displays at appropriate locations to assist with identification and awareness of Macquarie Perch (Medium priority).<br>5. Encourage community reporting of Macquarie Perch via the NSW DPI Threatened and Pest Species Sightings Program online form (Low priority).<br>6. Implement education initiatives to improve awareness of the status of the Macquarie Perch and ways to minimise impacts on the species by preparing and distributing appropriate advisory material (Low priority).<br>7. Foster long-term, two-way knowledge transfer and capacity building to enhance the role of indigenous ecological knowledge in the recovery of Macquarie Perch (Low medium). | **Strategy 6 – Increase participation by community groups in Macquarie perch conservation**<br>6a. Raise awareness for the conservation status of Macquarie perch in the community (Priority 1).<br>6b. Engage with private landholders and land managers responsible for the land adjacent to waterways which populations occur and encourage these key stakeholders to support the conservation of the Macquarie perch (Priority 2). |
| **Compliance / enforcement**<br>8. Maximise compliance activities at identified important sites (Medium priority). | 1b. Ensure that the impacts of recreational fishing are minimised (Priority 1). |
| **Enhance, modify or implement NRM planning processes to minimize adverse impacts on threatened species**<br>9. Negotiate with relevant authorities to encourage the identification, assessment, and modification of natural resource management plans and policies to minimise impacts on Macquarie Perch habitats and water quality (High priority). | |

| Priorities Action Statement (NSW DPI 2015) | National Recovery Plan for the Macquarie Perch (Commonwealth of Australia, 2018) |
|---|---|
| 10. Implement relevant State policies and programs (e.g. the NSW Diffuse Source Water Pollution Strategy) in an effort to reduce water pollution (particularly chemical pollution from agricultural pesticides) impacts on Macquarie Perch habitats in NSW (High priority). | |
| **Habitat rehabilitation**<br>11. Undertake work to identify, restore and protect known and potential Macquarie Perch habitats and address key threats such as habitat degradation and water quality decline from expanding development (High priority).<br>12. Allocate and manage environmental water flows in regulated rivers to restore natural seasonal flow patterns, and to reduce the impact of cold water downstream of dams (High priority).<br>13. Actively seek funds through grant schemes or other sources to implement riparian vegetation and water quality improvement projects in priority areas (High priority).<br>14. Undertake priority rehabilitation, restoration and enhancement work (e.g. rehabilitating riparian vegetation, cold water pollution reduction measures, reinstating large woody debris, removal of barriers to fish passage, removal of willows from riverbanks, sediment and erosion control measures) at key sites known to support Macquarie Perch populations (High priority). | **Strategy 1 – Conserve existing Macquarie perch populations**<br>**Strategy 2 – Protect and restore Macquarie perch habitat**<br>2a. Undertake priority habitat rehabilitation, restoration and enhancement work (Priority 1).<br>3e. Research best practice for habitat restoration (Priority 2).<br>2b. Seek to provide appropriate flow regimes in all waters where Macquarie perch occur below water storages or offtakes (Priority 2).<br>2c. Undertake works to minimise cold water pollution (Priority 2).<br>2d. Improve in-stream habitat to improve productivity of lower food web (Priority 2). |
| **Pest eradication and control**<br>15. Investigate and implement integrated management of introduced species in and adjacent to identified Macquarie Perch habitats and take action to prevent the spread of introduced species into these habitats (High priority). | 1a. Protect Macquarie perch from competition with and predation by introduced fish species (Priority 1).<br>1c. Protect Macquarie perch populations from outbreaks of disease and parasites (Priority 2). |
| **Research / monitoring**<br>16. Conduct research on the biology and ecology of Macquarie Perch, particularly the species' ecological role, environmental tolerances, factors influencing population dynamics, age and growth, life cycle and diet (High priority).<br>17. Monitor Macquarie Perch populations over time to assess trends in abundance and distribution and to identify emerging threatening processes (High priority).<br>18. Undertake research to identify, prioritise and improve understanding of the threatening processes and causes of decline of Macquarie Perch (High priority).<br>19. Actively seek grants or investor partnerships to fund research and monitoring programs for Macquarie Perch (High priority). | **Strategy 3 – Understand and address threats to Macquarie perch populations and habitats**<br>**Strategy 5 – Improve understanding of the biology and ecology of the Macquarie perch, and its distribution and abundance**<br>3a. Investigate methods to promote spawning and recruitment activity of Macquarie perch in naturally occurring and stocked populations (Priority 1).<br>3b. Better understand competition and predation on Macquarie perch by introduced fish species (Priority 1).<br>3c. Increase the confidence that the viruses and pathogens impacting Macquarie perch are all identified and known (Priority 2). |

| Priorities Action Statement (NSW DPI 2015) | National Recovery Plan for the Macquarie Perch (Commonwealth of Australia, 2018) |
|---|---|
| 20. Actively encourage community involvement in aspects of Macquarie Perch research and monitoring programs (Low priority). | 3d. Increase understanding of the degree of impact parasites are having on Macquarie perch populations (Priority 2).<br>5a. Implement a long-term monitoring program for the Macquarie perch which is able to record the size and importance of natural, self-sustaining populations and stocked populations (Priority 1).<br>5b. Increase understanding of spawning and recruitment ecology of the Macquarie perch and its relationship to habitat (Priority 2).<br>5c. Increase understanding of how the Macquarie perch's life cycle is related to flow and temperature (Priority 2). |
| **Stocking / translocation**<br>21. Implement the NSW Freshwater Fish Stocking Fishery Management Strategy to prevent significant impacts from stocking on Macquarie Perch populations (High priority).<br>22. Conduct research to evaluate the effectiveness of translocation of adult fish compared to stocking of juveniles to inform future conservation actions (High priority).<br>23. Conduct targeted sampling at stocked sites to assess the status of stocked populations including growth and recruitment rates (High priority).<br>24. Develop an emergency response policy to guide the collection and captive husbandry of Macquarie Perch. The policy should address the circumstances in which wild individuals may be collected, held and re-released, and identify holding facilities, potential funding sources and legal requirements (Low priority).<br>25. Identify potential candidate sites for possible future translocation of Macquarie Perch (Low priority).<br>26. Undertake emergency rescues of Macquarie Perch in response to droughts, oil spills/ pollution, detection of biosecurity threats (e.g. disease or pests), or to avoid imminent impacts in accordance with the emergency response policy (Low priority).<br>27. Review and assess the potential of artificial refuge areas for the protection of Macquarie Perch (Low priority). | **Strategy 4 – Establish additional Macquarie perch populations within the species' natural range.**<br>1d. Restore Macquarie perch population connectivity by conducting regular assisted gene flow (i.e. translocations) in order to decrease inbreeding, prevent further loss of genetic diversity by drift and improve adaptive potential (consistent with EPBC Act requirements) (Priority 1).<br>1e. Develop an emergency management response plan for rescue translocations (consistent with EPBC Act requirements) (Priority 2).<br>4a. Refine and improve captive breeding techniques for Macquarie perch (Priority 1).<br>4b. Undertake a conservation stocking program for Macquarie perch (Priority 1).<br>5d. Investigate the fate of released fingerlings (Priority 1). |
| **Survey / mapping**<br>28. Conduct targeted surveys to determine the current distribution and abundance of Macquarie Perch (Medium priority).<br>29. Collect data on the presence/absence of Macquarie Perch during incidental surveys (Medium priority). | |

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