Macquarie Perch – translocation strategy, Snowy 2.0

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December 2022

Arthur Rylah Institute for Environmental Research
Published Client Report

Arthur Rylah Institute for environmental research

VICTORIA State Government | Environment, Land, Water and Planning

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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Citation: Tonkin, Z., Lintermans, M., Gilligan, D. and Lyon, J. (2022). Macquarie Perch - translocation strategy, Snowy 2.0. Published client report for Snowy Hydro Ltd, Cooma. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

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).

Edited by David Meagher, Zymurgy SPS.

ISBN 978-1-76136-201-9 **(pdf/online/MS word)**

Accessibility

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Macquarie Perch – translocation strategy, Snowy 2.0

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

Arthur Rylah Institute for Environmental Research
Published Client Report for Snowy Hydro Ltd, Cooma, Department of Environment, Land, Water and Planning

Acknowledgements

We thank Lizzie Pope (Snowy Hydro), Lachlan Barnes (SLR),and Tarmo Raadik (DELWP-ARI) for providing comments on earlier drafts of this report. Lindy Lumsden (ARI) provided invaluable additional comments on the final draft of this document.

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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 (ARI) 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 details a translocation strategy for Macquarie Perch (*Macquaria australasica*). It outlines objectives and potential translocation activities aimed at improving the security and resilience of the species within the mid-Murrumbidgee River catchment. Given the long-term nature of such an endeavour, its value and relevance will extend beyond the Snowy 2.0 Management Plans.

Here we develop a translocation strategy for Macquarie Perch in the Murrumbidgee River catchment, which is based on relevant literature, including results and knowledge gained from past Macquarie Perch translocations and stocking activities undertaken in the southern Murray–Darling Basin (Lintermans 2013a,b, 2017; Lintermans et al. 2015; Ho and Ingram 2013; Lutz et al. 2020). While many of the early actions were aimed at recreational fishing outcomes, more recently, fish releases are better aligned with the species recovery plans (ACT Government 2007, 2018; Commonwealth of Australia, 2018), with recent planning and translocations and stocking currently underway in Victoria (e.g. Lutz et al. 2020; Tonkin et al. 2021) and NSW (Pearce 2013; NSW DPI 2021b) as part of the conservation management of species. This strategy has also taken into consideration relevant components of the following:

- National Policy Guidelines for the Translocation of Aquatic Animals (DAWE 2020).
- NSW Freshwater Fish Stocking Fishery Management Strategy (DPI 2005).
- NSW Translocation Operational Policy (DPIE 2019).
- Conservation Translocation Handbook for New South Wales Threatened Freshwater Fish (Zukowski et al. 2021).

Translocation is defined as the deliberate movement of living organisms from one area to another (IUCN 1987, Armstrong and Seddon 2008). Conservation translocations are those undertaken by humans with the intention of a measurable conservation benefit at the individual, population, species, and ecosystem level (IUCN/SSC 2013). The term stocking while often used in conjunction with translocation terminology, usually refers to the placement and release of captive-bred individuals from specialised fish hatcheries. While stocking is often related to recreational fishing objectives (i.e. the enhancement of a fishery), it is also a proven intervention technique for threatened fish species, including Macquarie Perch (e.g. Lintermans et al. 2015; Lutz et al. 2020). As such, from herein, we refer to both stocking (if aimed at conservation outcomes) and translocations as ‘conservation translocations’ as per the terminology of IUCN/SSC (2013).

Two types of conservation translocations are recognised, based on release of individuals either inside or outside of an organism’s indigenous range, with two activities recognised in each (IUCN/SSC 2013):

- Population restoration – within an organism’s indigenous range.
  - Reintroduction – the intentional movement and release of organisms into part of its native range from which it has disappeared.
  - Reinforcement (restocking) – the intentional movement and release of organisms into an existing population of conspecifics.
- Conservation introduction – outside of an organism’s indigenous range.
  - Assisted colonisation – the intentional movement and release of organisms outside its indigenous range to avoid extinction of populations of the focal species.
  - Ecological replacement – the intentional movement and release of organisms outside its indigenous range to perform a specific ecological function.

In each case, and depending on the situation, the source of organisms can be captive-bred or wild-caught stock.

For Macquarie Perch, the first three activities (reintroduction, reinforcement, and assisted colonisation) are relevant although reintroduction and reinforcement are those relevant to potential translocation activities in the mid-Murrumbidgee catchment. The fourth translocation activity is not relevant, as its aim is to fill a vacant ecological niche, e.g. a closely related, ecologically similar species of *Macquaria* spp. is introduced to outside of its indigenous range into a catchment in place of a former species which has become extinct.

This translocation plan will need to be adaptive, as it will depend heavily on outcomes from other activities within the catchment, including species monitoring, catchment survey, captive breeding, habitat works, pest fish monitoring, and on improvements in knowledge of Macquarie Perch biology, ecology and distribution from this work (Lintermans et al. 2022a,b,c).

1.1 Relevance to priority conservation actions

Priority actions for Macquarie Perch identified by NSW DPI (2021a) and the national recovery plan (Commonwealth of Australia 2018) that are relevant to this strategy include:

- 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 (NSW DPI 2021a).
- Identify potential candidate sites for possible future translocation of Macquarie Perch (NSW DPI 2021a).
- 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 (NSW DPI 2021a).
- Restore Macquarie Perch population connectivity by conducting regular assisted gene flow (i.e. translocations) to decrease inbreeding, prevent further loss of genetic diversity by drift and improve adaptive potential (consistent with EPBC Act requirements; Commonwealth of Australia 2018).
- Develop an emergency management response plan for rescue translocations (consistent with EPBC Act requirements; (Commonwealth of Australia 2018).
- Undertake a conservation stocking program for Macquarie Perch (Commonwealth of Australia 2018).

2 Translocation strategy

2.1 Objectives and rationale

The overall objective of the translocation strategy and other activities in the catchment is to:

- Improve the conservation status of Macquarie Perch in the upper Murrumbidgee catchment by enhancing condition and resilience of the current population/s.

Specific aims associated with translocation activities include identifying and implementing opportunities to:

- extend the range and abundance of the current population or establish new populations; and
- Improve the genetic fitness and ensure the persistence of the existing population/s in the catchment.

Actions to address this are:

- Establish a catchment specific translocation procedure to enable the harvesting, transport and release/return of Macquarie Perch for translocation, stock for a captive breeding program, and for emergency extraction if needed (post-fire, predator / disease incursion, etc.).
- Establish an ex-situ population maintained in captivity in the short term, as insurance against the loss of the population (and therefore unique genetic diversity for the species more broadly) in the wild.
- Undertake captive breeding and/or wild to wild translocation of Macquarie Perch to establish an insurance population in a new area of the catchment if a suitable area is identified, and to provide offspring to bolster the upper Murrumbidgee population if needed. The insurance population can also be used to restock the Murrumbidgee mainstem population if it is impacted and lost.

Monitoring data indicates that the core population of Macquarie Perch currently occupy an approximately 95 km reach of the Murrumbidgee River from near Yaouk (about 27 km downstream of Tantangara Dam) extending downstream to around the junction with the Numeralla River (approximately 25 km south of Cooma) (Lintermans 2021a). Individuals are recorded for another 40–50 km downstream of Murrells Crossing but there is no evidence of recruitment (Lintermans unpublished data).

The species has contracted substantially from its historical distribution (Trueman 2011), with the species undergoing a significant decline in the ACT concurrent with the establishment of Redfin Perch (*Perca fluviatilis*) in this part of the system (Lintermans et al. 1990; Lintermans 2002). The declining status of Macquarie Perch is also reflected in recent genetic assessment (Pavlova et al. 2017). Indeed, Pavlova et al. (2017) showed that in the absence of any intervention, the mid-Murrumbidgee population currently has a high probability of extinction.

The potential value of translocation to decrease the risk of extinction of this population was highlighted by Pavlova et al. (2017) who showed that a translocation scenario based on a starting population of 100 individuals involving the addition of 6 unrelated individuals every year for 50 years as part of a genetic rescue initiative would decrease the population probability of extinction for the mid-Murrumbidgee population 26-fold, and decrease inbreeding depression 1.5-fold compared to do-nothing scenarios. As a result of this research, a single translocation of 10 individuals, sourced from Cataract Dam, occurred in November 2019. Building on the recommendations of Pavlova et al (2017) and recent results from Lutz et al. (2020) suggest that translocations involving fish from populations with higher genetic diversity, or admixed populations (mixed from multiple sources), are more effective, measured as survival and recruitment outputs, than those from a single impoundment source.

Regardless of the identification of additional populations or possible translocation sites, translocation of a sufficient number of individuals to a hatchery for ex-situ management and captive breeding is considered a vital, complementary activity, as an insurance policy against the extinction of the species in the catchment, and if mixed with other genetic units via captive breeding, could generate additional, genetically healthy, stock for translocations back into the catchment.

Details of activities related to captive breeding of Macquarie Perch, to support translocations, will be addressed in a separate document.

2.2 Strategy details

Actions and decisions regarding potential future translocations of Macquarie Perch in the Murrumbidgee catchment are broadly outlined in Figure 1, including linkages with monitoring (populations suitable to support wild-to-wild translocations), catchment survey (identification of suitable translocation sites) and captive breeding activities (individuals for captive-to-wild translocation) (Lintermans et al. 2022b,c; Lyon et al. 2022). Once options for translocation are known, and risks/benefits of translocation have been considered (see IUCN/SSC 2013 and section 2.3 below), specific translocations activities should follow a detailed translocation plan which addresses aims, methods, timeframe, measures, and timeframe for assessing success. Key in this is knowledge of the source population(s) and translocation site(s) and type of translocation to be undertaken (i.e. hatchery-based or wild-to-wild). This should also consider an assessment of risks (e.g. unintended consequences) from the translocation, and controls to ensure activities to minimise potential impacts. This is an important step which is also addressed in the Review of Environmental Factors (REF) (see below) as part of the translocation approval process.

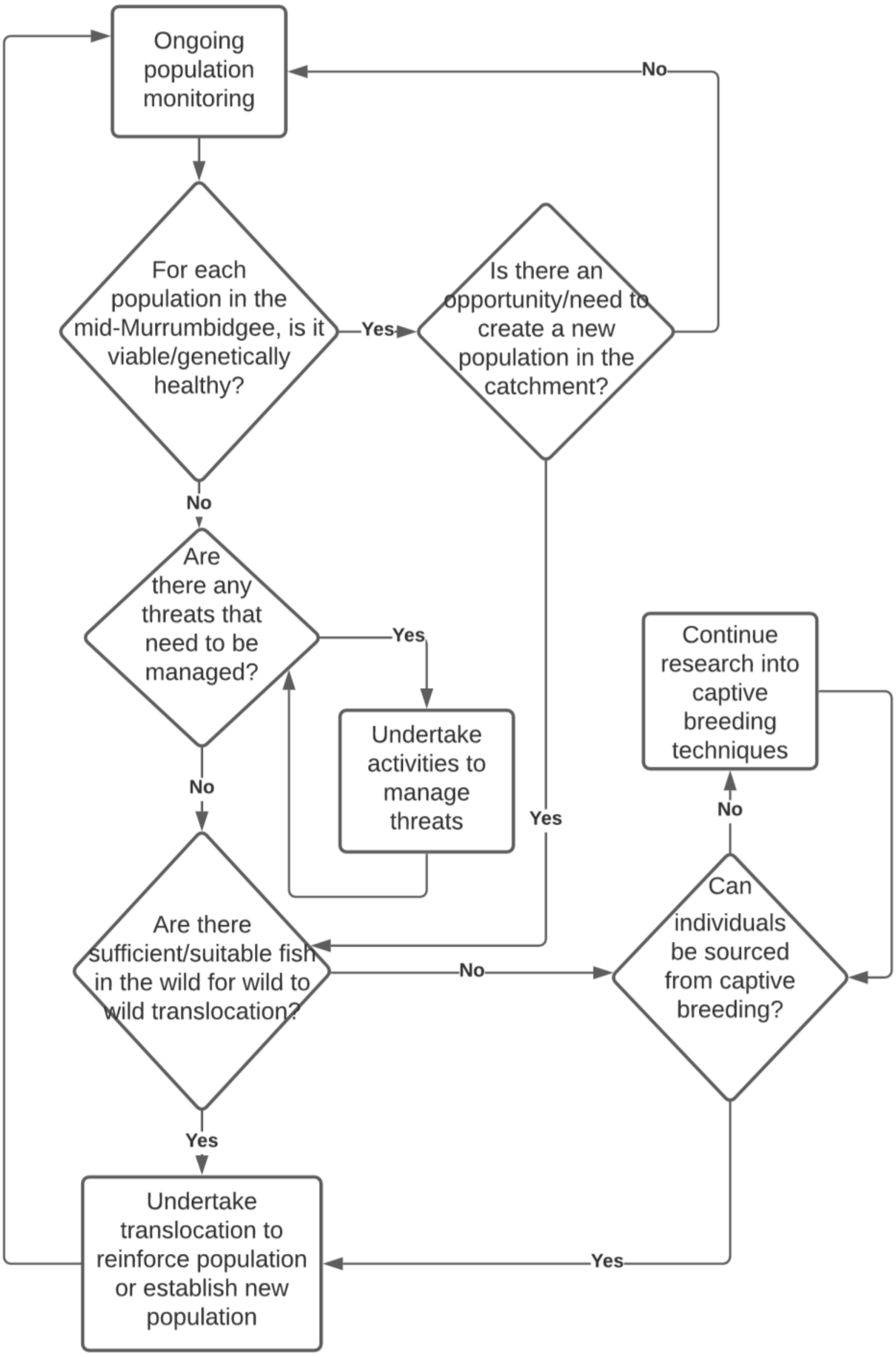

Figure 1. Flow chart of decisions (diamond boxes) and actions (square boxes) to guide translocations of Macquarie Perch in the Murrumbidgee catchment.

2.3 Translocation prerequisites and triggers

Simplistically, conservation translocations are reliant on 3 key prerequisites:

- A justifiable reason to shift or introduce additional individuals as determined by monitoring population demography, genetic structure and emerging threats.
- Sufficient individuals in the donor population(s) that can be removed without threatening their viability.
- Suitable location(s) to receive individuals (recipient location(s)).

For Macquarie Perch, based on the assessment by Pavlova et al. (2017), the first two criteria are met due to the low abundance and low genetic diversity observed in the Murrumbidgee population coupled with a known source of donors (e.g. Cataract Dam). Suitable receiving locations have yet to be identified but this can be achieved through a survey of the catchment and ongoing population monitoring (Lintermans et al. 2022c).

The specific categories of translocations can be grouped as follows:

Wild-to-captivity translocation

Specific situations that could trigger the translocation of individuals from the wild in the mid-Murrumbidgee catchment into captivity include:

- To safeguard against an imminent threat or reproductive issue.
- To maintain an insurance population in captivity.
- If population enhancement is considered required but sufficient numbers in the wild do not exist for wild-to-wild translocations.
- If genetic assessment considers that population 'fitness' can be improved via captive breeding using the mid-Murrumbidgee stock.

Once in captivity, individuals that are not required for captive breeding purposes would be returned to the wild when the threat can be controlled or abates (subject to state translocation protocols). Individuals considered required for ongoing captive breeding will be genetically assessed and based on the results of genetic modelling appropriately integrated into the captive breeding program.

Wild-to-wild or captive-to-wild translocation

Specific situations that could trigger the translocation of individuals from one wild population (either inside or outside the mid-Murrumbidgee catchment) to another population within the mid-Murrumbidgee catchment or captive to wild translocation include:

- To safeguard against an imminent threat or reproductive issue associated with the source population (in the case of wild to wild).
- If population enhancement by adding more fish or genetic diversity at the recipient location is required and sufficient numbers occur (and the genetic assessment considers them suitable) at the donor population or in captivity.
- If genetic assessment considers that population 'fitness' can be improved via wild-to-wild translocation or from captive-to-wild translocation.
- If the opportunity to establish a new or expand the range of the existing population has been identified.

Prior to any activities to translocate Macquarie Perch into the mid-Murrumbidgee catchment the following activities would be required to maximise the potential of success and minimise the potential for adverse outcomes:

- Genetic modelling and assessment of the donor and recipient populations.
- Translocation site identification and suitability assessment, including population modelling and assessment.
- Undertake Environmental Assessment and obtain necessary permits and approvals.
- Fish handling and transportation.
- Translocation monitoring.

These are all set out in detail below.

2.3.1 Genetic modelling and assessment

As the key objective of the translocation plan is to ensure the ongoing persistence of the Murrumbidgee population, the genetic condition of each wild source population, or captive bred stock, is critical to understand prior to translocations being undertaken. Fortunately, this has previously been undertaken for most Macquarie Perch populations across its range, although some populations were either not assessed, or were based on very low sample sizes (Pavlova et al. 2017). Future genetic assessments are however, still required to assess population structure and assess the outcomes of previous and future translocation attempts (see Lintermans et al. 2022b).

Genetic assessments are a crucial component of any plan to guide translocations and broodfish used in captive breeding (e.g. Lutz et al. 2020) to ensure these activities will maximize genetic diversity, adaptability, and resilience of populations (as per recommendations from Pavlova et al. 2017). This assessment would be based on genetic data from the target organism and size and number of available translocation sites, and its aim would be to preserve genetic diversity at the establishment phase, while giving populations the opportunity to evolve and adapt independently from one another. Fortunately, this approach has recently been used for Macquarie Perch across its range, therefore, much of the information is available to guide these actions (Pavlova et al. 2017).

To provide the best genetic foundation for the breeding program and maximise genetic diversity and adaptive potential the genetic assessment should consider sourcing broodstock or individuals for wild-to-wild translocations from multiple populations. As well as the Mid-Murrumbidgee River Macquarie Perch population, potential additional populations to supply broodstock include:

- Cotter River.
- Adjungbilly Creek.
- Mongarlowe River (following confirmation of original genetic provenance in the Murray–Darling Basin).
- Cataract Reservoir.
- Abercrombie/Retreat River.
- Lake Dartmouth.
- Yarra River.

2.3.2 Identification of suitable release sites

Potential translocation sites must be identified in advance and the habitat must be considered able to sustain a new population or, in the case of an existing population, the addition of individuals. Given the threatened status of Macquarie Perch, and current difficulty of producing large numbers of Macquarie Perch in captive settings, the small number of Macquarie Perch available for translocations have considerable conservation value. As such, identifying sites that provide the greatest likelihood of these fish surviving and establishing self-sustaining populations is paramount to the success of a translocation program in this catchment and to the future of the species. We suggest a two-tiered approach that compiles a list of potential waterways or reaches therein, for future translocation of Macquarie Perch, and ranks each using a combination of waterway attributes and long-term population projections under a range of climatic and management scenarios.

2.3.3 Site prioritisation framework

Information generated from a catchment survey on reach-scale habitat suitability (see Lintermans et al. 2022c), should be used in a site prioritisation framework (e.g. Ho and Ingram 2013; Tonkin et al. 2021) to prioritise potential waterways (and reaches therein) for Macquarie Perch stocking and translocation. The prioritisation is based on key site attributes previously identified by Ho and Ingram (2013) and Gilligan et al. (2010) coupled with new information that has emerged that may influence site selection (e.g. site drying during recent drought conditions; climate change projections and exotic fish abundance). These attributes should broadly encompass:

- Habitat suitability attributes such as the length and average discharge of a waterway (and therefore the likely carrying capacity of a system); river flow (permanency and variability); water temperature (particularly during the core spawning period); riparian habitat, instream habitat (e.g. complex habitat structure) and spawning habitat suitability and extent (e.g. run and riffle mesohabitat).
- Climate change projections and subsequent influence on the habitat attributes.

- Past and planned investment in waterway management interventions such as environmental flows, instream and riparian repair and as identified in Regional Waterway Management Strategies and Fisheries Management Plans.
- Current and proposed stocking activities (both native and introduced species).
- The existence of fish passage barriers limiting the incursion of pest fish – principally Redfin Perch.

Using the attribute weightings presented in previous studies, reaches can be ranked by considering a score of site attributes considered critical to supporting a self-sustaining population of Macquarie Perch into the future.

2.3.4 Population modelling

Decisions to re-establish populations and invest in ongoing management interventions depend critically on the likely long-term outcomes of those interventions. However, estimating long-term outcomes is challenging, especially given limited ecological data over relevant time scales and uncertainty in future climates. Population models are increasingly being used to predict long-term population trajectories under a range of climate and management scenarios. Population models make full use of existing knowledge and data and, importantly, are based on measurable processes, which allows their assumptions and predictions to be tested and updated as new data become available.

Population modelling can be used to predict the likely outcomes for (re-) established of Macquarie Perch populations over a multi-decadal period (so is suitable for long-lived fish like Macquarie Perch) under a suite of climate and management scenarios (stocking and translocations). The Macquarie Perch population model used by Tonkin et al. (2021) is supported by several earlier studies that provide detailed information on key population processes and associations with environmental conditions (Todd and Lintermans et al. 2015; Tonkin et al. 2014, 2017, 2019, 2020). The model considers age-specific survival and reproduction of Macquarie Perch up to 30 years of age, with separate survival estimates for eggs, larvae, and fingerlings. Importantly, as well as considering stochastic variation in vital rates and demographic outcomes, the recent model includes the effects of variable discharge and water temperature over a 50-year simulated time-period for each waterway/reach. Climate change scenarios can also be used in the process.

The model could be used to compare trends in population trajectories and risk for a subset of the top ranked waterways / reaches specific to their unique size, discharge and temperature regimes, under 5-year and 10-year translocation scenarios (e.g. 10,000 fingerlings stocked per year), with and without genetic mixing of stocked individuals and with and without the incorporation of different age classes (Todd and Lintermans 2015). We note that the existing population model construct would require some modification according to estimates of carrying capacity, waterway length, temperature and discharge parameters.

2.3.5 Approvals and permits

The following permits are required to undertake the collection and/or release of live fish into waters of New South Wales and will need to be organised well in advance. These are, but may not be restricted to, the following:

- Scientific Collection Permit – authorises the taking and possession of fish for the purpose of research, under section 37 of the NSW *Fisheries Management Act 1994*, and threatened species under the *Biodiversity Conservation Act 2016*. Available from the NSW Department of Primary Industries.
- Scientific Licence – authorises research in the National Parks and Wildlife Service reserve system, authorised under section 132C of the NSW *National Parks and Wildlife Act 1974*. Available from the NSW Office of Environment & Heritage.
- Animal ethics approval – for sampling of fish, and collection of voucher material (either NSW or institutional).
- Broodstock Collection Permit – authorises the take or possession of fish, under section 37 of the NSW *Fisheries Management Act 1994*. Available from the NSW Department of Primary Industries. (This is required only if broodstock collection was not included in the Scientific Collection Permit.)
  If brood fish are to be sourced from the Cotter River then an ACT Scientific Licence would be required under the ACT *Nature Conservation Act 2014*. See: https://www.environment.act.gov.au/parks-conservation/plants-and-animals/licensing-of-plants-and-animals/take-and-release-animals-for-scientific-purposes.

- Stocking Permit – authorises the release of live fish into waters of New South Wales, under section 216 of the NSW *Fisheries Management Act 1994*. Available from the NSW Department of Primary Industries. Issue of stocking permits requires compliance with the conditions under the NSW DPI Freshwater Fisheries Management Strategy for Fish Stocking, likely requiring meeting the standards of the Hatchery Quality Assurance Scheme covering aspects of genetic integrity and biosecurity. For details see: https://www.dpi.nsw.gov.au/fishing/aquatic-biosecurity/aquaculture/aquaculture/stocked-fish/fw-stocking https://www.dpi.nsw.gov.au/fishing/aquaculture/publications/species-freshwater/collecting-finfish-broodstock/info-sheet

Before NSW permits can be issued, an assessment of the merit and risks of conservation translocations would need to be undertaken by the proponent through a Review of Environmental Factors, approved by the NSW DPI Fisheries Threatened Species Unit, which is a requirement of the NSW Freshwater Fish Stocking Fishery Management Strategy (Zukowski et al. 2021). This is assessed as part of a Threatened Species Conservation Stocking Approval, and if approved, the details of each translocation would be notified to NSW DPI Fisheries through a Conservation Stocking Verification Form.

The NSW Freshwater Fish Stocking Fishery Management Strategy (FMS) outlines the rules, regulations and programs that are designed to manage the activity of fish stocking (i.e. translocation) in future, including the introduction of an appropriate management regime to minimise the environmental risks of stocking. As such, it is an important document guiding the NSW approach to both recreational and conservation stocking and guides activities from species and waters to be stocked, hatchery protocols, sufficient targeted research pre and post stocking, compliance and education and information management.

2.3.6 Fish handling and transportation

Biosecurity and fish health

Processes to ensure aquatic fieldwork hygiene should follow NSW DPI (2017) and any other relevant Biosecurity guidelines. Specific measures and controls should be determined during planning for the activity. These include, but may not be limited to, pre-departure and end of fieldwork inspection and removal of debris, cleaning, disinfecting and drying equipment, specific hygiene for aquatic fieldwork equipment and PPE, and destruction, disposal and investigation of suspected aquatic disease/pests.

During capture of fish for translocation, or before release at a translocation site, all fish will be visually assessed for signs of disease or damage. Sick fish will be euthanased. Similarly, all fish leaving a holding or aquaculture facility will first be checked by a veterinarian for visible signs of disease, damage or aberrant behaviour. During the translocation process at a site, all source water will be disposed of well away from the waterbody (see below).

Fish collection

Collection of Macquarie Perch from the wild for translocation or captive breeding should be undertaken using standard collection methods for the species (see Lintermans et al. 2022b). If possible, fish should be sampled along the length of the reach occupied by the species, with individuals selected from across all sexually mature size classes and both sexes (if sex is known), aiming for an equal sex ratio if possible. For wild-to-wild translocation, immature as well as sexually mature individuals can be included (Todd and Lintermans 2015; Lintermans 2017; Lutz et al. 2020). Care must be taken to ensure the number of fish collected does not overly deplete the wild source populations' reproductive potential. This can be assessed using data collected during the monitoring of the relevant populations (to estimate age structure and adult abundance) in combination with the population modelling approach described above (see Section 2.2.2 above). The model could estimate how likely a population is to persist when different numbers of fish (e.g. adults for captive broodfish and juveniles for translocation) are removed from the population at different rates (e.g. each year for 5 years, 10 years, or indefinitely). A key model output is the risk of populations declining below an abundance threshold, which can be displayed as a risk curve (e.g. Todd and Lintermans 2015).

All fish should be visually inspected for disease, parasites and injury, and only healthy fish collected. All selected fish should be fin-clipped for later genetic analysis and measured for weight (g) and total length (mm) (as per Lintermans et al. 2022b).

The optimum timing of Macquarie Perch capture, and translocation for population restoration (reinforcement, reintroduction) or conservation introduction (assisted colonisation) has not been studied, however based on previous programs (e.g. Lutz et al. 2020), this should be in late autumn, thereby minimising extremes in temperature and river flows; and also not during the reproductive period (unless specifically targeting 'running ripe' fish for breeding) that may cause unnecessary stress on translocated individuals. Autumn also provides optimal timing for collection of juveniles if they are included in wild-to-wild translocations and would also enable collection activities to be timed to coincide with population monitoring activities. Obviously, if fish require translocation as part of fish rescue (e.g. part of a TARP), seasonal timing will probably not be as important as the risk from the threat, and translocations should proceed rapidly.

General site characteristics such as GPS coordinates, date and time, and digital images should also be recorded prior to translocation of individuals from sites in the wild, in addition to water parameters at the source site, i.e. electrical conductivity, temperature, dissolved oxygen (mg/L and % saturation), pH and turbidity. All procedures applied during the translocation process must comply with conditions stipulated by the translocation permit, and those applied during translocation and post-release monitoring must minimise stress and avoid injury or illness to the fish.

Fish transport

Macquarie Perch will need to be transported from the site of collection to a facility for captive management or breeding (wild to hatchery), to the wild from a hatchery, or between sites in the wild. During transportation, care will be required to minimise harm and stress to fish. Specific measures and controls should be determined during planning for the activity. The following sections provide detail on controls for fish transport that are currently considered 'best practise' (Zukowski et al. 2021):

Between capture location and transport vehicle.

The transfer of fish between a capture location and a transport vehicle is similar in either direction.

- If vehicle is close to site of capture (< 200 m) shift fish in temporary transport containers (e.g. fishing buckets with lids). Ensure water is exchanged with fresh source water before shifting.
- If vehicle is far from the site of capture (> 200 m), fish may need to be shifted in aerated temporary transport containers (e.g. fish bins with lids) or carried in a container specifically attached to a hiking frame.
- Fresh source water should be added before shifting.
- Adequate aeration should be provided (e.g. high powered, rechargeable battery, portable air pumps and air-stones).
- Provide insulation around containers if required.
- Periodically check fish.
- Replace transport water if necessary (and possible).

Consider the transfer of fish between transport vehicle and capture/release site using helicopter if capture/release locations are very remote or difficult to drive to (e.g. rough terrain) and there is a high risk of fish mortality (i.e. Gooch and Roberts 2021).

Within transport vehicle

- Transport containers should be large enough to hold the number and size of fish requiring transport and insulated to minimise water heating during transport. They should also be filled to just below the brim to reduce water movement during transport to avoid physical damage to fish. For Macquarie Perch, this should be done using state agencies or other experienced operators and their equipment (insulated fish transport trailers and trucks fitted with oxygen tanks) and substantial experience in fish liberations, to minimise the stress placed on individuals.
- Animals should be transported in source water, which is at the lower end of the species' preferred temperature range to reduces metabolic activity to reduce waste production which can have consequences for water parameters and therefore animal condition (Sampaio and Freire 2016). Decrease temperature of water containing animals slowly to avoid shock (i.e. not more than 2°C/hr and ≤ 10°C/day; Johnston and Jungalwalla 2004).
- Transport water should be treated with a prophylactic additive such as Protech (Aquasonic Pty Ltd) to counter loss of protective outer mucus layer on fish due to capture, handling, and transport, and AmguardTM (Seachem) to reduce exposure of animals to toxic free ammonia released during transport.
- Each transport container should be fitted with adequate aeration, to prevent adverse water quality changes, and to meet the physiological requirements of the animals over the time they are being transported.
- Regular checks, at least once hourly, should be undertaken to ensure water parameters remain within the species' range, and that aerators remain functional.
- Spare equipment, necessary for the life support of individuals (i.e. aerators, air-stones, plastic tubing and connectors, and chillers), is also necessary to rapidly rectified breakdowns.

2.3.7 Monitoring of translocation sites

Pre-release monitoring

Following the identification of priority translocation sites, a period of pre-release monitoring will be required. Such monitoring will collect baseline information on the release area allowing future inference of the reasons for any observed changes after release of Macquarie Perch (e.g. the impacts of the released organisms) (IUCN/SSC 2013). Pre-release monitoring should cover habitat (e.g. water temperature regimes, refugia persistence and water quality) and other biotic measures (food resources; existing fish community) and be conducted for at least three years if this information is not already available or assessed as part of the catchment survey (see Lintermans et al. 2022c) and site selection and prioritisation process described above.

Post-release monitoring

Ongoing monitoring of translocated populations is crucial for documenting establishment success and informing translocation failure. It is also crucial to facilitate quick intervention if undesirable outcomes are detected (e.g. poor survivorship, inbreeding depression, and habitat changes) (Ayres et al. 2012) and to identify opportunities for improvement for future activities.

Such monitoring is usually poorly undertaken (Lintermans et al. 2015) and requires careful planning (Lindenmayer et al. 2013). As a minimum, monitoring of translocation sites should be undertaken annually, unless immediate threats are identified (Ayres et al. 2012; IUCN/SSC 2013). IUCN Red List criteria specify at least five years or three generations as the time before a translocated population could be considered to have established. As 5 years is less than one generation for Macquarie Perch, it would be considered inadequate. Previous experience in attempting to establish new Macquarie Perch populations using translocations has demonstrated that a long-term monitoring commitment is required requiring monitoring programs of 15+ years length before the outcome of the translocation can be confidently assessed (Lintermans 2013a,b, 2017). For example, the translocation in the Queanbeyan River was judged to be a failure after five years, a success after 16 years (as recruitment had commenced) and ultimately a failure after 26 years (as recruitment ultimately failed during the Millennium Drought) (Lintermans 2013a).

Post translocation monitoring should focus on physical (e.g. fish survivorship, natural spawning/recruitment, etc.) and genetic (genetic diversity, inbreeding, etc.) parameters using the established methods documented in the species monitoring plan (Lintermans et al. 2022b). The potential spread of fish from the translocation site should also be monitored and will require additional monitoring sites at suitable distances upstream and downstream.

2.4 Measures of success

A hierarchy of criteria to assess the success of translocated populations of Macquarie Perch should be developed involving short and long-term measures (Lintermans 2013a).

Short-term (1–5 years) success of translocation can be measured by the following for each of the three types of translocations:

- Survival – stocked individuals are still detected in monitoring after one year or longer.
- Dispersal - Increased distribution of fish that extend beyond release sites (reintroduction, assisted colonisation).
- Recruitment – in new populations, fish smaller than those originally translocated are found or in existing populations, genetic assessment of new recruits suggests breeding of translocated individuals.
- Condition - Growth and condition are comparable with other wild stocks or historical data.
- Abundance - Improvement in population abundance –recruitment and population size increases (reinforcement).

Long-term (5– >10 years) success of translocation can be measured by the following for each of the three types of translocations:

- Survival - Continuing persistence of fish (reintroduction, reinforcement, assisted colonisation).
- Recruitment - Establishment of initial successful recruitment – in new populations, fish smaller than those originally translocated are found or in existing populations, genetic assessment of new recruits suggests breeding of translocated individuals.

- Persistence – population length/age structure improves, and a healthy structure begins to be maintained (reintroduction, reinforcement, assisted colonisation).
- Occurrence of multiple generations of recruitment (i.e. offspring of offspring of offspring (3 generations)).
- Demographics – a range of size and age classes are present in the population.
- Improving genetic fitness – stabilising or increasing genetic diversity, declining level of inbreeding, reduced risk of extinction.
- Stable genetic fitness (e.g. continuing low level of inbreeding, stable genetic diversity, etc.) (reintroduction, reinforcement, assisted colonisation).
- Fish distributed over all available, suitable habitat within catchment (reintroduction, reinforcement, assisted colonisation).

2.5 A review of risks

Various actions in the translocation strategy are heavily reliant on outcomes from ongoing population monitoring, catchment survey, genetic assessments and future developments regarding captive breeding and have inherent risks (Table 1). For many of these there are no alternative options as they are critical, fundamental actions, though the risk may be able to be reduced by refining strategies, protocols, or actions.

Table 1. Identification of risks for translocation activities, including potential options to reduce risk

Action	Risk	Alternative Options	Difficulty of managing risk and risk controls
Initial translocation of some Murrumbidgee Macquarie Perch into captive management (wild-to-captive).	Impact on donor population. Loss of captive stock.	Minimising the number of fish removed from donor population.	Low; risk reduced by guidance of a translocation strategy and captive management plan; and information on donor population size from monitoring program.
Transporting and handling fish for all translocations (wild-to-wild; captive-to-wild; wild-to-captive).	Fish mortality. Biosecurity issues.	None.	Low; established protocols in place. Improve protocols if needed. Low; established protocols in place. Improve protocols if needed.
Post-translocation population decline	Decline in source population. Failure of translocation (mortality of released fish).	If fish releases are failing, consider new stocking locations, different donor fish source (either captive bred or wild stocks), different donor fish size (from wild populations), or time of release.	Moderate; failure of translocation could still occur in some years. Increase regularity of monitoring or refine monitoring targets.

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