NATIVE FISH RECOVERY STRATEGY

Native fish status assessment 2023

August 2024

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MDBA publication no: 3/25
ISBN (online): 978-1-922699-89-3
ISBN (print): N/A

Report citation

The Murray–Darling Basin Authority's preference is that you attribute this publication (and any Murray–Darling Basin Authority material sourced from it) using the following wording:

Lintermans, M., Koehn, J., Robinson, W., Cottingham, P., Butcher, R. and Brooks, S. *Native fish status assessment 2023*, Murray–Darling Basin Authority Canberra, 2025. CC BY 4.0

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray−Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connections to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated. Although Traditional Owners were not engaged in this assessment, future iterations may include Traditional Owner contributions.

First Nations people should be aware that this publication may contain images, names or quotations of deceased persons.

Other acknowledgements

Murray–Darling Basin Authority staff including Stuart Little, Greg Ringwood, Lauren McLeod, Shelley Thompson, Vince Oakley, Jim Clunie.

Native Fish Recovery Strategy Technical Advisory Group Members: Jarod Lyon, John Koehn, Katherine Cheshire, Lee Baumgartner, Lisa Evans, Luke Pearce, Matthew Beitzel, Michael Hutchinson, Michelle Hobbs, Qifeng Ye.

Jurisdiction science leads who provided advice, and in some cases data, included Matthew Beitzel, Katherine Cheshire, Michael Hutchinson, Jarod Lyon and Qifeng Ye.

The draft was reviewed by Dr Alison King (CSIRO) and the Murray–Darling Basin Authority. Their constructive feedback is gratefully acknowledged.

Glossary

Acronyms

Term	Definition
BWS	Basin-wide Environmental Watering Strategy
CEWO	Commonwealth Environmental Water Office
CEWO long-term MER program	Includes the Long Term Intervention Monitoring, Environmental Water Knowledge and Research, and Flow-MER programs
CLLMM	Coorong, Lower Lakes (Alexandrina and Albert) and Murray Mouth
EPBC	*Environment Protection and Biodiversity Act 1999*
IUCN	International Union for Conservation of Nature
BPEOM	Basin Plan Environmental Outcomes Monitoring (NSW)
MD-WERP	Murray–Darling Water and Environment Research Program
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
MDBFS	Murray–Darling Basin Fish Survey
MER	monitoring, evaluation and research
NFRS	Native Fish Recovery Strategy
SRA	Sustainable Rivers Audit
TLM	The Living Murray
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
WetMAP	Wetland Monitoring and Assessment Program
YoY	young of the year

Terms and definitions

Term	Definition
Assemblage	A group of species populations that occur together in space.
Baseline	Reference state(s) of species' spatial distributions and abundances at a particular point in time.
Bellwether species	A species whose population attributes can be an indicator of the general status or trend of other species with similar traits or habitat requirements.
Community	A group of interacting species occurring together in space.
Diadromous	A species that is migratory between fresh and marine waters during its life cycle.
Distribution	Can refer to a geographical or biological parameter, depending on context. In this report, we clarify using a preceding word. For example, we refer to geographical records as the spatial distribution of species. Biological parameters of populations or meta populations are referred to as age or length distributions.
Extent	The proportion of the sampling space (river, catchment or basin) that the species was detected in. Similar to spatial distribution but generally at a finer scale (e.g. spatial distribution = present in the catchment, extent = present in *x*% of sites in the catchment) and only uses sampled data, without modelling.
Endemicity	Restriction of a species to a particular place.
Meta population	A 'population of sub-populations' distributed in discrete habitat patches that are linked by occasional dispersal.
Population	The entire spatial population of each species. That is, all fish (total abundance and biomass) of each species in the Murray–Darling Basin.
Population demographics	Qualities such as fertility, mortality, survival, migration and population structure that occur and are reflected within a fish population or sub-population(s).
Population dynamics	Life history characteristics of a population that describe population attributes, such as fertility, birth rates (spawning), mortality, survival, migration, population life-stage structure and abundance.
Population status	Status as determined using the attributes presented in the proposed method (Cottingham et al. 2022) with respect to a baseline or reference state.
Population structure	The abundance, density, biomass, sex, age composition and size composition of a fish population or sub-population.
Recruitment	The presence of recruits in the population. These may be juveniles, immatures, young of the year or otherwise specifically defined. Unless clarified in the text, we can currently make no inference about the source of young fish as to whether they are stocked, bred in situ or migrants.
Sentinel or indicator species	Species used to detect threats or provide advance warning of a potential impact on other species. For this project, native fish species whose absence suggests conditions are unfavourable for other species with similar traits.

Term	Definition
Sub-population	A group of individuals of the same species or subspecies that are spatially, genetically or demographically separated from other groups.
Sub-population condition	The state of a sub-population's attributes in comparison with a reference sub-population, which may be a natural, undisturbed or otherwise defined sub-population.
Surrogate refuges	Artificial refuge habitats such as constructed farm dams and wetlands.
Surrogate species	A species that can be used to estimate population or biological parameters of another, perhaps closely related or similar species. For example, life cycle parameters for the well-known mountain galaxias (*Galaxias olidus*) may be used to estimate similar parameters in lesser-known *Galaxias* species.
Trend	A trajectory of change in population attributes from a baseline, reference point or through a specified period of time.

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Executive summary

The Murray–Darling Basin (MDB) is one of the world's most regulated river basins (Nilsson et al. 2005), also making the Murray–Darling one of the top 10 rivers at risk globally (Wong et al. 2007). As a result of water extraction, altered hydrology due to regulation and extraction, and many other threats (Koehn and Lintermans 2012), its rivers and catchments are now commonly in poor ecological condition (Davies et al. 2008, 2010a,b).

Consequently, MDB fish populations have suffered substantial declines, with almost half of the species now listed as threatened under state or national legislation (Koehn and Lintermans 2012, Lintermans 2023) and overall, native fish populations estimated to be at about 10% of pre-European settlement levels (mid-1800s) (MDBC 2004, Koehn et al. 2014).

Assessing the status of native fish populations across the MDB is a foundational action of the Native Fish Recovery Strategy (NFRS) (MDBA 2020a). This 2023 assessment is the first formal assessment of the status of MDB fish, and draws upon a wide variety of material to assess the status of native fish in the MDB pre- and post-2010. This 2023 status assessment will be used as an evidence base to contribute to:

- five- and 10-year outcome evaluations of the effectiveness of the NFRS
- assessing whether objectives of the Murray–Darling Basin Plan (Commonwealth of Australia 2012) and quantitative expected environmental outcomes of the Basin-wide Environmental Watering Strategy (BWS) (MDBA 2020c) have been met
- MDB Outlook reporting
- building the knowledge base of MDB fish science, including opportunities to create Basin-wide fish datasets (Basin Plan Chapter 13).

Assessing the status of all native fish species across the whole MDB (including freshwater and estuarine fish, mussels and crayfish), encompassing all habitats, regions and jurisdictions is a challenging task (Cottingham et al. 2022). Due to limitations on available data and resources, as well as the short timeframe to undertake the status assessment, a qualitative approach in the form of a narrative was used for this 2023 status assessment. The intention is that future assessments will strive to be more quantitative. A narrative is typically a qualitative account of a series of related events or experiences; in this instance using a combination of existing data, case studies and expert opinion, supported by published and technical literature, to describe the status of native fish species across the MDB. The narrative has been structured around four native fish attributes:

- the number of native fish species (Chapter 2)
- the conservation status of native fish (Chapter 3)
- the distribution of native fish species (Chapter 4)
- the population (sub-population) dynamics of native fish species (Chapter 5).

The status of spiny crayfish and freshwater mussels are presented in Chapter 6. Key findings and discussion on issues to address in future status assessment are presented in Chapter 7.
A summary of key findings is presented below.

Summary statement

In the early 2000s, an expert panel concluded that MDB native fish populations overall were at about 10% of their pre-European levels. An overarching management goal of the 2003 Native Fish Strategy was to return native fish populations to 60% over a 50-year period. It took many decades for the fish community to decline and recovery will take as long or longer. In 2020, an updated expert reassessment concluded that, in the face of many stressors, native fish populations had further declined and were now likely to be lower than 10% (MDBA 2020c). Both assessments utilised available data from historical baselines, expert opinion and distributions and abundances elicited from recent (post-1990) monitoring programs. There was, however, no quantitative assessment of data. This 2023 status assessment reinforces the 2020 assessment and concludes that native fish populations in the Basin have continued to decline. There is still much to be done to restore native fish to sustainable and secure levels.

Number of native fish, spiny crayfish and mussel species present

- There are 18 estuarine/marine species and 51 native freshwater fish species that occur across the MDB. There are also 15 alien fish species.
- Of the freshwater species, 27 occur only in the Southern Basin, five only in the Northern Basin, and 19 occur Basin-wide.
- The number of native fish species recognised in the MDB continues to grow, and this will likely continue into the future as the taxonomy of several species' complexes are resolved.
- While there have been 11 additional species included since 2010, almost all of these are the result of taxonomic resolution of species complexes. The only species new to the MDB since 2010 (not including taxonomic revision) is the silver tandan (*Porochilus argenteus*), which has been found in Queensland.
- The Yarra pygmy perch (*Nannoperca obscura*) is the only species known to have been lost from the MDB since 2010. This was despite captive breeding and reintroduction efforts.
- There are 13 species of spiny crayfish present across the MDB. Most occur in headwater streams, with only Murray crayfish (*Euastacus armatus*), alpine spiny crayfish (*E. crassus*) and Riek's spiny crayfish (*E. rieki*) being more widely distributed across Murray River and/or Darling River catchments.
- Several cryptic spiny crayfish species occur in the Basin with the number of species in the Basin to increase with further taxonomic work.
- There are five mussel species that occur across the MDB, the most common being the large riverine species, freshwater mussel (*Alathyria condola*), river mussel (*A. jacksoni*), and the smaller billabong mussel (*Velesunio ambiguous*), which is a floodplain species.
- The number of alien fish species in the MDB is growing slowly, mostly as a result of improved or new taxonomic knowledge. However, the threat of future establishment by new alien fish species is high, particularly by tilapia in the Northern Basin.

Conservation status of native fish, spiny crayfish and mussel species

- A large proportion of native freshwater fish species in the MDB (47%) are recognised as rare or threatened on state, territory, national or international listings. Noting that the conservation status of a species can vary between jurisdictions, and using the International Union for Conservation of Nature Red List of threatened species (IUCN)/*Environment Protection and Biodiversity Act 1999* (EPBC Act) listing criteria, threatened species include those that are:
  - Critically Endangered – three international, three national, five state and territory
  - Endangered – three international, five national, 11 state and territory
  - Vulnerable – one international, two national, two state and territory.
- The potential impacts of large-scale disturbances, such as bushfires, drought and climate change, and interactions with other threatening processes increases concern for the status of many listed species and species not yet listed as threatened. Post the 2019–2020 bushfires, an additional 19 MDB species were identified as being of conservation concern. Overall, this equates to 42 of the 51 freshwater fish species, or 82% in the MDB, being either listed or of conservation concern.
- The often fragmented sub-populations of rare and threatened species makes monitoring of species across their ranges challenging. However, appropriate and coordinated monitoring at the scale of the species' distribution is critical if we are to provide appropriate adaptive management strategies for the recovery of these species into the future.
- A range of management activities have been implemented to restore threatened species, with some successes (e.g. trout cod, *Maccullochella macquariensis*); however, improvements in conservation status appears to be reliant on ongoing conservation management.
- Under certain circumstances, in situ conservation interventions including translocations, conservation stocking, alien fish management and habitat remediation (e.g. resnagging, fishways, riparian management) can be used to improve populations of threatened native fish species.
- It is important to recognise that species took many years to decline and that successful recovery may take considerable effort over similar timeframes and that success may vary over time and is not guaranteed.
- Genetic recovery (e.g. via careful selection of individuals to improve the genetic diversity of sub-populations) is increasingly recognised as important in securing viable sub-populations and populations capable of adapting to future and current threats.
- The expanded distribution and abundance of trout cod is an important success story for this threatened species, although more work is needed before its conservation status can be revised to classify it as less threatened.
- Not all populations have improved since 2010. There has been a significant declining trend in mountain galaxias (*Galaxias olidus*) and northern river blackfish (*Gadopsis marmorata*) abundance across the MDB. There are concerns about low numbers of silver perch (*Bidyanus bidyanus*) and declines of sub-populations in the Northern Basin, where there has been very limited recruitment. Recent population modelling has considered the species to be functionally extinct. Other species assessed have had relatively stable populations in recent times.

- Many threatened, short-lived wetland species remain at low abundance and occurrences throughout the Basin. For example, the decline and loss of Yarra pygmy perch and several sub-populations of southern pygmy perch (*Nannoperca australis*) and southern purple-spotted gudgeon (*Mogurnda adspersa*) is significant.
- Ex situ conservation interventions, including the creation of surrogate refuges for small-bodied taxa and captive breeding programs for both small- and large-bodied taxa, are increasingly important tools for managing and conserving threatened species populations, particularly during extreme events such as droughts and bushfires.
- There is no centralised repository of threat distribution, prevalence or change for the MDB. Assessing threats is key to identifying recovery options and progress for recovering threatened species.
- Similarly, there is no central repository of threatened fish management interventions and their success. Such an inventory will allow synthesis and analysis of strengths and weaknesses of current management approaches to common threats.
- Some river valleys are of particular concern (e.g. Paroo catchment, which is seemingly losing two large-bodied threatened fish species: Murray cod (*Maccullochella peelii*) and freshwater catfish (*Tandanus tandanus*)), while silver perch numbers are in serious decline in the Northern Basin catchments. The drivers of such declines need to be investigated.
- *Euastacus* is the most threatened genus of crayfish in the world.

Distribution of native fish species

- The total fish species recorded in the Basin before and after 2010 declined by one species, from 48 to 47 species (noting that the undescribed few-spined river blackfish, *Gadopsis* sp. nov 'Wimmera' from the Wimmera River, Goulburn two-spined blackfish, *Gadopsis* sp. nov 'Goulburn' and short-headed lamprey, *Mordacia mordax,* were omitted from the database used for assessment). However, there were further differences in the species present in the pre- and post-2010 periods (e.g. record of silver tandan and loss of ornate galaxias (*Galaxias ornatus*) and estuary perch (*Percalates colonorum*) in the post-2010 period).
- Although changes in species at the river valley scale were noted between the two time periods, this may reflect the different lengths of the two time periods and differences in sampling intensity. It is possible that the records of species being lost to particular river valleys since 2010 could be inflated.
- There is no centralised data repository for fish distributional records within the MDB. The current status assessment relies on a collation of records that was compiled for another purpose (broad distribution mapping, not valley-by-valley assessment across set time periods). It is acknowledged that records exist that were not made available for inclusion in this assessment.
- Improvement in and widespread use of environmental DNA (eDNA) detection methodology will greatly improve presence reporting in the coming years, particularly for rarer and cryptic species.
- Using genetics to examine patterns of population connectivity in the MDB will also be useful in the future; for example, by identifying fragmentation and barriers to the mixing of sub-populations of individual species.

- A case study using a phylogeographic approach looked at population connectivity in four fish species with quite different degrees of commonness. Results for Australian smelt (*Retropinna semoni*), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus)*, olive perchlet (*Ambassis agassizii*) and southern purple-spotted gudgeon demonstrate a lack of panmixia (i.e. random mating across the entire population is not possible) across the Basin as a whole and highlight that there is differential movement between the Murray and Darling-Baaka catchment and into the Lower Murray. Only Australian smelt and unspecked hardyhead had high levels of connectivity. All sub-populations were grouped by river catchment, with the Murray River typically split into an upper section (usually above Yarrawonga Weir) and a midsection down to the Darling-Baaka River junction. Gene flow between many rivers is not frequent, and in some cases there's little gene flow between sub-populations within river sub-catchments too.

Population dynamics of native fish, spiny crayfish and mussel species

- Declines in MDB native fish populations have previously been described over multiple decades (e.g. Cadwallader 1981, Cadwallader and Gooley 1984, Reid et al. 1997). Thus, it is important to remember that assessment of recent trends in fish occurrence and abundance (such as this one) represents changes from a relatively low base when compared with historical levels.
- The nature of the datasets used for this assessment, together with the often highly variable relative fish abundance for many species, means that care is needed in analysing and interpreting results. Furthermore, most data are collected in lowland channel environments, and the assessment of wetland, floodplain lake and upland species is of a lower standard.
- Although native fish populations in the MDB remain degraded and face numerous ongoing or even escalating threats (e.g. due to climate change effects), there has been recent increases in the abundance of some native species at both localised and broad geographic scales. This is an encouraging sign that restoration efforts may be improving native fish populations in the MDB.
- Murray cod, golden perch (*Macquaria ambigua ambigua*) and Murray–Darling rainbowfish (*Melanotaenia fluviatilis*) have shown overall positive trends across the Basin in occurrence and abundance over the past two decades. Spangled perch (*Leiopotherapon unicolor*) abundance and distribution in the Northern Basin has also shown an upward trend. It should be noted that this analysis was undertaken with data prior to the 2023 Darling-Baaka River fish death event and such trends may not hold for some valleys.
- Recruitment and distributions of age and length have not been consistently sampled or analysed for many species over the longer timeframe. However, recruitment levels of some longer lived species may be resilient and can maintain populations throughout highly variable flow and environmental conditions. Population modelling could help determine population trends. Intermediate- and short-lived species are less resilient in the short term, and population numbers take longer to recover from disturbances or recruitment failure in any given year.
- Riverine connectivity plays a major role in allowing migratory species to move freely throughout their life cycle. Connectivity is crucial for diadromous species that need to move through the Coorong, Lower Lakes and Murray Mouth marine and freshwater interface to complete their life cycles. Connectivity is, however, also a key component of changes to the

population of many other solely freshwater species (e.g. golden and silver perch) and has not been considered in any status assessments.

- Murray crayfish and river mussel populations have been affected by large-scale disturbances, such as drought and blackwater events. Recovery of their populations throughout their range is likely to take a long time.
- River mussel (*Alathyria jacksoni*) sub-populations in the Northern Basin are showing declines since the 2017–2019 drying, with thousands of dead mussels surveyed and site mortality estimates between 20–100% across the Northern Basin.
- Monitoring, analyses and reporting must be undertaken at river reach as well as overall Basin scales.

Future status assessments

There are significant challenges in collecting and analysing monitoring data to inform status assessments for fish in the MDB:

- Assessing widespread and abundant species accurately requires broadscale, often generic sampling; however, broadscale generic sampling is inefficient for rare or cryptic species and targeted sampling is considerably more effective.
- Fish sampling methods have varying efficacy (e.g. different species or life-stage capture efficiency when electrofishing), depending on the species and local conditions (e.g. habitat type, salinity, turbidity).
- Sampling for native fish recruits (e.g. young of the year) to characterise recruitment success or presence often requires different techniques than sampling for species presence only.
- Sampling spatially requires selecting individual sites as the sampling unit, which is a different sampling frame from sampling fish populations, in which individual fish are the sampling units.

Information on fish 'health' is patchy and ad hoc. There is no Basin-wide, standardised fish health monitoring or recording system. Identification of prevalence, intensity, and distribution of priority diseases or parasites (e.g. *Lernaea* and epizootic haematopoietic necrosis virus; EHN) would be of benefit to future status assessments.

A targeted, robust monitoring approach (i.e. not just generic river monitoring) is needed to assess the status of native fish species throughout the MDB, particularly threatened species. Such an approach should seek to make best use of existing monitoring programs in terms of analysis of existing data to assess current trends in fish population dynamics and inform future status assessments. To assist future status assessments, the following actions are recommended:

- That the Murray–Darling Basin Authority (MDBA), federal and state agencies, and research institutes collaborate as partners to undertake a detailed, quantitative assessment of native fish status using appropriate long-term datasets and fish population modelling to assess attributes such as species conservation status, species distribution and population dynamics.
- That the MDBA, federal and state agencies, and research institutes collaborate to catalogue the prevalence of identified threats to native fish populations (e.g. dam and weir construction or enlargement, cold water pollution extent, blackwater extent, disease incursions, fish deaths, toxicant spills, alien fish abundance and distribution) and management responses to these threats (e.g. riparian restoration extent, riverine fencing, environmental flows).

Characterisation of changes in threat distribution and intensity will assist with interpretation of changing fish, mussel and crayfish status.

- Inclusion in this assessment of a First Nation's assessment of native fish across the Basin.
- That partners use the findings to prepare and refine more targeted approaches to status assessment in the future, particularly for species and habitats that are under-represented in current broadscale (state or regional) and Basin-scale monitoring programs. The MDBA and management agencies should require better analyses of data to meet their management needs. For example, assessing the percentage catch of legal-size fish for angling species as an indicator may be useful for fishery managers.
- Trends in relative biomass can also be included for relevant species.
- That efforts to improve our taxonomic understanding of cryptic diversity in Murray–Darling fishes, crayfishes and mussels is expanded and continued, as this is essential for management and accurate assessment of both species and community status and trend. It will also be needed for future assessments of conservation status.
- That future status assessments include the development of standardised reporting metrics for alien fish distribution and abundance, as alien species are a major threat to many fish species and a constraint on threatened fish recovery.
- That a Basin-wide threatened species monitoring program be established, including sampling methods and frequency (e.g. annual) that can produce standardised reporting metrics for individual species and their sub-populations across jurisdictions, address knowledge gaps and inform ex situ conservation methods.
- A Basin-wide inventory of threatened fish management interventions and their success is required. This will allow synthesis and analysis of strengths and weaknesses of current management approaches to common threats.
- That any regions of concern (e.g. Paroo catchment, which is seemingly losing two large-bodied fish species) or species of particular concern (e.g. silver perch in the Northen Basin) be investigated to confirm status and drivers/threats to species of concern as a matter of priority.
- Monitoring and assessment analyses must be reported on river, sub-population or valley scales to ensure correct interpretations for management. For example, although the Basin-wide population of silver perch indicates no discernible trend, individual catchments in the Northern Basin (Barwon–Darling, Macquarie–Castlereagh, Namoi and NSW Border Rivers) show very low abundances with limited recruitment. There is also the possibility that the presence of small silver perch may be from hatchery stocking rather than natural recruitment, the lower Darling-Baaka River has been subjected to large fish death events (2019–20 and 2023), and other Northern Basin rivers in Queensland have had marked declines in abundance (M. Hutchison, pers. comm.)
- Additional efforts be made to include assessments of recruitment and to integrate monitoring data with population modelling to provide more predictive information for managers regarding likely population trends.
- That the MDBA and its partners establish a database and metadata (e.g. sampling locations, methods, frequency, effort) to house native fish data from all MDBA-funded programs. This will greatly assist in future species distribution assessments.

Recommendations

Nineteen recommendations are made. They focus on improvements for future status assessments.

Improving collaboration

Recommendation 1: The MDBA, federal and state agencies, research institutes and First Nations collaborate to establish a process to undertake detailed, quantitative assessments of native fish status using appropriate long-term datasets and fish population modelling to assess attributes such as species conservation status, species distribution, and existing and likely future population dynamics (e.g. existing, and likely future population trends).

Improving the assessment method

Recommendation 2: The MDBA and its partners refine more targeted approaches to status assessment, particularly for habitats, species and life stages that are under-represented in current Basin-scale monitoring programs. Current priority monitoring and status gaps include off-stream and small-stream species, recruitment metrics (young of the year, spawning) and the status of Murray cod, silver perch, freshwater catfish and Australian smelt in the Paroo valley. Notably, silver perch are poorly surveyed by electrofishing and should be a priority species for targeted sampling in multiple valleys.

Recommendation 3: Use the findings of this assessment to refine a more targeted, quantitative approach to status assessment:

- Integrate additional variables in analyses and undertake new and novel analysis methods to enhance the presentation and interpretation of results.
- Include calculations of fish biomass and fish condition as standard metrics in data analysis.
- Develop standardised reporting metrics for alien fish distributions and abundances, as alien species are a major threat to many fish species.
- Address knowledge gaps to assist in data analysis, predictive population modelling and interpretation for managers.

Recommendation 4: Articulate the key management questions for which these data will be used and progress from status data modelling to predictive population modelling to better assist management decision making.

Recommendation 5: Include data on angler harvest, hatchery stocking, fish death events and other relevant management actions that may influence populations in species' status assessments. At the very least these should be included in the interpretation of results (out of scope in the current assessment).

Recommendation 6: Future status assessments should include greater consideration of alien species including assessment of trends in number of species, abundance and distribution (see recommendation 18).

Recommendation 7: Continue support for research that relates to distribution, conservation status and population dynamics that can provide knowledge for improved analysis and interpretation of monitoring results.

Data management

Recommendation 8: That the MDBA and its partners establish a database which includes all relevant metadata (e.g. data source, project name, sampling locations, methods, frequency, effort) to house native fish data from all Commonwealth- and state-funded programs (and other programs, such as those undertaken by universities and research institutions) including intervention, condition, threatened species monitoring.

Monitoring priorities

Recommendation 9: Develop a revised, more rigorous fish monitoring program that addresses key gaps and deficiencies of current monitoring programs. This should specifically target wetland species, threatened species, newly described species (e.g. *Galaxias* species, *Gadopsis* species), and recovery of populations from fish death events (including population trends), at appropriate spatial and temporal scales.

Recommendation 10: That a Basin-wide threatened species monitoring program be established, including fit-for-purpose sampling methods and frequency (e.g. annual) that can produce standardised reporting metrics on individual threatened species populations and their status across jurisdictions.

Initial target species for monitoring include those that lack significant information on population dynamics which are essential for assessing conservation status (extent of occupancy, area of occupancy, number of adults in the population, number of sub-populations, key threatening processes). This includes:

- recovering species: Murray cod (and other species) following fish death events
- MDB species and sub-populations of concern: freshwater catfish, short-headed lamprey, southern purple-spotted gudgeon, Murray–Darling rainbowfish, olive perchlet, southern pygmy perch, Darling River hardyhead (*Craterocephalus amniculus*), river blackfish (*Gadopsis marmorata*), barred galaxias (*Galaxias fuscus*)
- declining species: mountain galaxias, mussels, Murray crayfish, silver perch (Northern Basin), threatened short-lived and wetland species.

Recommendation 11: Investigate the drivers of decline in key species in river valleys identified as of particular conservation concern. This includes the Paroo which is seemingly losing at least two large-bodied threatened fish species: Murray cod and freshwater catfish, with silver perch now being extremely rare, and considered functionally extinct.

Recommendation 12: Undertake additional monitoring to quantify the immediate loss of fishes (abundance for each species) and the effects on populations due to fish death events.

Recommendation 13: Support supplementary sampling in existing programs to better assess population structures for key species within known ranges. For example, the current broadscale electrofishing-based surveys do not target habitats where many recruits may be present. Additional sampling of eggs, larvae or small fish using other methods may also be needed.

Develop recruit-specific sampling methodologies and analysis for species and sites as appropriate.

Recommendation 14: Undertake an audit of key fish habitat attributes across the MDB, with monitoring of habitat amount/condition and other threats included in the interpretation of data and status assessment for each species.

Research and management needs

Recommendation 15: Improve and support taxonomic understanding of cryptic diversity in Murray–Darling fishes and crayfishes. This is essential for management and accurate assessment of species and community status and trend and should be enhanced and continued. It will also be needed for future assessments of conservation status.

Recommendation 16: Undertake a Basin-wide inventory of threatened fish management interventions and their success; this will allow synthesis and analysis of strengths and weaknesses of current management approaches to common threats.

Recommendation 17: Undertake a Basin-wide inventory of the prevalence of key threatening process to native fish populations and required management responses to these threats (e.g. riparian restoration extent, riverine fencing, environmental flows). Characterisation of changes in threat distribution and intensity will assist with interpretation of changing fish, mussel and spiny crayfish status.

Recommendation 18: Develop a Basin-wide alien fish management strategy to be implemented under the Native Fish Recovery Strategy; it must include:

- an alien fish surveillance program, for example using eDNA followed with conventional sampling.
- protection of priority locations inhabited by threatened native species.

Program evaluation

Recommendation 19: The frequency of future status assessments should be at 5-year intervals. Targeted assessments may be required at shorter intervals for key or at-risk species. The next assessment should improve on collaborative approaches, be quantitative in nature and make best use of available data, expertise, and interpretation.

1 Introduction and context

The Murray–Darling Basin (MDB) is one of the world's most regulated river basins (Nilsson et al. 2005), also making the Murray–Darling system is one of the top 10 river systems at risk globally (Wong et al. 2007). As a result of water extraction, altered hydrology due to regulation and extraction, and many other interacting threats (Walker and Thoms 1993, Maheshwari et al. 1995, Kingsford 2000, Hart et al. 2020), its rivers and catchments are now commonly in poor ecological condition (Gehrke et al. 1995, Davies et al. 2008, 2010a,b). Long-held concerns continue regarding the over-allocation of water, flow regulation and environmental damage (Walker et al. 1995, Kingsford 2000, Lester et al. 2011), along with concern of predictions that climatic extremes are expected to occur more frequently in the future due to climate change (e.g. CSIRO 2008, Adamson et al. 2009, Whetton and Chiew 2020, Prosser et al. 2021). Indeed, recent severe drought conditions, large-scale fish death events (commonly known as fish kills), and extreme bushfires (2019–2020) have heightened concerns over the ecological health of the Basin (Vertessy et al. 2019, Legge et al. 2021, van Leeuwen et al. 2023).

Freshwater biodiversity, and freshwater fish, are among the most threatened globally (Dudgeon et al. 2006, Arthington et al. 2016, Darwall et al. 2018, Cantonati et al. 2020, Miqueleiz et al. 2020, Feio et al. 2023 and references therein). Freshwater fish account for approximately 55% of all fish species (Darwall et al. 2018) but are likely to become extinct at a more rapid pace than marine or terrestrial species due to the multiple and persistent threats (Reid et al. 2019, Ahmed et al. 2022). Native fish populations in the MDB have suffered substantial declines, and almost half of the species are now listed as threatened under state or national legislation (Cadwallader 1978, Gehrke et al. 1995, Reid et al. 1997, Koehn and Lintermans 2012, Lintermans 2023).

As part of establishing a Native Fish Strategy, an expert panel assessment in the early 2000s estimated that native fish populations were at around 10% of pre-European settlement levels (mid-1800s) (MDBC 2004, Koehn et al. 2014). The Native Fish Strategy identified a range of key threatening processes and mitigation strategies necessary to recover MDB fishes (MDBC 2004). The second iteration, the Native Fish Recovery Strategy (NFRS) (MDBA 2020a), was developed as one of the responses of the Australian and Basin state governments to the fish death events in the lower Darling-Baaka River in 2018–19. The NFRS builds on efforts of the Native Fish Strategy (2003–2013) as a coordinated approach to fish recovery.

Assessing the status of native fish populations across the MDB was identified as a foundational action of the NFRS (MDBA 2020a); specifically, Action 5 that will establish the basis for the future evaluation of the effectiveness of the NFRS and other complementary programs. Within the limitations of the available data (see Section 1.4 below) this 2023 status assessment will be used as an evidence base to contribute to:

- five- and 10-year outcome evaluations of the effectiveness of the NFRS
- the assessment of the Basin-scale Basin Plan objectives and quantitative expected environmental outcomes of the Basin-wide Environmental Watering Strategy (BWS) (MDBA 2020b)
- MDB Outlook reporting
- building the knowledge base of MDB fish science, including opportunities to create Basin-wide fish datasets (Basin Plan Chapter 13, Commonwealth of Australia 2012).

The methodology for this native fish status assessment was developed with discussions, collaboration and directions from the NFRS Technical Advisory Group, which included representation from each of the MDB jurisdictions as well as fish biologists (Cottingham et al. 2022). The general approach to undertaking the status assessment is presented in Appendix 1, which focuses on native fish, spiny crayfish and freshwater mussels, and analyses the available data using four attributes: number of species, conservation status, distribution and population dynamics. This assessment is predominantly qualitative in nature (see Chapter 2) with the intent to adopt more quantitative approaches in future assessments. The agreed outputs for the status assessment include:

- a series of simple, key statements on the status of native fish in the Basin
- a 2–4-page summary of the major findings on the status of native fish in the Basin
- a comprehensive report that collates the evidence in support of the summary and key messages.

This report delivers Output 3, providing a report that documents and summarises the status assessment and its key findings.

1.1 What do we mean by 'status'?

The intent of this status assessment is to describe the status of native fish populations across the MDB over two time periods, pre- and post-2010, using the following attributes:

- number of native fish species present at varying spatial scales (e.g. river valley, Northern and Southern Basins)
- conservation status for each species (this may be at a range of spatial scales)
- species distributions, and whether distributions remain stable, or have expanded or declined (i.e. compared with a defined point of refence/baseline), are connected or fragmented
- population dynamics including recruitment, abundance, spatial distribution, biomass and extent of native fish species.

Native fish species are inclusive of all native fish species that occur in the MDB, from montane/upland species to those in lowland areas and the Lower Lakes (lakes Alexandrina and Albert), Coorong and Murray River estuary. Each attribute will be considered at all relevant spatial scales where suitable data were available. The time periods were chosen to capture a significant period of data either side of the Millennium drought, to be reflective of an extended dry period (1980–2010) and a more typically variable period post-2010.

1.2 Narrative approach

There are significant monitoring efforts underway across the MDB; however, many are not coordinated, nor are data entered into a centralised database ready for analysis. Furthermore, fish monitoring programs often have different objectives (e.g. status or condition, assessment of restoration activities) (King et al. 2022); scales of reporting (e.g. individual sites, valleys, or regions); target species, methods and replication.

The current monitoring programs are not designed to facilitate a rigorous Basin-wide status assessment. The physical and technical difficulties of undertaking robust fish monitoring, and the fact that analyses of these varied data are not necessarily straightforward is acknowledged. The varied nature of the information collected (or not), differences in species ecology, abundance/rarity and their distributions and the lack of a centralised data warehouse means that an overall, standard quantitative approach was not possible. In addition, some species have only been described relatively recently and the ecology of many others is not well known, hindering data interpretation. Such interpretation is not only to provide statements about species' status, but also to inform management priorities and options.

Therefore, the Murray–Darling Basin Authority (MDBA) specified that a qualitative approach in the form of a narrative is appropriate for the 2023 status assessment (Cottingham et al. 2022). This is due to limitations on data and resources available as well as the timeline of the status assessment.

This project demonstrates that there are several tiers to each of the attributes of data or information used in a status assessment that need to be considered so that a series of more quantitative assessments can be undertaken to provide and overall status and inform future methods. Some of the tiers encountered that need to be considered include:

- the quality of data – none, expert opinion, inadequate for some analyses (or areas), adequate
- temporal scale – from ~100 years (historical records for perspective on current status), ~70 years (for commercial catch data), ~30 years (for some current monitoring) to 1–5 years for recent projects
- spatial scale – whole of Basin, sub-Basin (Northern or Southern Basin), river valleys, river reaches, sites.

There are also considerable geographic and ecological differences between the northern and southern MDB. In the northern river systems, hydrology typically exhibits greater intra- and inter-annual variability, and flow is less impacted by smaller headwater dams, but more so by direct water abstraction (Breckwoldt et al. 2004). These matters necessitate an approach that can accommodate such issues.

A ***narrative*** is typically a qualitative account of a series of related events or experiences; in this instance using a combination of existing data, case studies and expert opinion, supported by published and technical literature to describe the status of native fish species across the MDB.

There was limited opportunity for the collection and analysis of data and information for input to the 2023 status assessment. However, as the method is to contribute to the five- and 10-year evaluation of the NFRS, to the MDB Outlook and to the Basin Plan evaluation, we have used targeted datasets to better help the current and subsequent assessments. While a narrative approach to status assessment will be applied here, the intent is that future assessments will move progressively to more structured, quantitative and inclusive analyses. Future quantitative assessment will be critical as:

- data suitable for analysis accrues
- sampling and/or analytical and modelling methods improve
- Basin Plan objectives, targets and expected outcomes become more quantitative and specific.

1.3 Trends of interest

The status assessment method considers both spatial and temporal trends in native fish spatial distributions, species richness, abundance, and sub-population structure. For example, spatial trends may be in terms of increase or contraction in the geographic range of a species over time, while temporal trends may be in terms of changes in the abundance of a species over time within a spatially defined area.

Spatial trends of interest may be applied at any temporal scale but for this status assessment have focused mainly on the period leading up to and including, and the period after, Millennium Drought (i.e. 1980–2010 and 2011-present). While it is acknowledged that major declines in many fish species occurred pre-1980 (Lintermans 2023), these historic declines are outside the scope of this review. Temporal trends of interest may be applied at any spatial scale but for this assessment are mainly at the scale of the spatial distribution of individual fish species.

Spatial trends of interest include:

- positive or negative spatial trends in the distribution of individual species
- positive or negative spatial trends in the abundance of individuals within sub-populations
- positive or negative spatial trends in species richness over different spatial scales (e.g. localised to river valley level).

Temporal trends of interest include:

- positive or negative temporal trends in species richness or sub-population structure (including recruitment) over time at varying spatial scales (e.g. river valley, basin scale)
- positive or negative temporal trends in response to significant events, such as bushfires or floods, fish death events, or large-scale management interventions.

Rather than the pre and post 2010 comparisons, in the population dynamics chapter we look at the trends in the context of the duration of the long-term monitoring sets, which cover the period since the previous status report, 2004 to present.

A particular challenge for any assessment will be that rare, threatened and cryptic species often require targeted sampling for detection Maxwell and Jennings 2005; Poos et al. 2007; Ebner et al. 2008); such species can easily be missed in coarse-scale sampling or sampling that does not target the correct habitats.

1.4 Status assessment – data and information for current and future assessments

1.4.1 Monitoring fish populations in the MDB

There is considerable information on MDB fish populations, but until recently this has mostly been collected through a range of independent monitoring or research projects, rather than through a dedicated, standardised monitoring program. Monitoring using standardised fisheries-independent methodologies was only initiated by a short-term survey of the NSW portion of the MDB in the early 1990s (Harris and Gehrke 1997) and was then redesigned to the whole of the MDB under the Sustainable Rivers Audit (SRA 2004–2013), which was then adapted and continues as the Murray–Darling Basin Fish Survey (MDBFS 2014–present).

In earlier times (1950s on) ‘monitoring’ was rare and occurred through examination of commercial catch data for a very limited number of species (especially Murray cod, *Maccullochella peelii*, and golden perch, *Macquaria ambigua*; Reid et al. 1997). Even by the 1980s, catches appear to have been considerably reduced from circa 1900 levels (Dakin and Kesteven 1938, Humphries and Winemiller 2009). Historical examinations of a fisheries inspector's records had been collated for the Murray River (Cadwallader 1977), distribution records have been recorded for many species (Cadwallader and Backhouse 1983), and detailed assessments have been undertaken for species such as Macquarie perch (*Macquaria australasica*) and Murray cod, to compare 1980s levels to historical ones (Cadwallader 1981, Cadwallader and Gooley 1984). Differences in the movements of migratory fish over a 50-year timespan were explored to determine population changes (Mallen-Cooper and Brand 2007). In some cases, there has been a need to rely on oral history accounts (Roberts and Sainty 1996, Copeland et al. 2003, Trueman 2011). While such observed changes are hard to quantify they are invaluable to provide perspectives on historical changes and avoid the trap of 'shifting baselines' (Humphries and Winemiller 2009).

The SRA was the first attempt at an MDB-wide fishery-independent assessment program (Davies et al. 2008, 2010a), which later transformed into the MDBFS. Additional longer-term monitoring now occurs at specific environmental watering locations through the Commonwealth Environmental Water Office's (CEWO) long-term monitoring, evaluation and research program (MER) (e.g. Stoffels et al. 2016, Hladyz et al. 2021), NSW Basin Plan Environmental Outcomes Monitoring (BPEOM) and the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP; Tonkin et al. 2020). Monitoring programs have generally been only undertaken in larger rivers and some impoundments and therefore can only provide adequate data for a small portion of MDB's fish species. Dedicated assessment for fish in wetlands has been relatively rare, often spatially biased (Southern Basin well surveyed relative to Northern Basin) and targeted to non-random sites (e.g. Ramsar sites), and consequently the data are insufficient for assessing rare or difficult-to-detect species.

Other types of monitoring do occur and can contribute to our knowledge and datasets. There is considerable effort placed on intervention monitoring to assess the effect of a restoration activity; for example, environmental flows (e.g. CEWO's long-term MER program, VEFMAP) and environmental wetland watering (e.g. Victorian Wetland Monitoring and Assessment Program, WetMAP). Both types of monitoring are often specific to the site, species and intervention, but can contribute additional data for status assessment purposes.

1.4.2 This assessment

The scope and approach of this status assessment was dependent on the data available. There are many large-scale, long-term fish datasets that exist for the waters of the MDB. However, combining such datasets to undertake a detailed quantitative assessment using all available data was beyond the time and resources available to this assessment. For future assessments, some of the issues that must be addressed for such an undertaking include:

- allowing for differences in spatial and temporal scales of monitoring and collected data
- combining or rationalising data collected from different habitats (e.g. riverine, wetland, lake) and using different sampling techniques
- allowing for differences in sampling effort at different times and locations
- reconciling data custodianship and intellectual property issues
- selecting appropriate analytical and modelling approaches to answer specific questions in relation to native fish status

- providing time and resources for parties (e.g. MDBA, Federal and State agencies, research institute researchers) to confirm the evaluation questions and undertake such a complex quantitative analysis.

This 2023 narrative-based status assessment is considered an interim approach until a large, collaborative, quantitative assessment can be undertaken. The narrative for each attribute listed in Section 1.3 will include insights gained from analysis of existing published studies, bolstered by assessment of any available data.

1.4.3 Existing datasets at the MDB scale

There are several hundred individual research projects that have investigated native fish in the MDB over the past several decades, but these typically have restricted temporal or spatial scales, or are limited in the species studied, or are research projects designed to answer specific scientific questions. A summary of projects funded under the MDB Native Fish Strategy (MDBC 2004) is available (Barrett et al. 2013).

The MDBFS and SRA fish datasets are two successive monitoring programs that were designed to collect fish data at the Basin scale to inform a river health assessment for the whole of the MDB (Davies et al. 2008, 2010a, Robinson et al. 2019). These river health assessments do not require precise assessments of fish species present, their abundance or biomass, populations genetics or recruitment status. Thus, these two datasets are available to make whole-of-Basin assessments, but only in a coarse manner for assessing fish status for some attributes and for general trends. Nevertheless, the programs were well designed, allowing consistent assessments through time with the intention of allowing basic trend estimates after eight sampling rounds and statistically powerful trend estimates after 15 sampling rounds. Data collected in 2022 marked the 11th sampling round (three SRA, eight MDBFS) and the data collected in these monitoring programs are invaluable to the current status assessment.

The SRA/MDBFS datasets inform Chapters 4 (species distribution) and 5 (population dynamics) of this report. Fish location data were compiled by the MDBA from multiple source datasets including SRA, MDBFS, NSW BPEOM, The Living Murray and other information collated for the revised edition of *Fishes of the Murray–Darling Basin* (Lintermans 2023). Each location record was assigned to the SRA valley it was located in and partitioned into three date classes (pre-1980, 1980–2010 and 2011 onwards). Accuracy of species identifications, sampling location and capture dates are inherited from the various source datasets. Approximately 96% of the nearly 270 000 fish records[1] had location information recorded to an accuracy of 100 m or better in the compiled data provided by MDBA. Fifty-two data sources were used for this status assessment; the complete list of data sources is found in Appendices 1 and 4.

1.4.4 Future datasets at the MDB scale

The environmental management landscape when the SRA sampling programs were designed in 2003 is not the same as today. For example, objectives for research and management, priorities for sampling, technologies for sampling and analyses have all changed. The SRA and MDBFS

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[1] This is for the trend analysis; the distribution mapping dataset contained 6.6 million fish records (G. Ringwood, MDBA, pers. comm.).

programs were aware of these issues in advance and always promoted the use of supplementary sampling to address local or species-specific issues.

A major constraint on adapting or supplementing the Basin-wide SRA/MDBFS data is that the programs were designed as large-scale spatial sampling programs. That is, the SRA/MDBFS were designed to assess river kilometres, not individual fish or fish populations. This has two major limitations:

- The dataset currently is constrained to flowing channels (more than 25 ML day), and small order streams and wetlands are not represented at all.
- Fish populations cannot be well assessed because
  - a genuine population study would select fish at random, rather than river kilometres
  - rare, cryptic and/or threatened species are not well assessed by generic monitoring programs.

Thus, while Chapter 5 of this report gives a coarse assessment for many fish population parameters, it is desirable that future assessments use population-specific or management-question–specific (e.g. effects of environmental water, effects of threatened fish reintroductions) and potentially policy objective–specific sampling programs. The monitoring program for Melbourne Water's Healthy Waterways Strategy (Melbourne Water 2018) is an example of an integrated monitoring program using background monitoring while addressing species-specific, intervention-specific and jurisdictional-specific objectives. The trade-off in designing an integrated program is the requirements for different populations or management scenarios are unique, subject to change in the future, and the costs can be significant. Inevitably, without very large-scale investment, the current situation in the MDB with a large background surveillance monitoring program (the SRA/MDBFS) and multiple smaller-scale specific research projects is the best possible interim product. However, further coordination between the Basin state programs would improve the value of fish monitoring outputs and outcomes, particularly if species population assessments were included.

1.5 Key findings – undertaking a status assessment

Key findings

This is a first attempt at preparing a status assessment on native fish at the Basin scale; it is an important exercise that highlights knowledge gaps and the need for additional information to ensure future more quantitative assessments.

Although there have been numerous native fish projects implemented across the MDB in recent decades, relatively few were established to assess the status of native fish at the scale of the MDB. Most projects have been tailored to local conditions to answer specific evaluation questions at smaller spatial and temporal scales than is required to assess the status of native fish across the MDB over time. However, many projects, particularly jurisdictional fish monitoring programs, are now at the stage where the combination and coordination of data and expertise can be used to inform future status assessments.

2 Number of native fish species

2.1 Background

Knowing how the number of fish species in the MDB has changed over time is important, as the loss of species can be a powerful indicator of declining aquatic ecological health (Davies et al. 2010a). Species richness describes the number of species inhabiting a given area. While an area of high native richness may suggest high conservation value, species richness alone does not consider anything about the identity of the species (e.g. whether they are rare or endemic, or their functional role in aquatic ecosystems). A reduction in observed species richness through time could indicate permanent loss of the species (extinction) or that the detection of the species is declining, and potentially that the species is declining in abundance and/or distribution.

Overall, the number of fish species reported from the MDB has grown over time for several reasons. Early species counts often excluded the estuarine and marine species found in the Coorong (Lake 1967, Cadwallader and Lawrence 1990). There are also reported introductions of native fish species to several river valleys that are outside their natural range (referred to as translocated species) (e.g. climbing galaxias, *Galaxias brevipinnis*) and rare discoveries of truly 'new' occurrences of native species. The major driver of the increase in the number of native fish species has been the discovery and description of several cryptic fish species (i.e. species have been recognised and split from within existing species). It has been estimated that 25–33% of Australian freshwater fish are currently undescribed (Hammer et al. 2013a, Unmack 2013).

2.2 Assessment approach

The assessment of the number of native fish species is based on the work of Lintermans (2023), who reviewed existing data for the fish of the MDB. This included searches of the scientific literature, and ad hoc interactions with state agencies and independent researchers to capture surveys and information gained since the early 2000s. The results of the dedicated fish monitoring programs in the MDB (SRA, 2004–2013) and the MDB Fish Survey (2014–present) have also been assessed. Dedicated survey and monitoring work in the Coorong and Lower Lakes has greatly improved understanding of the fish fauna of these waterbodies (e.g. Bice et al. 2018, Wedderburn et al. 2012). The assessment presents the latest native fish species list for the MDB, including those of the Coorong and Lower Lakes, and identifies new native fish species recorded since 2010.

Species that occur upstream of the Coorong are broadly characterised as either Northern Basin, Southern Basin or Basin-wide, with species that only occur in Coorong identified as such, with their life history categorised as a simplified version of that used in Bice et al. (2020).

In addition to native fish, there is also interest in the status of freshwater spiny crayfish and freshwater mussels across the MDB, as many are listed as threatened under national and state legislation (e.g. Queensland *Fisheries Act 1994*). However, assessing the status of freshwater spiny crayfish and mussel populations is difficult due to the often patchy (spatially and temporally) nature of sampling and monitoring for these species across the MDB. Thus, the status of freshwater spiny crayfish and freshwater mussels is described in case studies that utilise (sometimes limited) information and reports (see Chapter 6).

While this status assessment focuses predominantly on native fish, it is recognised that alien fish species are a significant component of fish assemblages and biomass across the MDB (Gehrke et al. 1995, Gehrke and Harris 2000, Stuart et al. 2021, Lintermans 2023, Crook et al. 2023). A case study on carp (*Cyprinus carpio*) has been included (Section 2.4) to emphasise the dominance of this and other alien fish species.

2.3 Results – number of species

2.3.1 Native fish

There are 18 marine or estuarine fish species that are found in the Coorong, including iconic species such as mulloway (*Argyrosomus japonicas*) and black bream (*Acanthopagrus butcheri*) (Table 1). Upstream of the Coorong, there are 51 native fish species, including two (both river blackfish, *Gadopsis* spp.) that are not formally described, in the freshwater environments of the Lower Lakes and the Murray and Darling-Baaka rivers and their tributaries (Table 2). A full list of species based on body size (small-, medium- and large-bodied species), and preferred environmental zones (headwaters, montane, slopes, upland, lowland, estuary) is presented in Appendix 2.

There are 27 freshwater fish species that occur only in the Southern Basin, five species that only occur in the Northern Basin, and 19 that occur Basin-wide (see Table 2).

Table 1. Native fish found in the Coorong (i.e. downstream of the barrages) and their life history category

Scientific name	Common name	Life history category
Acanthopagrus butcheri	Black bream	Estuarine
Aldrichetta forsteri	Yellow-eyed mullet	Marine
Ammotretis rostratus	Long-snouted flounder	Marine
Arenogobius bifrenatus	Bridled goby	Estuarine
Argyrosomus japonicas	Mulloway	Marine
Arripis georgianus	Australian herring	Marine
Arripis truttaceus and *A. trutta*	Australian salmon	Marine
Cnidoglanis macrostomus	Estuary catfish	Estuarine
Contusus brevicaudus	Prickly toadfish	Marine
Engraulis australis	Australian anchovy	Marine
Gymnapistes marmoratus	Soldier fish	Estuarine
Hyperhamphus regularis	River garfish	Estuarine
Hyperlophus vittatus	Sandy sprat	Marine
Liza argentea	Goldspot mullet	Marine
Platycephalus speculator	Blue–spotted flathead	Marine

Scientific name	Common name	Life history category
Rhombosolea tapirina	Greenback flounder	Marine
Sillago schomburgkii	Yellowfin whiting	Marine
Tetractenos glaber	Smooth toadfish	Marine

Marine stragglers (i.e. marine taxa that are rarely recorded in the Coorong) are excluded, with estuarine and freshwater species that occur upstream of the Coorong listed in Table 2.
Source: Lintermans 2023

Table 2. Freshwater fish of the Murray–Darling Basin, their origin, distribution and requirements for marine or estuarine access

Family	Scientific name	Common name	Origin	Distribution	Estuarine or marine access required
Mordaciidae	*Mordacia mordax*	Short-headed lamprey	N	South	Yes
Geotriidae	*Geotria australis*	Pouched lamprey	N	South	Yes
Anguillidae	*Anguilla australis*	Short-finned eel	N/T	South	Yes
Anguillidae	*Anguilla reinhardtii*	Long-finned eel	N/T	Basin	Yes
Clupeidae	*Nematalosa erebi*	Bony herring	N	Basin	No
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	N/T	South	Yes*
Galaxiidae	*Galaxias fuscus*	Barred galaxias	N	South	No
Galaxiidae	*Galaxias olidus*	Mountain galaxias	N	Basin	No
Galaxiidae	*Galaxias oliros*	Obscure galaxias	N	South	No
Galaxiidae	*Galaxias arcanus*	Riffle galaxias	N	South	No
Galaxiidae	*Galaxias maculatus*	Common galaxias	N/T	South	Yes
Galaxiidae	*Galaxias rostratus*	Flathead galaxias	N	South	No
Galaxiidae	*Galaxias truttaceus*	Spotted galaxias	N/T?	South	Yes*
Galaxiidae	*Galaxias tantangara*	Stocky galaxias	N	South	No
Galaxiidae	*Galaxias ornatus*	Ornate galaxias	T?	South	No
Retropinnidae	*Retropinna semoni*	Australian smelt	N	Basin	No
Plotosidae	*Porochilus rendahli*	Rendahl's	N	North	No

Family	Scientific name	Common name	Origin	Distribution	Estuarine or marine access required
		tandan			
Plotosidae	*Porochilus argenteus*	Silver tandan	N	North	No
Plotosidae	*Neosilurus hyrtlii*	Hyrtl's tandan	N	North	No
Plotosidae	*Tandanus tandanus*	Freshwater catfish	N/T	Basin	No
Atherinidae	*Craterocephalus amniculus*	Darling River hardyhead	N	North	No
Atherinidae	*Craterocephalus fluviatilis*	Murray hardyhead	N	South	No
Atherinidae	*Craterocephalus stercusmuscarum fulvus*	Unspecked hardyhead	N	Basin	No
Atherinidae	*Atherinosoma microstoma*	Small-mouthed hardyhead	N	South	Yes*
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray–Darling rainbowfish	N	Basin	No
Melanotaeniidae	*Melanotaenia splendida tatei*	Desert rainbowfish	N	North	No
Ambassidae	*Ambassis agassizii*	Olive perchlet	N	Basin	No
Percichthyidae	*Macquaria ambigua ambigua*	Golden perch	N	Basin	No
Percichthyidae	*Macquaria australasica*	Macquarie perch	N	South	No
Percichthyidae	*Percalates colonorum*	Estuary perch	N	South	Yes
Percichthyidae	*Maccullochella macquariensis*	Trout cod/Bluenose cod	N	South	No
Percichthyidae	*Maccullochella peelii*	Murray cod	N	Basin	No
Percichthyidae	*Nannoperca australis*	Southern pygmy perch	N	South	No
Percichthyidae	*Nannoperca obscura*	Yarra pygmy perch	N	South	No
Percichthyidae	*Gadopsis bispinosa*	Two-spined blackfish	N	South	No
Percichthyidae	*Gadopsis* sp. *nov* *'Goulburn'*	Goulburn two-spined blackfish	N	South	No

Family	Scientific name	Common name	Origin	Distribution	Estuarine or marine access required
Percichthyidae	*Gadopsis marmorata*	Northern river blackfish	N	Basin	No
Percichthyidae	*Gadopsis* sp. *nov 'Wimmera'*	Few-spined river blackfish	N	South	No
Terapontidae	*Leiopotherapon unicolor*	Spangled perch	N	Basin	No
Terapontidae	*Bidyanus bidyanus*	Silver perch	N	Basin	No
Bovichtidae	*Pseudaphritis urvillii*	Congolli	N	South	Yes
Eleotridae	*Philypnodon grandiceps*	Flat-headed gudgeon	N	Basin	No
Eleotridae	*Philypnodon macrostomus*	Dwarf flat-headed gudgeon	N	Basin	No
Eleotridae	*Mogurnda adspersa*	Southern purple-spotted gudgeon	N	Basin	No
Eleotridae	*Hypseleotris klunzingeri*	Western carp gudgeon	N	Basin	No
Eleotridae	*Hypseleotris bucephala*	Boofhead carp gudgeon (formerly Midgley's carp gudgeon)	N	Basin	No
Eleotridae	*Hypseleotris acropinna*	Cryptic carp gudgeon (formerly Murray–Darling carp gudgeon)	N	Basin	No
Eleotridae	*Hypseleotris gymnocephala*	Bald carp gudgeon	N	South	No
Gobiidae	*Pseudogobius olorum*	Western blue-spot goby	N	South	No
Gobiidae	*Afurcagobius tamarensis*	Tamar goby	N	South	Yes
Gobiidae	*Tasmanogobius lasti*	Lagoon goby	N	South	Yes

Origin: N = native; T = translocated; distribution: North (Northern Basin), South (Southern Basin), Basin (Basin-wide); estuarine/marine: Yes, No (asterisk on estuarine/marine indicates landlocked populations can occur)
Source: Lintermans 2023

Since 2010 there have been 11 'new' fish species found in the MDB. Eight of these are newly described species with five new galaxiids (barred galaxias, *Galaxias fuscus*; obscure galaxias, *Galaxias oliros*; riffle galaxias, *Galaxias arcanus*; stocky galaxias, *Galaxias tantangara* and ornate galaxias, *Galaxias ornatus*) (Raadik 2014) and three new carp gudgeons (boofhead carp gudgeon *Hypseleotris bucephala*; cryptic carp gudgeon *Hypseleotris acropinna* and bald carp gudgeon, *Hypseleotris gymnocephala*) (Thacker et al. 2022). Two new but undescribed blackfish have been identified (one each in the Goulburn and Wimmera catchments in Victoria). In addition to the newly described or recognised species, there has been a recording of a new catfish for the Basin (silver tandan, *Porochilus argenteus*) from Queensland (Lintermans 2023). This species is common in northern Australia and the adjacent Lake Eyre Basin and has likely naturally moved across the slight catchment divide into the western Paroo drainage (Lintermans 2023).[2]

The nationally threatened Yarra pygmy perch (*Nannoperca obscura*) is the only species lost entirely from the MDB since 2010. It was first recognised as occurring in the MDB in 2001 (Hammer 2007), with the species only recorded in Lake Alexandrina in South Australia. The significant lowering of water levels in the Lower Lakes during the Millennium drought (2006–2010) resulted in the local extinction of Yarra pygmy perch when essential fringing reedbed habitat became isolated, exposing the species to increased predation from alien species such as redfin perch (*Perca fluviatilis*) (Wedderburn et al. 2012). Prior to extinction, some individuals were rescued, bred in captivity, and reintroduced between 2011 and 2015; however, this reintroduction was unsuccessful (Hammer et al. 2013b, Wedderburn et al. 2019, 2022). Yarra pygmy perch occur outside of the MDB in coastal catchments in South Australia and Victoria. This is the first documented extinction of a fish species from the MDB, although it is possible that other species may have been lost before they were recognised or described.

2.3.2 Recent taxonomic advances

Galaxias

The five new galaxiids were all formerly part of the mountain galaxias complex (*Galaxias olidus*) and were described in 2014 (Raadik 2014). Historically, the Galaxiidae in Australia has a long history of taxonomic confusion and revision. Prior to the 1981 revision of the Galaxiidae by McDowall and Frankenberg (1981), common galaxias (*G. maculatus*) was known in the literature under 17 names in Australia alone, and a further nine names in other parts of its range. Climbing galaxias had been described under seven names in Australia and a further eight in New Zealand, and mountain galaxias had a total of eight synonyms in Australia. Ten previously described *Galaxias* species were combined into mountain galaxias by McDowall and Frankenberg (1981) with the redescribed species containing a variety of morphological forms. Prior to the recent taxonomic review of Raadik (2014), the mountain galaxias complex consisted of a single described species that included a long-recognised, nationally threatened, but not formally redescribed taxa (barred galaxias); a previously described but no longer valid species (ornate galaxias) and a range of previously unrecognised cryptic taxa. The review of Raadik (2014) redescribed barred, ornate and mountain galaxias and identified a further 12 cryptic taxa. All 15 taxa in the mountain galaxias complex are restricted to southern Australia, with all five of the newly described taxa for the MDB occurring in the Southern Basin, and two of these species (ornate and obscure galaxias) also

[2] Note that the boundary of the MDB is a legislative boundary and has slight imperfections that cannot be changed to reflect the minor but true discrepancies. Mapping may indicate the species is either in or outside of the Basin. Best available data indicate it is within the Basin.

occurring in coastal streams. Mountain galaxias occurs in both the Northern Basin and Southern Basin (as well as in some coastal rivers).

Carp gudgeons

The three new carp gudgeons were only recently described (Thacker et al. 2022) and now resolve all of the parental, sexual species in the *Hypseleotris* complex in the MDB. Genetic studies in the early 2000s showed that there were several sexual species of carp gudgeon occurring in coastal and inland drainages in eastern Australia, as well as a range of hemiclonal unisexual hybrids.[3]

Many of the carp gudgeon groups formerly considered as 'species' were not formally described (e.g. Lake's, Murray–Darling and Midgley's carp gudgeons), with one of these (Lake's) now considered to only consist of hemiclonal hybrids. Because many of the hemiclonal and sexual lineages look very similar, for around 20 years carp gudgeons in the MDB have been combined into a generic group and referred to as '*Hypseleotris* spp.'(i.e. *Hypseleotris* of undefined species).

In late 2022 the taxonomic situation became clearer, with five species formally described or redescribed, plus a range of hemiclonal hybrids identified. In the MDB there are four sexual species present (western, bald, boofhead and cryptic carp gudgeons). There are also multiple hemiclonal unisexual lineages of hybrid origin between the latter three species. Western carp gudgeon (*Hypseleotris kunzingeri*) does not form hybrids. In some parts of the MDB up to three sexual species co-occur with three hemiclonal forms, all being captured in the same location (Thacker et al. 2022, Lintermans 2023).

Species formerly anecdotally known as Murray–Darling carp gudgeon, Lake's carp gudgeon, and Midgley's carp gudgeon are all now known to be mixes of both sexual species and hemiclonal hybrid forms. The discovery in 2012 of the bald carp gudgeon in the upper Lachlan River in NSW was the key to understanding the taxonomy of this group (Unmack et al. 2019). Previously the genetic identity of this species had been inferred from the genetic structure of some of the hemiclonal hybrids (Lake's and Midgley's), but the sexual species had never been collected, and it was referred to as 'species x': a ghost species (Bertozzi et al. 2000, Unmack et al. 2019). The critically endangered bald carp gudgeon is the most restricted of the new MDB species, being found only in two small creeks in the upper Lachlan River catchment (Unmack and Pearce 2019).

Blackfish

The two undescribed blackfish, *Gadopsis* sp. nov. 'Goulburn' and *Gadopsis* sp. nov. 'Wimmera', bring the total number of taxa in the genus *Gadopsis* to seven (Hammer et al. 2014), with four of these present in the Basin.

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[3] Hemiclonal hybridization is the production of two or more individuals via hybridization between two closely related species.

Species complexes still to be resolved

The number of native fish species recognised in the MDB is increasing and is likely to continue into the future, given that:

- the taxonomy of Ambassids (perchlets or glass fishes), Plotosids (catfish, including Hyrtl's tandan, *Neosilurus hyrtlii*), and purple-spotted gudgeons (*Mogurnda* spp.) still contains multiple cryptic species (Unmack 2013)
- there are more undescribed galaxias outside the MDB, and possibly within (T. Raadik, unpublished data)
- there are further cryptic species within the flathead and dwarf flathead gudgeon (*Philypnodon* species) (Hammer et al. 2019)
- there are cryptic species within the gobies (*Pseudogobius* species) (Hammer et al. 2021).

Whether future taxonomic reviews add to the species count or simply change the names of species currently known from the MDB remains to be seen.

2.3.3 Alien fish species

There are 15 alien fish species established in the MDB, including 12 from overseas plus several translocated native species from outside the Basin (Table 3). A further six native species occur as both native and translocated sub-populations (excluding translocations for conservation purposes) within the Basin (see Table 2). For some of these, the native distribution is extremely limited (e.g. climbing galaxias is native to the lower Murray but invasive translocated sub-populations are still expanding in the upper Murray and Murrumbidgee catchments).

One new alien species from overseas (crucian carp, *Carassius carassius*) and one new translocated native species, ornate galaxias, have been confirmed to be present in the MDB since 2010. The crucian carp has an extremely limited known distribution (Campaspe River) but confusion with goldfish (*Carassius auratus*) may obscure a wider distribution than this. Most alien species (nine of 13 species) occur in the Southern Basin, with four of the nine species also occurring in the Northern Basin (i.e. they are Basin-wide) (Table 3). Brook char (*Salvelinus fontinalis*) formerly had very limited occurrences in both the Northern Basin and Southern Basin, but it is believed the northern sub-population did not survive the Millennium drought (Lintermans 2023). There are no alien species that are restricted solely to the Northern Basin.

Table 3. Alien and translocated 'native' freshwater fish of the Murray–Darling Basin, their origin and current distribution

Family	Scientific name	Common name	Origin	Distribution
Galaxiidae	*Galaxias ornatus*	Ornate galaxias	T?	South
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	N/T	South
Galaxiidae	*Galaxias truttaceus*	Spotted galaxias	N/T	South
Salmonidae	*Salmo trutta*	Brown trout	I	Basin
Salmonidae	*Salmo salar*	Atlantic salmon	I	South
Salmonidae	*Salvelinus fontinalis*	Brook char	I	Basin
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	I	Basin
Cyprinidae	*Cyprinus carpio*	Carp	I	Basin
Cyprinidae	*Carassius auratus*	Goldfish	I	Basin
Cyprinidae	*Carassius carassius*	Crucian carp	I	South
Cyprinidae	*Tinca tinca*	Tench	I	South
Cyprinidae	*Rutilus rutilus*	Roach	I	South
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	I	South
Poecilidae	*Gambusia holbrooki*	Eastern gambusia	I	Basin
Percidae	*Perca fluviatilis*	Redfin perch	I	Basin

N/T = species that are native to part of the Basin but have been translocated outside their natural range.
Origin: I = alien; T = translocated 'native'; distribution: South (Southern Basin), Basin (Northern and Southern Basins)
Source: Lintermans 2023

The number of alien species present in the Basin has remained fairly constant for several decades, with the last significant invasion – from oriental weatherloach (*Misgurnus anguillicaudatus*) – occurring in the mid-1980s (Lintermans et al. 1990, Lintermans and Burchmore 1996). Both 'new' alien species have likely been present for decades but have either been unrecognised because of taxonomic confusion (e.g. crucian carp) or taxonomic revision (ornate galaxias was part of mountain galaxias complex until 2014). Crucian carp was historically listed as present in Australia in early fish texts (Tenison-Woods 1882, Gale 1927, McCulloch 1934, Lake 1967) but has not been listed in contemporary fish texts since the early 1980s (Merrick and Schmida 1984, Clements 1988, Allen et al. 2002, Lintermans 2007) as the early accounts were considered misidentifications. The greatest risk of establishment of new alien fish is via the ornamental fish industry (Lintermans 2004, García-Díaz et al. 2018) or translocations from previously established populations. Waterways in warmer climatic locations (e.g. the Northern Basin) are considered most at risk of translocations (Ebner et al. 2020). One alien species that is threatening to invade the Northern Basin is Mozambique tilapia (*Oreochromis mossambicus*). This species is listed in the top 100 of the world's worst invasive alien species (Lowe et al. 2000), and currently occurs in Queensland in catchments adjacent to the Basin, and is still expanding its range (Russell et al. 2012).

2.4 **Case study** – Carp

Prepared by John Koehn

Carp are an internationally abundant species that are implicated in the declines of many fish species (Koehn 2004) and potentially are reservoirs of parasites that may infect native fish (Lintermans 2022b). Carp numbers increased strongly after their introduction into the MDB (Forsyth et al. 2013) then fluctuated over time, often in response to higher flows (Todd et al. 2019, Stuart et al. 2021). Crook et al. (2023) showed that their relative abundance in the NSW portion of the MDB showed no clear general trend over 2011–2022 but was characterised by a series of peaks and troughs, with a major peak associated with a large recruitment event occurring around 2010–12 following floods. There was an overall declining trend in biomass punctuated by a sharp increase in the years following recruitment (2011–13) and a sharp decline after 2019 (Crook et al. 2023). Carp population structure alternated between periods dominated by adults and by small fish (<20 cm total length). Stuart et al. (2021) estimated carp total numbers (for Australia) to be 199 million (95% confidence interval: 106 million to 358 million) for an 'average' hydrological scenario, and 358 million (95% confidence interval: 179 million to 685 million) for a 'wet' hydrological scenario. Sharp peaks in biomass of juvenile carp occurred following flooding in 2011 and 2016–2017 (Stuart et al. 2021), with field observations suggesting the same occurred in the 2023 floods (Stuart et al. 2023).

Key messages:

- Carp remain a prominent alien species in the MDB, often forming a large proportion of the total abundance and biomass of fish present (Stuart et al. 2021).
- Numbers and biomass have fluctuated in response to varying environmental conditions since 2010.

2.5 Key findings – number of fish species

Key findings

Potential status assessment questions were identified in Cottingham et al. (2022) and refined in consultation with the Native Fish Recovery Strategy Technical Advisory Group (see Appendix 1, Table 18) for each attribute; however, some questions are not addressed due to scope and data limitations.

What is the total number of native fish species?

There are 18 estuarine/marine species and 51 native freshwater species that occur across the MDB. There are also 15 alien fish species.

Of the freshwater species, 27 occur only in the Southern Basin, five only in the Northern Basin, and 19 occur Basin-wide.

The number of native fish species recognised in the MDB continues to grow, and this will likely continue into the future as the taxonomy of several species' complexes is resolved.

Has the total number of species increased, decreased or remained stable? Why has this occurred?

Trend is increasing from 2010 point of reference due to taxonomic resolution of species complexes.

While there have been 11 additional species included since 2010, almost all of these are the result of taxonomic resolution of species complexes. The only species new to the MDB since 2010 (not including taxonomic revision) is the silver tandan (*Porochilus argenteus*) found in the Paroo River, Queensland.

The Yarra pygmy perch (*Nannoperca obscura*) is the only species known to have been lost from the MDB since 2010. This was despite captive breeding and reintroduction efforts.

There are 13 species of freshwater spiny crayfish present across the MDB. Most occur in headwater streams, with only Murray crayfish (*Euastacus armatus*), alpine spiny crayfish (*E. crassus*) and Riek's crayfish (*E. rieki*) being more widely distributed across Murray River and/or Darling River catchments.

There are five freshwater mussel species that occur across the MDB including the freshwater mussel (*Alathyria condola*), river mussel (*Alathyria jacksoni*), and the smaller billabong mussel (*Velesunio ambiguous*).

Has the total number of alien species increased, decreased or remained stable?

Trend is slowly increasing from 2010 point of reference, with only a single new species identified, crucian carp, via taxonomic resolution.

The number of alien fish species in the MDB is growing slowly, mostly as a result of improved or new taxonomic knowledge. However, the threat of future establishment by new alien species is high, particularly in the Northern Basin.

3 Species conservation status

3.1 Background

Freshwaters have long been considered one of the most highly threatened biomes globally (WWF 2023, Sala et al. 2000, Millennium Ecosystem Assessment 2005, Collen et al. 2014, Dudgeon 2019, Reid et al. 2019, Feio et al. 2023), with freshwater fish a highly threatened faunal group (Malmqvist and Rundle 2002, Dudgeon et al. 2006, Vorosmarty et al. 2010). Existing known threats to freshwater fish, and new pressures from issues such as microplastics and endocrine disrupting chemical pollution, are only expected to increase in future as human populations increase. Furthermore, impacts of climate change, such as increases in maximum water temperatures, more extreme flow conditions, and increased water use are projected to put additional pressure on freshwater fish populations likely resulting in localised species extinctions (Barbarossa et al. 2021).

Globally, the number of threatened freshwater fish taxa on the International Union for Conservation of Nature (IUCN) Red List listed as Extinct in the Wild, Critically Endangered, Endangered or Vulnerable has increased nearly 17-fold over the last 25 years, from 140 in 1996 to 2 325 in 2020 (version 2020.2; IUCN 2020) (Lintermans 2022a). Australian freshwaters are similarly under significant pressure, with freshwater a highly contested resource for agricultural, consumptive, industrial, environmental and aesthetic uses throughout Australia. These competing pressures on freshwater manifest in multiple ways with habitat alteration and loss, flow regulation, impeded fish passage, water quality degradation, and the impacts of alien species considered the major threats to native fish (MDBA 2020a, Lintermans et al. 2020, Malmqvist and Rundle 2002, Dudgeon et al. 2006, Vorosmarty et al. 2010). Rivers in the MDB are one of the most regulated and fragmented systems in the world (Grill et al. 2019), with numerous impoundments, diversions, irrigation canals, weirs and extraction points. Consequently, almost half of the MDB native freshwater fish species have been listed as rare or threatened for several decades (Koehn and Lintermans 2012, Lintermans 2007, 2013a). Species in the MDB can be listed at international, national or state/territory scales, with listings being both legislative (e.g. the EPBC Act 1999) or advisory (e.g. IUCN 2023).

The use of threatened species lists is a key mechanism for tracking the conservation status of individual taxa and biotic groups (Possingham et al. 2002, Hoffman et al. 2010, Harris et al. 2012) and threatened species legislation provides a primary mechanism to recover threatened species (Male and Bean 2005, Doub 2013, Favaro et al. 2014). Tracking how many species are listed and changes in the level of endangerment of fish in the MDB over time is important, as this can provide insight into whether species or fish community recovery and management programs are successful (Koehn and Lintermans 2012).

There is considerable variation in the content, listing status and temporal relevance between the different conservation listings. State jurisdictional listings are in part driven by public nominations and, therefore, not necessarily undertaken in a comprehensive or priority order. Under the EPBC Act there is an annual prioritisation process that considers public nominations as well as entities nominated by experts and the Threatened Species Scientific Committee. This list is provided to the Minister for the Environment, and if approved becomes the Final Prioritised Assessment List for that year. In 1999, the Australian Society for Fish Biology (the national professional society for fish and fisheries) supported a group of scientists to undertake a targeted assessment of Australia's freshwater fish, which then informed the most recent IUCN assessment in 2019

(M. Lintermans, University of Canberra, unpubl. data). This IUCN assessment, however, only deliberates on species within the national or international setting without consideration of regions, sub-populations or subspecies. There are several species for which MDB populations are under significant threat (e.g. freshwater catfish, *Tandanus tandanus*; southern pygmy perch, *Nannoperca australis*) despite these species being relatively secure in coastal catchments outside the MDB (Gilligan and Clunie 2019, Pearce et al. 2019).

3.2 Assessment approach

Threatened fish species and community listings from all state/territory, national and international lists were examined and compiled, including both statutory and advisory lists. Statutory lists are available for NSW, Queensland, ACT, South Australia and Victoria, but no fish species from the MDB in Queensland are currently listed as threatened (as of December 2022) although two species are protected in some valleys.

Although most lists are largely consistent in the categories used (Extinct, Critically Endangered, Endangered, Vulnerable) there is some slight variation, usually at the lower status levels. The IUCN Red List has a Near Threatened category, which is not present in any listings other than Queensland. The IUCN Red List also has a Data Deficient category that is not present in any other listing. South Australia has a 'Rare' category that is broadly equivalent to the IUCN Near Threatened. Three lists contain listings at below species level, with NSW listing populations, and both Victoria and the EPBC national lists including lineages. Non-statutory listings included those of the IUCN Red List, Australian Society for Fish Biology, and provisional listings for South Australia (not yet adopted under legislation).

The IUCN Red List is assessed at a described species scale, which means that for species that are known to contain subspecies, cryptic taxa or multiple lineages, the assessment combines all of these. For example, the two described and one undescribed taxa within golden perch (from the Lake Eyre, Fitzroy and MDB drainages) (Beheregaray et al. 2017) are combined into a single assessment (Lintermans and Kerezsy 2019). Similarly, the IUCN assessment of southern pygmy perch includes the MDB, and coastal lineages combined. The IUCN assessment is also at a global scale, so for non-endemic Australian species (i.e. that also occur outside Australia), the assessment combines results from all range countries. For example, the IUCN assessment of pouched lamprey (*Geotria australis*) includes populations in New Zealand and South America, and because the status in South America was unknown, the assessment was Data Deficient, even though Australian and New Zealand populations were clearly declining (Bice et al. 2019).

All categories of endangerment were included in this assessment if they were data-driven and defendable.

3.3 Results – species conservation status

3.3.1 Threatened fish

At the time of analysis (March 2023), 24 of the 51 native freshwater species in the MDB are recognised as rare or threatened on state, territory, national or international listings (Table 4).

The unprecedented summer bushfires of 2019–20 had a devastating impact on Australia's natural and cultural riches. As part of the Australian Government's bushfire response, there has been an accelerated program of listing assessments by utilising expert scientific groups to undertake listing assessments on groups of species or ecological communities. The Species Expert Assessment Plans (SEAP project) addressed both fire-affected and non-fire-affected species over a 2-year period. Under the SEAP project, over 90 native fish species across Australia were identified by experts as being eligible for assessment, which included 39 MDB native freshwater species. Along with the 24 species already listed at the state, national or international level (Table 4), another 18 species were of potential conservation concern post the fires, and three of those are currently being assessed for listing as threatened at the national level under the EPBC Act (see Table 5). Overall, this equates to 42 of the 51 freshwater species, or 82%, in the MDB being either listed or of significant conservation concern given the potential impact of large-scale threats such as bushfires.

A number of MDB fish communities are also listed as threatened. In NSW, three aquatic ecological communities are categorised as Endangered (the lower Murray, lower Darling-Baaka, and lower Lachlan), and in Victoria the Lowland Riverine Fish Community of the Southern Murray–Darling Basin is listed as threatened.

Table 4. Threatened fish species in the Murray–Darling Basin according to state, territory, national and international listings

Scientific name	Common name	ACT	NSW	Vic	SA	Qld	National[a]	Internat.[b]
Ambassis agassizii	Olive perchlet		EN POP	EX	PROT [EX]			LC[c]
Anguilla australis	Short-finned eel				[R]			NT[c]
Bidyanus bidyanus	Silver perch	EN	VU	EN	PROT [EN]	REG Warrego and Paroo	CE[d] {VU}	NT
Craterocephalus amniculus	Darling River hardyhead		EN POP[e]				{VU}	LC
Craterocephalus fluviatilis	Murray hardyhead		CE	CE	[EN]		EN{CE}	CR
Gadopsis bispinosa	Two-spined blackfish	VU						NT
Gadopsis marmorata	Northern river blackfish		EN POP[e]		PROT [EN]	REG (no take)		LC[c]
Galaxias fuscus	Barred galaxias			CE			EN {CE}	EN
Galaxias olidus	Mountain galaxias				[R]			LC
Galaxias	Flathead		CE	VU	[EX]		CE {VU}	CR

Scientific name	Common name	ACT	NSW	Vic	SA	Qld	National[a]	Internat.[b]
rostratus	galaxias							
Galaxias tantangara	Stocky galaxias		CE				CE	CR
Galaxias truttaceus	Spotted galaxias				[EN]		EN – WA only	LC
Geotria australis	Pouched lamprey				[R]			DD[c,f]
Maccullochella macquariensis	Trout cod	EN	EN	EN	PROT [EX]		EN {CE}	VU
Maccullochella peelii	Murray cod			EN	[EN]		VU	LC
Macquaria australasica	Macquarie perch	EN	EN	EN	[EX]		EN	EN
Melanotaenia fluviatilis	Murray–Darling rainbowfish			EN				LC
Mogurnda adspersa	Southern purple-spotted gudgeon		EN	CE	PROT [CE]			LC[c]
Mordacia mordax	Short-headed lamprey				[R]		{VU}	LC[c]
Nannoperca australis	Southern pygmy perch		EN	VU [MDB LIN]	PROT [EN]		VU LIN	NT[c]
Nannoperca obscura	Yarra pygmy perch			VU	[CE]		VU	EN
Percalates colonorum	Estuary perch				[R]			LC
Pseudaphritis urvillii	Congolli				[R]			LC
Tandanus tandanus	Freshwater catfish		EN POP	EN	PROT [EN]			LC[c]

EX = Extinct in the Wild; CE = Critically Endangered; CR = Critically Endangered (IUCN); REG EX = Regionally Extinct; EN = Endangered; VU = Vulnerable; EN POP = Endangered Population; NT = Near Threatened; LIN = MDB Lineage; R = Rare; LC = Least Concern; DD = Data Deficient; PROT = Protected under SA *Fisheries Management Act 2007*; REG (no take) = Regulated under Qld *Fisheries Act 1994*; [xx] = provisional SA status (Department for Environment and Water, unpublished data September 2022): administrative status assessments that are yet to be adopted under legislation; {xx} status under the Australian Society for Fish Biology list (if listed and different to EPBC)

a National status under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC).
b Status under IUCN Red List.
c IUCN Red List combines described, recognised but undescribed (e.g. southern and northern river blackfish), multiple lineages, and sometimes countries of occurrence in a single species status.
d Proposed for reclassification as Endangered in 2021.
e Only populations outside the MDB listed.
f Has declined in Australia and New Zealand, but status of South American population is unknown.

Note: Relevant legislation:
Environment Protection and Biodiversity Conservation Act 1999 (national)
Flora and Fauna Guarantee Act 1988 (Vic)
Nature Conservation Act 2014 (ACT)
Fisheries Management Act 1994 (NSW)
Fisheries Management Act 2007 (SA)
Fisheries Regulation 2008 (Schedule 2), under the *Fisheries Act 1994* (Qld)

3.3.2 Changes in species conservation status

The Australian Government and all states and territories have agreed to establish a common assessment method (CAM) for the assessment and listing of threatened species. The CAM will maintain a high level of scientific rigour in the assessment and listing of threatened species across Australia, while promoting a more consistent, efficient and harmonised process. Threatened species assessments undertaken by a jurisdiction using the CAM are adopted under the EPBC Act. The time of listing for nationally threatened fish and spiny crayfish is presented in Table 5 (note this listing is correct up to March 2023), with the majority of listings occurring post-2010. Listing dates in Table 5 refer only to EPBC listing, some species (Barred galaxias, trout cod, macquarie perch) were listed under the previous national legislation and automatically transferred to EPBC in 2000.

Additional information on spiny crayfish and mussels is presented in Chapter 6.

Table 5. Date of listing for nationally threatened species, including pending listings.

Scientific name	Species common name	Date listed	EPBC status
Galaxias fuscus	Barred galaxias	2000[a]	EN
Macquaria australasica	Macquarie perch	2000[a]	EN
Maccullochella macquariensis	Trout cod	2000[a]	EN
Nannoperca obscura	Yarra pygmy perch	2000	VU– under reassessment
Maccullochella peelii	Murray cod	2003	VU
Craterocephalus fluviatilis	Murray hardyhead	2012	EN

Scientific name	Species common name	Date listed	EPBC status
Bidyanus bidyanus	Silver perch	2013	CE – under reassessment
Galaxias rostratus	Flathead galaxias	2016	CE
Galaxias tantangara	Stocky galaxias	2021	CE
Nannoperca australis	Southern pygmy perch	2021	VU
Gadopsis sp. nov. 'Western Victoria' Vic	Western Victorian blackfish	pending	Proposed EN
Mogurnda adspersa	Southern purple-spotted gudgeon (MDB population)	pending[b]	TBA
Hypseleotris gymnocephala	Bald carp gudgeon	pending[b]	Proposed CE
Euastacus armatus	Murray crayfish	pending[b]	TBA
Euastacus gamilaroi	Gamilaroi crayfish	pending[b]	Proposed EN
Euastacus jagara	Jagara hairy crayfish	pending[b]	Proposed CE
Euastacus rieki	Riek's crayfish	pending[b]	Proposed EN
Euastacus suttoni	Sutton's crayfish	pending[b]	Proposed EN
Euastacus simplex	Simple crayfish	pending[b]	Proposed EN
Euastacus spinichelatus	Small crayfish	pending[b]	Proposed EN
Euastacus sulcatus	Mountain crayfish	pending[b]	TBA
Euastacus vesper	Cudgegong giant spiny crayfish	pending[b]	Proposed CE

CE = Critically Endangered; EN = Endangered; VU = Vulnerable; TBA = to be announced
a Original listing as threatened occurred prior to the creation of the EPBC Act in 2000. Listing dates only refer to EPBC listing, hence 2000 for these species.
b Species identified as pending may have been listed post-analysis but prior to publication.

Using listing status as a measure of conservation success or recovery is problematic for a number of reasons (Possingham et al. 2002). Firstly, many threatened fish species in Australia remain unlisted under the EPBC Act even though they may have been listed for decades under state or advisory lists (Lintermans 2013a). Of the 22 most imperilled freshwater fish in Australia, 19 were unlisted under the EPBC Act (Lintermans et al. 2020), with freshwater fish identified as the most imperilled vertebrate group by Garnett et al. (2022). Secondly, there is no regular review of conservation status in Australia, nor is there mandated national trend monitoring (Lintermans 2013a). In fact, a recent review of national monitoring approaches for listed threatened species found them to be inadequate (Scheele et al. 2019). State monitoring programs may be satisfactory, but they may not be standardised between jurisdictions (Lintermans and Robinson 2018) or may use generic fish community sampling methods that are not robust for particular species or life stages (see Lintermans 2016).

While the conservation status for several species may not have changed in recent years, this should not be interpreted as meaning that the species' decline has been arrested. For example, Macquarie perch has been listed as Endangered under the predecessor to the EPBC Act since 1998, the NSW *Fisheries Management Act 1994* since 2008, the ACT *Nature Conservation Act*

2014[4] since 1997 and the Victorian *Flora and Fauna Guarantee Act 1988* since at least 2003. However, the species' conservation status trend is downward as sub-populations were lost during the Millennium drought of 1997–2010, and also the 2019–20 Black Summer bushfires. Very few large, self-sustaining sub-populations of Macquarie perch remain, with most sub-populations being small and isolated, and therefore prone to stochastic extinction events (Lintermans et al. 2019).

Other species have an improving national conservation status. Murray cod was listed as Vulnerable under the EPBC Act in 2003, but the most recent national assessments categorised the species as Least Concern (Gilligan et al. 2019b, Woinarski et al. 2023). The gradual recovery is largely due to fishing regulation and successful stocking programs, despite ongoing deterioration in habitat quality across much of its range, and apparent losses in the lower Darling-Baaka River fish death events of 2018–19 and 2023, and from the Paroo River. In particular, the fish deaths have impacted local populations (Thiem et al. 2017, NSW DPI unpubl. data). While Murray cod may ultimately be delisted it does not mean it has 'recovered' to now occupy all of its former range or abundance. Sustained recovery will rely on ongoing active management (Woinarski et al. 2023). Similarly, the conservation status of trout cod (*Maccullochella macquariensis*) has improved from Endangered (1980–present) under the EPBC Act, to Vulnerable in the latest assessment by the IUCN Red List (Koehn et al. 2019b). This is a notable result that reflects more than 30 years of concerted recovery actions.

The increasing number of cryptic species being taxonomically described in Australian freshwater fish inevitably means that the individual ranges of the newly recognised species are considerably smaller than the range of the original species complex. For example, mountain galaxias, which was broadly distributed across the MDB and not previously of conservation concern, was split into 15 species (Raadik 2014), with nine of the 14 newly described species plus two other newly recognised species immediately recognised as highly threatened (Lintermans 2016, TSSC 2021, 2023a–k). Consequently, as well as species being listed in the future for declines in abundance and/or distribution, the number of threatened fish species in the Basin is likely to increase as more species are described and assessed for listing.

There are several species and sub-populations that are declining and are of conservation concern. Northern river blackfish currently consists of a single described species, *Gadopsis marmorata,* but there are five cryptic taxa within this species (Hammer et al. 2014). Two cryptic blackfish taxa or sub-populations are listed or about to be listed (upper Wannon form; south-west Victorian blackfish) and more sub-populations will likely follow. The Darling River hardyhead (judged to be Least Concern in the 2019 IUCN Red List; Gilligan and Moy 2019) has suffered subsequent significant declines during the 2017–19 severe drought in northern NSW (Moy et al. 2020) and needs reassessment. In the Paroo valley, two large-bodied species have declined significantly in recent decades – Murray cod and freshwater catfish are now either absent or undetectable and silver perch has only been detected once since 2017 (Lintermans 2023). There are also concerns about Australian smelt (*Retropinna semoni*) in the Paroo (P. Unmack pers. Comm.) In the absence of comprehensive and rigorous fish monitoring programs for threatened species for many catchments in the MDB, such valley-scale declines in particular fish groups (e.g. wetland, large bodied, small bodied) are also likely in other catchments.

[4] Original *Nature Conservation Act 1980* was repealed, and replaced by the 2014 Act.

Previously, no fish species was known to have become extinct in the Basin, but the discovery of Yarra pygmy perch in the Lower Lakes in the early 2000s and then its subsequent loss during and after the Millennium drought represents the first known extinction of a fish species within the MDB (Wedderburn et al. 2019, 2022). Several localised extinctions (wetlands or valleys) have also occurred, but these are not documented here, as recent reintroduction events (translocations or stockings – for example, Murray hardyhead (*Craterocephalus fluviatilis*) and southern purple-spotted gudgeon – have also occurred and the results of these are not yet known.

Recovery of threatened freshwater fish is a slow process: species decline is often multidecadal, and recovery will likely take a similar timeframe. Monitoring of threatened fish has been judged to be nationally inadequate on several measures (Lintermans and Robinson 2018, Scheele et al. 2019) so determining trend and recovery is problematic. Several policy changes since the mid-2000s have also not assisted threatened fish recovery with recovery plans no longer mandatory since 2006 and recovery teams no longer funded. While Conservation Advice's are now prepared for all EPBC-listed species, these advices do not galvanise on ground recovery actions like recovery plans used to, and the move towards multi-species plans or regional approaches mean that species-specific actions are often lost (see Lintermans 2022a).

There have been 19 recovery plans for freshwater fish since 2001, although most have sunsetted and have been replaced with an updated conservation advice. The most recent recovery plan for fish species made was for the Macquarie perch in 2019. Although no freshwater fish were identified in the first 5-year iteration of the National Threatened Species Strategy (DAWE 2015), five priority freshwater fish were identified in the subsequent 5-year iteration (DAWE 2021) and were retained in the revision of the Threatened Species Strategy by the current Australian Government (DCCEEW 2022b). In addition, there are currently over 30 freshwater fish under assessment for listing at the national level, several of which are found within the MDB.

Although no fish-only EPBC-listed key threatening process (KTP) has been developed yet, there are several KTPs that are relevant through the potential for both direct and indirect impacts on freshwater fish and or their habitat. These include:

- *novel biota and their impact on biodiversity*, an overarching threat that includes multiple introduced taxa (terrestrial and aquatic) and applies to both terrestrial and aquatic threatened species
- *fire regimes that cause declines in biodiversity*, which applies to both terrestrial and aquatic ecosystems
- *predation, habitat degradation, competition and disease transmission by feral pigs*, which applies to both terrestrial and aquatic ecosystems
- *loss of climatic habitat caused by anthropogenic emissions of greenhouse gases*, which applies to both terrestrial and aquatic ecosystems
- *land clearing*, which is predominantly terrestrial but can lead to changes in water regimes and other impacts.

Many threatened species in the Basin have extremely small distributions, having lost substantial parts of their former range as a result of interactions with alien fish species (NSW DPI 2016, Lintermans and Allan 2019, TSSC 2021). Notable cases include the impacts of predation by salmonids and redfin perch on small-bodied species such as galaxiids and pygmy perch (McDowall 2006, Hammer 2002, Raadik 2014, Lintermans et al. 2020). Maintenance or installation of barriers to alien fish invasion is all that prevents local extirpation of several threatened species or populations (Lintermans 2022b, Bylemans et al. 2016, Lintermans et al. 2021). Other impacts include aggressive interactions (e.g. Eastern gambusia, *Gambusia holbrooki*) (Pink et al. 2011, MacDonald et al. 2012), resource competition (e.g. carp, redfin perch; Koehn et al. 2000), and diseases and parasites (Langdon 1989, Dove et al. 1997, Becker et al. 2013, Kaminskas 2021, Zhu et al. 2021). This status report does not address alien fish abundance and distribution, but future status assessments should include the development of standardised reporting metrics for alien fish distribution and abundance, as alien species are a major threat to many fish species.

While the general nature of the current threats to MDB fish are broadly known (MDBC 2004, Koehn and Lintermans 2012, Lintermans 2013a, 2023), there is no coordinated monitoring or benchmarking of these threats to delineate current extent (spatial, temporal), how threats may be changing (magnifying, reducing, synergistic), and the effectiveness of current management approaches to mitigate them. A decade on, there is still no central repository of threatened fish management interventions and their success (see Lintermans 2013b) – and such a database would be of considerable use in synthesising and analysing strengths and weaknesses of current management approaches to common threats. Under the current EPBC Act and the proposed legislative reform there remain options for multispecies conservation planning and listing to occur, as well as the potential to nominate additional KTPs.

3.4 **Case study** – Threatened species success stories

Prepared by Mark Lintermans with contributions from Luke Pearce, John Koehn, Nick Whiterod

Context

A very high proportion (47%) of the freshwater fish present in the MDB are threatened, with concerns for an even higher proportion of species from large-scale threats such as the widespread bushfires of 2019–20 (see Section 3.3.1).

Large disturbance events, such as the Millennium drought, the 2017–2019 drought and the 2019–20 bushfires across the MDB, can place enormous stress on species already vulnerable due to threatening processes and impacts associated with: river regulation and water extraction; pollution; habitat loss and degradation; and alien species. Interactions between threatening process can escalate when combined with the effects of climate change (Ahmed et al. 2022, Patil et al. 2022, Pirotta et al. 2022, Rose et al. 2023), making aquatic ecosystem and threatened species management more challenging.

While activities in support of threatened large-bodied native fish species (e.g. fishing restrictions, habitat improvement, fishing enhancement stocking) have been occurring for decades, particularly for popular recreational fishing species, actions to protect and improve the condition of threatened small-bodied fish species are a relatively recent occurrence. Conservation measures, such as conservation stocking, capture and preservation in special refuges and ex situ breeding programs, have been some of the emergency measures taken to protect some species, in some cases from extinction, within the MDB. Other important conservation measures have included habitat reintroductions and restocking of threatened species by the careful[5] release of hatchery-raised stock.

[5] To ensure genetic diversity is not lost.

This case study identifies examples of conservation measures that demonstrate how fish biologists, water resource managers and the community have successfully protected and recovered some local sub-populations of threatened fish species. It is not a comprehensive review of all such activities but shows that the hard work and diligence of dedicated people can result in positive conservation outcomes. Learning from such efforts will be important if we are to protect all threatened fish species in the future.

Assessment approach and findings

This case study provides examples of capture/reintroduction and habitat restoration activities across the MDB and focuses on examples of successful reintroductions or recovery in wild sub-populations for both large-bodied (e.g. Macquarie perch and trout cod) and small-bodied species (e.g. southern pygmy perch, purple-spotted gudgeon).

Management of threatened native fish species occurs in every jurisdiction of the MDB. Increasingly, there is recognition of the need to act in partnerships across jurisdictions and organisations, to better manage threatened fish species across their range, which can be across jurisdictional boundaries. Some examples of MDB large-scale threatened species recovery projects include:

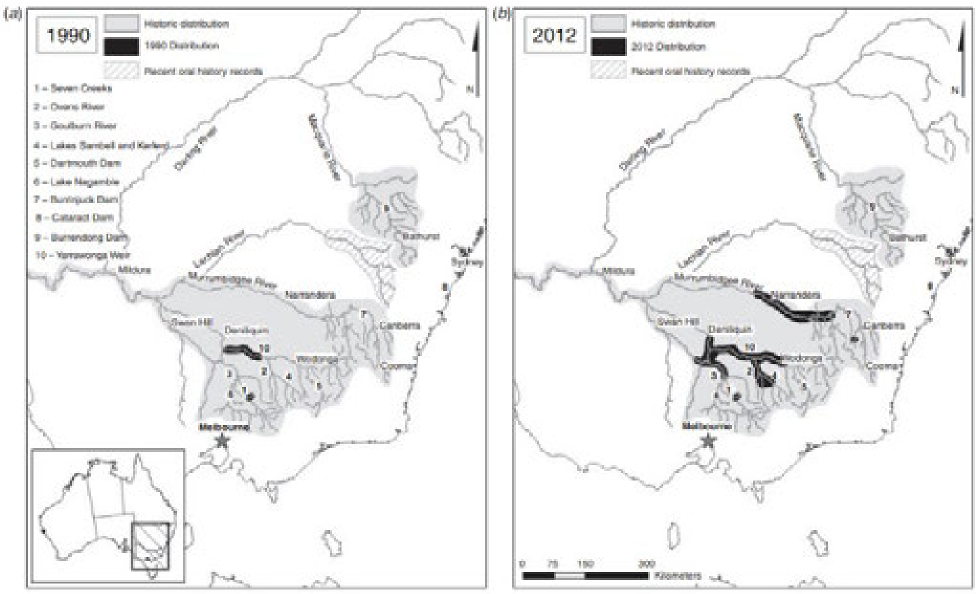
- The Tri-State Alliance, Native Fish Recovery Strategy (NFRS) Mid-Murray Floodplains Recovery Reach, which spans Victoria, NSW and South Australia along the Southern Connected Basin, with government and non-government organisations working together to protect threatened fish species. A key focus has been on the plight and management of the 'magnificent six' that includes Murray hardyhead (*Craterocephalus fluviatilis*), olive perchlet (*Ambassis agassizii*), flathead galaxias (*Galaxias rostratus*), Yarra pygmy perch, southern purple-spotted gudgeon and southern pygmy perch.
- Four recovery reaches established under the NFRS (MDBA 2020a) at locations across the MDB, including
  - Lower Darling-Baaka Recovery Reach
  - Mid-Murray Floodplains Recovery Reach
  - Upper Condamine Recovery Reach
  - Upper Murrumbidgee Recovery Reach.

Trout cod

Trout cod was once widespread and abundant within the mid-reaches of the MDB. The species suffered a major decline in its distribution and abundance, particularly in the 1970s and 1980s, due to threatening processes including the removal of woody debris, flow regulation and dam construction. By the late 1980s, only a single, naturally occurring sub-population was known to exist in the Murray River – between Yarrawonga and Cobram (Koehn et al. 2013). In response, a national recovery plan for trout cod (DSE 2008) was prepared that identified objectives and management actions to protect this critically endangered species.

The strategy of the national recovery plan included a continued focus on the protection and management of locations with natural and reintroduced sub-populations of trout cod. The mid-reaches of the Ovens River (Bundalong to Myrtleford) supported trout cod until the early 1980s (DELWP 2018), after which the species' disappearance was attributed to a range of threats including overfishing, river regulation (including altered river flows and loss of connectivity) and the loss of a key habitat attribute, instream woody debris. The Ovens River Demonstration Reach

(2008–2022) was established to build on the actions of the national recovery plan. Actions within the Demonstration Reach included habitat restoration, improved river connectivity through construction of fishways, restoring riparian vegetation and undertaking angler awareness. These actions provided restored habitat and connectivity for trout cod hatchlings and translocated fish released to the Ovens River. Subsequent monitoring of the trout cod sub-population recorded young-of-the-year (YoY) trout cod in seven of 10 years, indicating that the sub-population was successfully breeding and recruiting. The management actions resulted in trout cod numbers increasing by up to 270% (numbers of other species, such as Murray cod, also increased). Successful breeding and recruitment, the presence of a broad range of fish size classes and increasing catch rates all point to a sustainable trout cod sub-population in the Ovens River (DELWP 2018). Management interventions has also seen the distribution of trout cod expand in the Murray and Murrumbidgee rivers following implementation of the national recovery plan (Figure 1). Further detail on the recovery of trout cod can be found Koehn et al. (2013) and Lintermans et al. (2018).



Source: Koehn et al. 2013

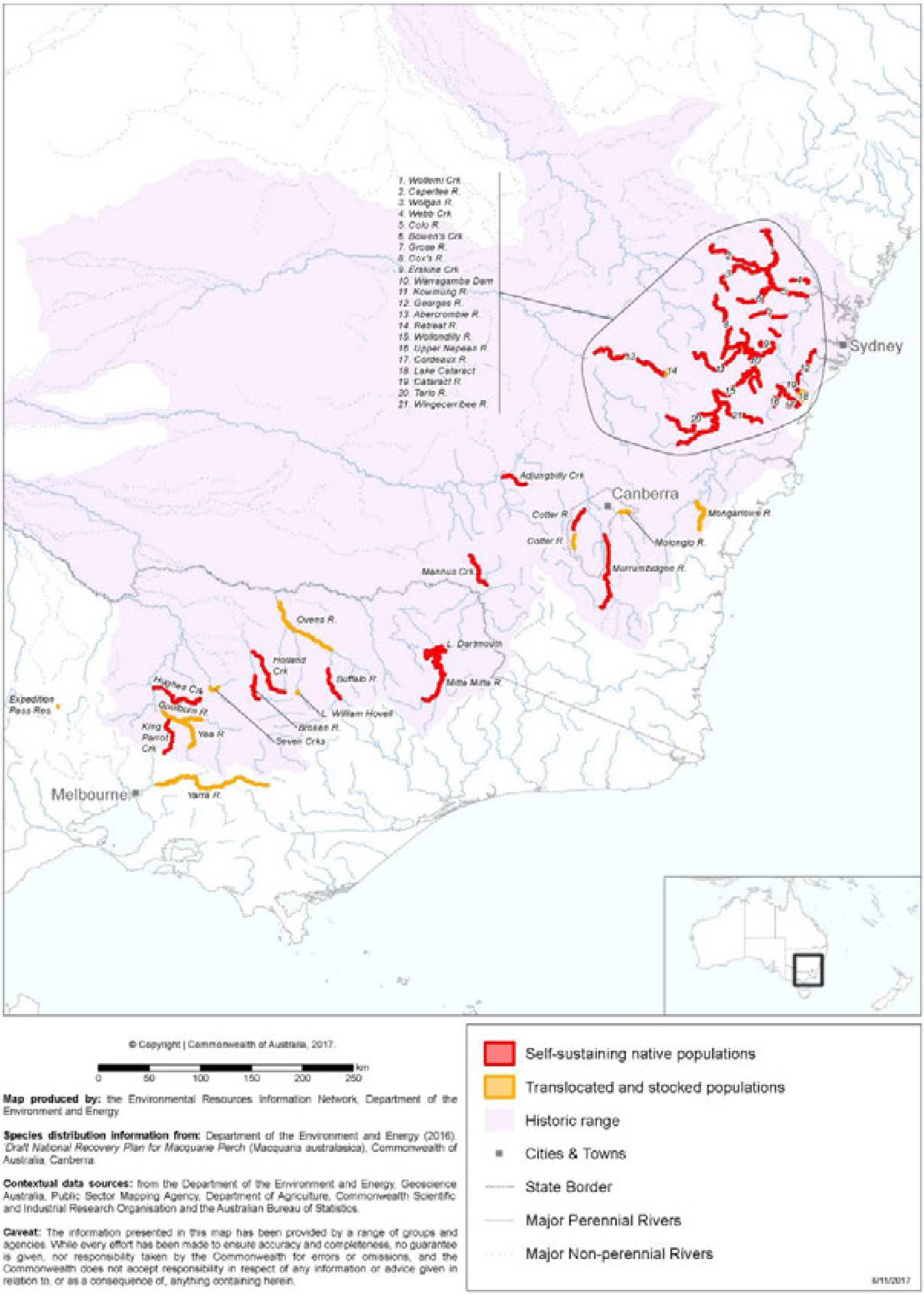
Figure 1. Historic and recent distribution of trout cod in Australia (a) 1990, (b) 2012

Macquarie perch

The historical geographical distribution of Macquarie perch included all major river systems in the south-eastern part of the MDB in NSW, the Australian Capital Territory (ACT) and Victoria (DEE 2018) (note: the species also occurs in the coastal catchments of the Hawkesbury-Nepean and the Shoalhaven in south-eastern NSW, and the Yarra catchment in southern Victoria). The distribution of Macquarie perch has declined across its range since the middle of the twentieth century, with their distribution reportedly declining by 75% post-1990 compared with pre-1990 extent (Lintermans et al. 2019). This decline has been attributed to habitat loss, fragmentation by barriers to movement, increased river sedimentation, alien fish species, overexploitation and altered flow regimes (e.g. Lintermans et al. 2019, Pavlova et al. 2017). The species now generally occurs in small and fragmented sub-populations (Figure 2); and this fragmentation is expected to continue into the future given their vulnerability to a range of threats and pervasive impacts such as those from droughts and other climatic extremes (Lintermans et al. 2014) and from bushfires (Legge et al. 2021, Pearce et al. 2021). There is also the possibility that the impact of predation and competition from redfin perch and the effect of the epizootic haematopoietic necrosis (EHN) virus might be transferred to the upper Murrumbidgee catchment due to intervalley water transfers associated with the Snowy 2.0 scheme (Harris and Lintermans 2020).

The main remaining MDB sub-populations of Macquarie perch occur in Dartmouth Reservoir (Victoria), Cotter River (ACT) and Upper Murrumbidgee (NSW), with several small, isolated sub-populations in Victorian and NSW tributaries. All the sub-populations have become genetically impoverished because of long isolation and fragmentation (Lintermans et al. 2019, Pavlova et al. 2017).

Listing of Macquarie perch as Endangered led to the preparation of a national recovery plan to ensure the recovery and ongoing viability of Macquarie perch throughout the species' range (DEE 2018). A key objective of the national recovery plan was to establish additional Macquarie perch sub-populations within the species' natural range (DEE 2018). An example activity addressing this objective has been the return of Macquarie perch to the Ovens River catchment. Macquarie perch became extinct in the Ovens River in the 1980s, due to excessive recreational fishing, increased sedimentation, habitat degradation and introduction of predatory and competitor fish (Cadwallader 1981, Trueman 2011). Lutz et al. (2020) reported on a program conducted between 2010 and 2017 that released translocated and hatchery-reared fish from Dartmouth Dam and the Yarra River catchment in the Ovens River. The fish were a mix of individuals from Dartmouth and from the Yarra, as well Dartmouth–Yarra crosses. Macquarie perch are now well established within the Ovens River, having been previously considered locally extinct.



Source: DEE 2018

Figure 2. Current and historical distribution of Macquarie perch in south-eastern Australia

Another example of Macquarie perch reintroduction is the establishment a population in the Retreat River in the upper Murrumbidgee to Abercrombie catchment (Pearce 2013, Rojahn et al. 2021b). Within NSW, there are currently only four known remaining sub-populations of Macquarie perch (upper Murrumbidgee River, Abercrombie/Lachlan rivers, Mannus Creek and Adjungbilly Creek). Until the mid-2000s, the Abercrombie and upper Lachlan River sub-population was considered relatively secure, due partly to the fact that this catchment remained free from redfin perch. However, once redfin perch was detected in a tributary of the upper Lachlan catchment in 2005, they quickly spread and within three years were present along the entire length of the upper Lachlan River. Redfin perch became the most abundant fish species present, and since its invasion only a single Macquarie perch has been captured from the upper Lachlan; it now appears that this sub-population has been lost. Fear of a similar fate for the Abercrombie sub-population led to the collection of Macquarie perch to attempt to establish a refuge sub-population safe from the impacts of redfin perch. The collected fish were held at the Narrandera Fisheries Centre as part of a captive breeding program while a safe refuge location was identified. This included development of reliable production methods for Macquarie perch; ultimately 20 000 Macquarie perch were produced and subsequently stocked into a new refuge within the Retreat River, a tributary of the Abercrombie River that has a waterfall in the lower reaches to preclude invasion by redfin perch.

Ongoing monitoring of the Retreat River has shown that the stocked Macquarie perch have survived well, have spread along the length of the system, and are now recruiting in the system, demonstrating that a recruiting sub-population can be established from captive bred animals.

The spread of the alien redfin perch has continued through the catchment; redfin perch are now present along the entire length of the Abercrombie River, and the Retreat River is one of the few places in the catchment that remains free of redfin perch.

Southern pygmy perch

Southern pygmy perch generally occurs in still and slow-flowing water with abundant aquatic vegetation cover. Historically, Southern pygmy perch occurred in the coastal catchments of south-east South Australia and southern Victoria, the north of Tasmania, and King and Flinders Islands and the southern MDB (Whiterod 2019). In the Southern Basin, it was formally found in the lower Murrumbidgee and Murray catchments, including tributaries (Broken, Ovens, Goulburn, Kiewa, Mitta Mitta) and the lower reaches (Lower Lakes and Mount Lofty tributaries). Southern pygmy perch sub-populations have experienced significant range reductions since European settlement. These reductions are associated with the degradation and loss of wetland habitat, impact of alien species (Lintermans 2007) and drought (e.g. Beheregaray et al. 2021). The impact of the Millennium drought was severe (Whiterod 2019), with local extirpation occurring from middle and upland Murray River catchment sites (including Barmah–Millewa, Normans Lagoon, Happy Valley Creek, Tallangatta Creek, Khancoban Lagoon, Oolong Creek and likely the lower Ovens River floodplain), as well as sites in Mount Lofty Ranges and Lake Alexandrina (and Hindmarsh Island) (Whiterod 2019).

As the Millennium drought unfolded, individual Southern pygmy perch from Lake Alexandrina and surrounding areas were rescued by a collaborative effort of government, universities, non-government organisations and community members to establish backup sub-populations (Hammer at al. 2013b). Eleven breeding groups were established based on genetic analyses aimed at ensuring low estimated relatedness between individuals within each group. The number of generations in captivity prior to reintroduction was kept to the smallest possible (one generation) to minimise adaptations to captivity and, given the small size of captive populations, avoid loss of genetic diversity (Attard et al. 2016). A contingency plan was also put in place in the event that self-sustaining wild sub-populations were not established; this consisted of maintaining individuals from multiple family groups in captive breeding, both at the breeding facility and in artificial refuges monitored by government agencies. Reintroduction of southern pygmy perch began in the Lake Alexandrina during spring 2011 using equal numbers from each family group to improve genetic diversity. Post-release monitoring at the reintroduction sites demonstrated persistence and recruitment of fish in subsequent years (Beheregaray et al. 2021).

Additional information is provided in relation to the successful species reintroduction project, as well as less successful efforts for Yarra pygmy perch in Beheregaray et al. (2021), which should be referred to for more detail.

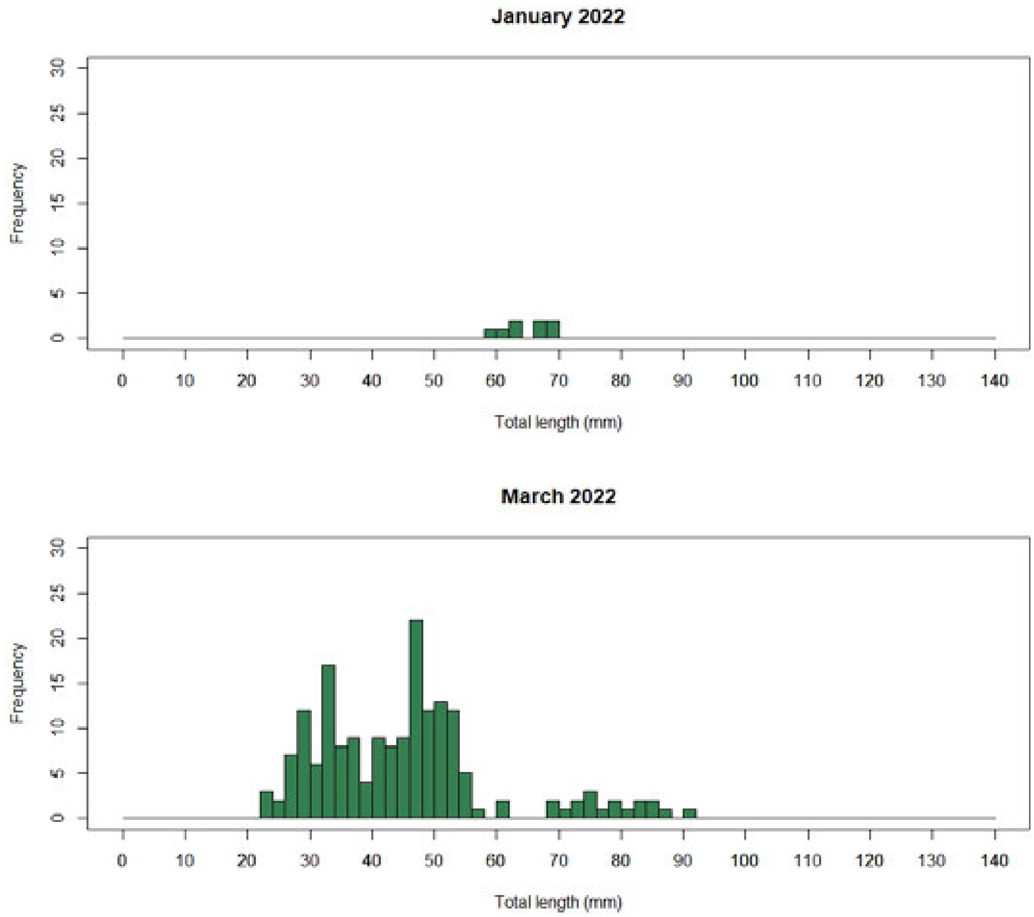
Southern purple-spotted gudgeon

Southern purple-spotted gudgeon is a wetland specialist species, with a strong preference for dense physical and aquatic vegetation cover (Hammer et al. 2015, Lintermans 2007). Historically, it was broadly distributed across coastal areas of Queensland and NSW as well as patchily occurring in the MDB. In the southern MDB, it was once widespread and common in wetland and fringing vegetation along rivers in the Murrumbidgee, Lachlan and Murray catchments, including the Lower Murray and Cardross Lakes.

The species has experienced substantial decline in distribution across the MDB (Whiterod et al. 2019, 2021c) and is now considered extinct from Cardross Lakes (last records in 1990s) and was declared extinct in South Australia in the early 1990s (Hammer et al. 2009). In 2002, southern purple-spotted gudgeon were rediscovered in a single wetland in South Australia, Jury Swamp near Murray Bridge, signalling its rediscovery after 30 years (Hammer et al. 2015). This species was also likely locally extinct from the NSW southern MDB, with the last record dating from 1996 (Whiterod et al. 2019, 2021c). The species was also considered locally extinct in Victoria, until its recent rediscovery in the Kerang Lakes system in 2019 (Stoessel et al. 2022).

Deteriorating conditions due to reduced flows and water availability associated with the Millennium drought necessitated the rescue of the South Australian fish into three captive breeding facilities, with the view of establishing surrogate sub-populations to help safeguard the species (Hammer 2007). By spring 2009, Jury Swamp had completely dried, with presumed local and regional extinction of the species (Hammer et al. 2015). Fish rescued at the height of the Millennium drought were used to establish backup sub-populations (Hammer et al. 2013a). Three captive maintenance and breeding facilities were established and have continued to produce moderate numbers (100s) of southern purple-spotted gudgeon annually. Additionally, the establishment of a surrogate refuge for the species has been successful with high numbers (population estimated at >10 000 fish) and regular spawning and recruitment observed. These backup sub-populations enabled the reintroduction of fish to occur in the attempt to re-establish the species. In 2011 and 2012, 1 120 fish were reintroduced into a historical site with several recaptures (*n* = 15) before the site unexpectedly dried (Bice et al. 2014). Subsequently, 5 043 fish were reintroduced to Jury Swamp rediscovery site between 2014 and 2019. Southern purple-spotted gudgeon were regularly detected at the site in low numbers (most recently, in February 2019 one fish was detected), but the re-establishment of self-sustaining populations has not occurred (Whiterod 2019).

Whiterod et al. (2022) investigated in more detail the habitat requirements of three small-bodied fish, including southern purple-spotted gudgeon, prior to translocation at sites in the Victorian Mallee. One of the three sites investigated (Nowingi Ornamental Lakes) was deemed suitable for receiving fish and early results based on size structure suggest that southern purple-spotted gudgeon bred and recruited soon after release (Figure 3). The approach of Whiterod et al. (2022) demonstrates the benefits of collaboration to identify and assess potential reintroduction sites for captively bred fish. Active management of the site and post-release surveys will be undertaken to track the population trajectory and the ongoing success of the translocation.



Source: Whiterod et al. 2022

Figure 3. Length structure of the translocated southern purple-spotted gudgeon population in Nowingi Ornamental Lakes during January and March 2022 surveys

Key messages

- Introductions (conservation stocking) and translocations can be used to improve populations of threatened large-bodied and small-bodied native fish species. However, successful reintroductions may take considerable effort over many years, and success may vary over time.
- Surrogate refuges and captive breeding programs are increasingly important tools for managing and conserving threatened species populations.
- Sub-populations of rare and threatened species are often fragmented, which can make monitoring of species across their range challenging. However, appropriate monitoring is critical if we are to provide appropriate adaptive management strategies for the recovery of these species in the future (Lintermans and Robinson 2018).

3.5 Key findings – conservation status

Key findings

Potential status assessment questions were identified in Cottingham et al. (2022) and refined in consultation with the NFRS Technical Advisory Group (see Appendix 1, Table 18) for each attribute; however, some questions are not addressed due to scope and data limitations.

What is the current conservation status of each species?

A large proportion of native fish species in the MDB (47%) are recognised as rare or threatened on state, territory, national or international listings. The current status of listed species is presented in Table 4.

Has the number of threatened species increased, decreased or remained stable (compared with a reference point)?

Trend in number of Basin fish and spiny crayfish species listed as threatened at the national level is increasing. Since 2010, five species of fish have been listed under the EPBC Act. Silver perch was listed in 2013 and is undergoing a current reassessment, as is the Yarra pygmy perch, which was listed in 2000.

Five of the 13 spiny crayfish are currently listed at the state/territory level, with nine species under assessment for national listing under the EPBC Act.

A range of management activities have been implemented to restore threatened species, with some successes (e.g. trout cod); however, improvements in conservation status will depend on ongoing conservation management in many cases.

In certain circumstances, in situ conservation interventions including translocations, alien fish management and habitat remediation (e.g. resnagging, fishways, riparian management) can be used to improve populations of threatened large-bodied and small-bodied native fish species:

✧ It is important to recognise that species took many years to decline and that successful recovery may take considerable effort over similar timeframes, and that success may vary over time.

✧ Genetic recovery (e.g. via careful selection of individuals to improve the genetic diversity of sub-populations) is increasingly recognised as important in securing viable sub-populations and populations capable of adapting to future and current threats.

Management of the impacts of alien species (exclusion and control) is critical for the recovery of many threatened species.

Ex situ conservation interventions, including the creation of surrogate refuges for small-bodied taxa and captive breeding programs for both small- and large-bodied taxa, are increasingly important tools for managing and conserving threatened species populations, particularly during extreme events such as drought and bushfires.

Are there yet-to-be-listed species whose decline is of concern?

Yes, currently five fish and nine spiny crayfish under assessment for listing. Two species of mussels in the Northern Basin are also of concern, but not yet nominated for listing assessment.

The potential impacts of large-scale disturbances, such as bushfires, drought and climate change interactions with other threatening processes, increases concern for the status of many species not yet listed as threatened.

The often fragmented sub-populations of rare and threatened species can make monitoring of species across their range challenging. However, appropriate and coordinated monitoring at the scale of the species' distribution is critical if we are to provide appropriate adaptive management strategies for the recovery of these species into the future.

4 Species distribution

4.1 Background

The species spatial distribution attribute describes changes in the known distributions, or geographic ranges of species across the MDB. Changes in the known spatial distribution of a species can reflect coarse changes in the density of sub-populations and can therefore provide an indicator of sub-population status relative to a previous assessment period. For example, the current spatial distribution of a species can be compared with that at a previous reference time period to describe whether the distribution is expanding, contracting or stable in scale. Current known distribution could also be compared to hypothesised or modelled range using habitat simulation or species distribution modelling for either past or future scenarios (Bond et al. 2011).

The robustness of this attribute is particularly dependent on data availability, sampling effort/intensity in target species' habitats or regions, catchability or detection rates of species (e.g. rare, cryptic or small-bodied species) and reporting of collected individuals on centralised databases, such as the Atlas of Living Australia (Lyon et al. 2014, Lintermans and Robinson 2018, Scheele et al. 2019). For example, although there are a number of regular monitoring programs that sample main channel habitats and species in the MDB, small channel, wetland and/or floodplain habitats are by comparison sampled less frequently and therefore the distribution of wetland specialists (especially small species) is likely to be underestimated (Robinson 2019). These issues are important limitations for the utility and robustness of this method as a status assessment attribute.

The spatial scales of interest for this attribute include (see Appendix 3):

- whole of MDB
- sub-Basin (Northern or Southern Basin)
- river valley and Coorong Lower Lakes Murray Mouth (CLLMM).

4.2 Assessment approach

Two datasets were used to explore changes in species richness at the Basin, sub-Basin and river valley scales. A larger dataset (termed the combined dataset) was the result of a previous project to map fish distributions in the MDB, originally for the 2007 *Fishes of the Murray–Darling Basin* book (Lintermans 2007) and then for the new edition (Lintermans 2023) (see Appendix 4). The 2007 edition of the book mapped distributions pre- and post-1980 to show variation between historic (pre-1980) and current (post-1980) distributions. Here we developed a combined dataset by constructing multiple existing datasets (SRA 2004–2013; MDBFS 2014–15 to 2021–22, NSW BPEOM, TLM, CLLMM, the Commonwealth Environmental Water Office's monitoring, evaluation and research program, Australian Museum records, Museums Victoria records, Queensland Museum records) and a series of smaller, targeted datasets from state agencies, consultants and individual scientists. Records for rare, threatened or out-of-range taxa were particularly sought as these rarities are often missing from conventional monitoring datasets. While extensive effort was made to access records, there were instances where some data were not available. Individual records are reported at the SRA river valleys (Davies et al. 2010a).

The combined dataset (all years from 1980) was then mapped by taxon, and circulated to species experts for comment, with queried records further investigated and either excluded or included based on expert opinion.

Sampling methods and sampling effort vary substantially across datasets, and so comparisons of standardised catches were not possible for most of the combined datasets, and records therefore only represent positive records – not true absence or abundance. Much of the targeted record collection from individual scientists and consultants occurred between 2015 and 2017. The combined dataset accounts for recent changes in taxonomy – for example, galaxiids (Raadik 2014) and carp gudgeons (Thacker et al. 2022), with the carp gudgeons recorded as both a combined taxon (*Hypseleotris* spp.) and as a small number of the newly described taxa (only genetically verified individuals included). However, undescribed taxa (e.g. the cryptic diversity within blackfish; Hammer et al. 2014) were treated as only the two described taxa (*Gadopsis marmorata* and *G. bispinosa*).

The second dataset interrogated was from the targeted fish monitoring programs in the MDB: the SRA (2004–2013) and its replacement the MDBFS from 2014–15 to 2021–22. These two programs do not recognise the new carp gudgeon taxonomy, with all individuals recorded as *Hypseleotris* spp.

Whether using the combined or the SRA/MDBFS datasets, all results are to be treated as a guide only. Both comparisons include different timespans and different effort within each timespan.

4.3 Results – species distribution

After removing the combined *Hypseleotris* taxa code from both time slices and just leaving the described taxa in this genus (Thacker et al. 2022), the number of native species recorded at the Basin scale from the combined dataset has notionally declined by one taxon from 1980–2010 to the post-2010 period (Table 6 and Appendix 2), but the species composition differs by more than this single taxon complex. The post-2010 taxa list includes one additional taxon recorded and two taxa not represented since 2010; namely:

- the addition of silver tandan recorded in 2016 from a single location on the Paroo valley
- no representation post-2010 for ornate galaxias (only found in a single stream in the Southern Basin, and only recently redescribed; Raadik 2014) and estuary perch (*Percalates colonorum*).

A summary of the distribution of each species in the MDB by river valleys pre- and post-2010 can be found in Appendix 4.

It was noted in Chapter 2 that there are 51 freshwater fish species present across the MDB. Only 48 species are nominated in Table 6 because species such as the undescribed Wimmera River blackfish and Goulburn two-spined blackfish (Hammer et al. 2014) and the short-headed lamprey (*Mordacia mordax*), found in the Coorong and Lower Lakes (Bice et al. 2021) were not represented in the dataset used for analysis. The western blue-spot goby (*Pseudogobius olorum*) is also absent from the dataset even though these fish are commonly recorded in the Coorong, Lower Lakes and associated wetlands (Smith et al. 2009, Wedderburn et al. 2014, Lintermans 2023).

Table 6. Number of native fish species by time periods across the Basin from the combined dataset

Sub-Basin	1980–2010	Post-2010
Northern Basin	24	26
Southern Basin	45	42
Total Murray–Darling Basin	**48**	**47**

At the sub-Basin scale, the number of native species was substantially higher in the Southern Basin than the Northern Basin. This is largely a result of the presence of species that require marine or estuarine access in their life cycle, or that may require cooler, high-altitude streams. Post-2010, the number of native species increased by two in the Northern Basin and decreased by three in the Southern Basin (after removing the combined *Hypseleotris* taxa code from both time periods and just leaving the described taxa at genus level) (Table 6).

In the Northern Basin, no native taxa were lost post-2010 compared with the 1980–2010 species composition, although flathead galaxias were recorded pre-1980 but have had no records since. The two additional species recorded post-2010 are Macquarie perch, which was released in the Macquarie catchment in 2021 (but not yet known if it has become established) and silver tandan present on the western edge of the Paroo catchment.

In the Southern Basin, there was a decline in species recorded across the two time periods. There were three species lost post-2010 from the 1980–2010 species composition: long-finned eel, estuary perch and ornate galaxias. Estuary perch is extremely rarely represented in the combined dataset, with a total of only two records post-1980, both from the lower Murray (Lintermans 2023). Similarly, long-finned eel (*Anguilla reinhardtii*) is extremely rare in the Southern Basin with only two records: from 1907 (near Wilcannia) and 2010 (Canberra, likely a translocation).

After removing the combined *Hypseleotris* taxa code from both time slices and just leaving the described taxa in this genus, the comparisons of native species present in each valley across the two time periods (1980–2010; post-2010) from the combined dataset show a mixed pattern of change, with notional losses of up to five taxa and notional gains of up to four taxa (Table 7). However, this pattern is clouded by year coverage and how the combined dataset was constructed. The post-2010 dataset is for a much shorter timespan (~10.5 years) compared with 31 years for the 1980–2010 dataset. Also, because the complete dataset was compiled just for mapping purposes (not for analyses) with a different and coarser temporal focus (pre- and post-1980), there was little effort to locate datasets from individual researchers from recent years (post-2010) where the post-1980 presence of a species in a valley was already mapped (Lintermans 2007). This means that taxon losses from post-2010 may be inflated, but such considerations would have little effect on taxon gains (see Appendix 3 for list of species records by valley). Caveats aside, two valleys (Darling and Lachlan) had the same taxa count across the two time periods of interest, five valleys had a notional change of one taxon, six valleys had a change of two taxa, two valleys had a change of three taxa, six valleys had a change of four taxa, and three valleys had a change of five taxa (all changes of five species were in the Southern Basin).

The lower Murray had the highest (31 taxa) post-2010 number of species present in the Basin, as it contains many of the taxa that are normally associated with the Coorong and Lower Lakes (e.g. small-mouthed hardyhead, Tamar goby *Afurcagobius tamarensis*, western blue-spot goby, lagoon goby *Tasmanogobius lasti*, congolli *Pseudaphritis urvillii*) as well as vagrants displaced from the Darling during high flows (e.g. olive perchlet, spangled perch *Leiopotherapon unicolor*). The lowest post-2010 species presence was recorded in the Paroo (seven taxa) closely followed by the Avoca and Wimmera valleys (eight taxa) and the Castlereagh (nine taxa).

The species record figures in most valleys were highly influenced by many species with very low recorded abundances (<10 individuals) in the dataset (see Table 8). This may reflect true rarity, vagrants, lack of sampling effort, new taxonomy (e.g. new carp gudgeon species not verified), project focus, the reduced year coverage of the post-2010 data, or simply missing data, as the dataset was not intended to represent valley species distribution or to be used to monitor change over time. For example, eight of the 13 taxa recorded from the Avoca, four of the 11 taxa recorded from the Paroo, and 11 of 24 taxa recorded from the Murrumbidgee had abundances <10 between 1980 and 2010. This low abundance almost certainly obscures true change in species records at the valley scale and highlights the urgent need for a dedicated fish distribution database for the MDB.

Table 7. Species distribution (record in combined dataset) of native species occurring in each valley across time periods from the combined dataset

Basin	Valley	1980–2010	Post-2010	Net change
Northern Basin	Border rivers	19	15	−4
	Castlereagh	7	9	+2
	Condamine	17	18	0
	Darling (northern)	13	14	+1
	Gwydir	13	16	+3
	Macquarie	19	21	+2
	Namoi	12	14	+2
	Paroo	11	7	−4
	Warrego	13	12	−1
Southern Basin	Avoca	13	8	−5
	Broken	20	16	−4
	Campaspe	14	11	−3
	Central Murray	19	24	+5
	Goulburn	23	22	−1
	Kiewa	13	12	−1
	Lachlan	16	16	0
	Loddon	19	15	−4
	Lower Darling	12	15	+3
	Lower Murray	32	31	−1
	Mitta Mitta	16	13	−3
	Murrumbidgee	24	19	−5
	Ovens	16	15	−1

Basin	Valley	1980–2010	Post-2010	Net change
	Upper Murray	14	13	−1
	Wimmera	10	8	−2

Red text indicates net losses of taxa since 2010; blue text indicates net gains.

Table 8. Species distribution (record in combined dataset) per valley with recorded abundance <10 individuals

Basin	Valley	1980–2010	Post-2010
Northern Basin	Border Rivers	5	3
	Castlereagh	3	5
	Condamine	4	4
	Darling (northern)	5	5
	Gwydir	2	4
	Macquarie	7	9
	Namoi	0	3
	Paroo	4	1
	Warrego	4	4
Southern Basin	Avoca	8	3
	Broken	6	7
	Campaspe	3	3
	Central Murray	4	9
	Goulburn	4	7
	Kiewa	3	5
	Lachlan	4	4
	Loddon	6	5
	Lower Darling	2	5
	Lower Murray	6	7
	Mitta Mitta	2	8
	Murrumbidgee	11	5
	Ovens	2	2
	Upper Murray	3	4
	Wimmera	0	3

It is instructive to examine the same spatial breakdowns just using the purpose-designed fish monitoring programs for the MDB (The SRA 2004–2013 and the MDBFS 2014–2022) (Table 9). As this dataset only uses data collected from the SRA/MDBFS, it does not include any data collected pre the commencement of the SRA (2004). It must also be noted that the taxonomic uncertainty around *Hypseleotris* and the widespread presence of hybrids within this genus resulted in the dedicated fish monitoring datasets deflating the taxa count, as all three *Hypseleotris* species in the Basin are scored as a single taxon (*Hypseleotris* spp.).

The dedicated fish monitoring dataset shows a change in species detected for eight species at the Basin scale post-2010, and six and eight taxa at the sub-Basin scale for the Northern and Southern Basins respectively (Table 9). The explanation for fewer taxa recorded at all scales post-2010 in the dedicated fish monitoring programs is unlikely to be related to changed environmental conditions, as the combined fish dataset showed no such trend at these higher spatial scales, and intuitively it would be expected that species records would be the same or higher after the ending of the Millennium drought in 2010. The decline is possibly driven by the lower spatial coverage/intensity of the MDBFS compared to the SRA, with the MDBFS also decreasing the number of sites sampled post-2017. The SRA sampled many more sites per valley than the MDBFS (Table 10), but the MDBFS has a higher temporal intensity of sampling (annual as opposed to triennial for SRA). Overall, there were 520 different sites sampled post-2010 and 856 different sites sampled pre-2010. For spatially restricted or rare species, false negatives in sampling programs are a significant issue in terms of detectability (e.g. Lyon et al. 2014, Lintermans 2016) and the reduced spatial coverage in the MDBFS increases the likelihood of false negatives.

Table 9. Species distribution (record in combined dataset) at the Basin and sub-Basin scale, recorded from each valley across two time periods (2004–2010 and post-2010) from the dedicated MDB fish monitoring programs (SRA/MDBFS)

Dataset Spatial Scale	SRA/MDBFS, 2004–2010	SRA/MDBFS, post-2010
Whole Basin	40	32
Northern Basin	24	18
Southern Basin	33	25

Table 10. Number of sites sampled for SRA/MDBFS

SRA/ MDBFS	SRA1	SRA2	SRA3	MDB1	MDB 2	MDB 3	MDB 4	MDB 5	MDB 6	MDB 7
Period	2005–2007	2008–2010	2011–2013	2015	2016	2017	2018	2019	2020–2021	2022
Total sites sampled	487	510	343	145	145	145	105	105	105	106

The 105 sites from 2018 onward are essentially the same sites, whereas the 487 sites between 2005 and 2007 are completely independent sites. About half the sites sampled in each of the first three SRA rounds are new sites each round.

The dedicated fish monitoring programs usually return a species count lower than the combined dataset at both spatial scales (Basin and sub-Basin scales), with the exception being a marginally higher count for the fish monitoring programs in the Northern Basin for the earlier time period.

There is a strong difference in species records between the two datasets post-2010 (Table 11, Appendix 1). The generally lower record in the dedicated fish monitoring programs is because the combined dataset:

- contains records from a wide variety of sampling strategies with multiple sampling methods (fyke nets, bait traps, electrofishing, seine nets, gill nets etc.)
- includes spatially- or species-specific targeted sampling programs (e.g. species-specific sampling, spatially targeted)
- includes known previous occurrences
- includes sampling that occurs in diverse habitats (riverine, estuarine, lacustrine and off-channel), often with higher temporal sampling intensity, often of threatened or rare taxa, as opposed to the generic MDB sampling strategies (restricted methods, representative randomly selected sites, only riverine, low sampling intensity – annual or greater)).

Comparison of species records at the valley scale has not been included here due to the potentially misleading results influenced by large number of species represented by low abundances in the combined dataset (see Table 8).

As an example of how sampling methods influence species detection at a site, Macquarie perch monitoring, if restricted to a single sampling technique (boat electrofishing), returns a high rate of false negatives at the site scale compared to multimethod sampling (Lintermans 2016). These false negatives are because boat electrofishing fails to adequately or reliably detect the most abundant age class of this species (young of the year) (Lintermans 2016). Similarly, boat electrofishing in the MDB requires larger sampling effort to return rare species (Ebner et al. 2008). The pattern of multimethod sampling returning higher species richness is widely accepted across multiple animal groups (e.g. King and Porter 2005, Hutchens and DePerno 2009, da Silva 2010).

Table 11. Comparison of native species distribution (record in combined dataset) at Basin and sub-Basin scale for the dedicated fish monitoring (SRA/MDBFS) and combined datasets

Dataset Spatial Scale	SRA/MDBFS, 2004–2010	Combined, 1980–2010	SRA/MDBFS, post-2010	Combined, post-2010
Whole Basin	40	44	32	44
Northern Basin	24	22	18	25
Southern Basin	33	40	25	40

Taxa number for combined dataset has had *Hypseleotris* taxa adjusted to match SRA/MDFS (only *Hypseleotris* spp. included).

When comparing years of detection for threatened or rare species between the dedicated fish monitoring program (SRA/MDBFS) and the combined dataset at the sub-Basin scale, it is clear that the dedicated fish monitoring program performs poorly for most taxa (Table 12). The combined dataset detects these species on average in substantially more years than the dedicated fish monitoring, or the dedicated fish monitoring program does not detect them at all. Mainstem species (e.g. Macquarie perch, trout cod) fare slightly better. A similar pattern is expected for wetland species and the estuarine/diadromous taxa. While jurisdictions may have targeted threatened species monitoring programs, these are often ad hoc, do not necessarily have comparable sampling methods or frequency, and do not have secure or ongoing funding

(Lintermans and Robinson 2018, Scheele et al. 2019). Thus, a dedicated, targeted and comparable long-term monitoring program is required for threatened fish.

Similarly, there is no comprehensive monitoring dataset for wetland or off-channel taxa in most jurisdictions, and a targeted monitoring program is required for these ecosystems. Estuarine species are monitored in a separate monitoring program covering the Coorong, Lower Lakes and Lower Murray (e.g. Ye et al. 2022) but funding is not secure. This monitoring program needs secure ongoing funding as it is the only dataset available for these habitats and species.

Table 12. Missing or poorly represented taxa from dedicated fish monitoring programs; counts are number of years recorded in each dataset

Dataset	SRA/MDBFS, 2004–2010	Combined, 2004–2010	SRA/MDBFS, post-2010	Combined, post-2010
Northern Basin				
Rendahl's tandan	0	5	1	4
Olive perchlet	4	7	5	11
Southern purple-spotted gudgeon	2	3	5	7
Southern Basin				
Yarra pygmy perch	0	2	0	2
Murray hardyhead	1	6	0	12
Barred galaxias	1	3	0	1
Stocky galaxias	0	0	0	2
Flat-headed galaxias	0	3	2	5
Macquarie perch	4	7	9	12
Trout cod	5	7	8	12
Southern purple-spotted gudgeon	0	1	0	3
Southern pygmy perch	6	7	10	12

4.4 **Case study** – Using genetics to examine patterns of population connectivity in the Murray–Darling Basin

Prepared by Peter Unmack

Context

Understanding connectivity of fish species sub-populations is critical to understanding how they may be affected by changes to river systems, such as by drought or due to barriers to movement and migration. For some species with high levels of migration these impacts may be immediate, while for species with lower migration rates the impacts may be more subtle and occur over longer time periods. Understanding movement is also critical for understanding what may be expected following droughts that may isolate or extirpate sub-populations in terms of which species may be expected to recolonise and which species may need assistance. If assistance is required, then decisions will need to be made as to where to source fish for restocking and what may be an appropriate way to mix sub-populations to provide improved levels of genetic variability.

Given there are thousands of potential barriers to movement along waterways across the MDB (Lintermans 2023), it can be very difficult to assess their impact on native fish populations and sub-populations. This case study provides an example of how a phylogeographic approach (e.g. Georges et al. 2018) can be useful to infer the geographic origin of sub-populations and subspecies, the course of range expansions, and the presence of genetic bottlenecks. Population genetic data (levels of single nucleotide polymorphism (SNP)) (e.g. Hughes et al. 2012, Unmack et al. 2019) from four fish species with quite different degrees of commonness were used to represent different likely historic levels of connectivity between sub-populations.

Australian smelt (*Retropinna semoni*) is one of the most common native fishes in the MDB. They are widespread, typically common, often abundant, fairly continuously distributed, inhabit a wide range of habitats and are thought to be relatively migratory, because they often accumulate in large numbers below obstructions. Despite these traits, Australian smelt have declined or been extirpated from some parts of the MDB, such as the Paroo River (extremely rare, only two records since 1997 – in 2016 and 2017) and the Gwydir River above Copeton Dam, and they were absent or became rare in much of the Darling-Baaka River and probably the lower reaches of some tributaries in the past decade or so due to a lack of water.

Unspecked hardyhead (*Craterocephalus fulvus*), is a moderately common native fish in the MDB, being widespread and likely historically present in most of the MDB except the higher reaches of southern tributaries, where conditions are too cold and the environment unsuitable. They are likely to make at least moderate movements, although specific data are lacking. Today the species remains fairly common in some parts of the MDB but has declined in its extent in many rivers due to dams either blocking access to upstream areas (e.g. it is absent above Lake Hume and Copeton Dam, despite being common below these structures), or drying of downstream reaches such as in the Darling-Baaka River and the lower reaches of its tributaries. The 2019 drying event would have also resulted in extensive sub-population losses in the Northern Basin, although it is unclear if those sub-populations are rebounding or not. For some unknown reason, it has mostly been rare in Victorian tributaries of the Murray River, despite similar species like Murray–Darling rainbowfish (*Melanotaenia fluviatilis*) extending well up these rivers.

Olive perchlet is likely to have been widespread across much of the MDB, although historic records are quite limited. They show a preference for habitats with aquatic vegetation. The species has likely been heavily impacted by predation from the introduction of redfin perch as well as by potential impacts on aquatic vegetation due to carp. They are likely to make at least moderate movements, although specific data are lacking. Today they are primarily restricted to mostly northern rivers, especially within the Condamine, Mcintyre and Bogan catchments. They appear to have been lost from the Warrego River (last capture was in 1997), despite them being regularly recorded in prior studies through the late 1980s and the early 1990s. The only known sub-population in the Gwydir River was lost in 2019. They are also known from a single small region in the Lachlan River. Today they can be found in some smaller lowland tributary streams as well as in larger rivers. Clearly, they have a great ability to disperse under the right conditions based on recent records of the species just below the Darling-Baaka River and in Menindee Lakes during high flows. The last record from South Australia in 1984 (Lloyd and Walker 1986) was probably also a fish that had dispersed there from far afield.

Southern purple-spotted gudgeon (*Mogurnda adspersa*) was also likely quite widespread; while historical records are relatively few, they span the broader Basin. This species is often not readily detected in standard sampling methods and some sub-populations have been present since European settlement despite extensive sampling over the years (e.g. sub-populations in the vicinity of Kerang, Mildura (Cardross Lake) and Murray Bridge). Fishes in the genus *Mogurnda* are known to be good colonisers, often occurring above major barriers like waterfalls. However, some genetic studies have shown quite low levels of movement in creeks with larger established sub-populations (Hughes et al. 2012). Today, extant MDB sub-populations are usually present in smaller, more isolated, often degraded creeks with limited extents of occupation where they often live alone or with few other fish species (although there are exceptions to this, such as the Victorian and South Australian sub-populations). The 2019 drought had a massive impact on this species, with a number of sub-populations apparently being extirpated (P. Unmack unpub. data; NSW Fisheries pers. comm.).

Approach and findings

The fish samples used in this study were all obtained from separate projects and were not collected with the idea of specifically addressing questions of connectivity. Thus, they have different geographic coverage, different sample sizes and different numbers and locations from where they were collected. Ideally, 10–20 individuals per sub-population would be sampled to obtain robust estimates to be more thoroughly assess generic variation within sub-populations. In many cases sample size range from 3–5 for unspecked hardyhead and olive perchlet to around 10 per sub-population for the other two species, but when combined into river valleys sample sizes improve. The data from the four species are broadly comparable so long as these limitations are kept in mind. Sample details for each of the four species are in Table 13, and the distribution of sub-populations samples is in Figure 4. Note that Australian smelt and unspecked hardyhead have much higher numbers of variable loci than the other two species, even when taking into consideration the differences in their overall sample sizes.

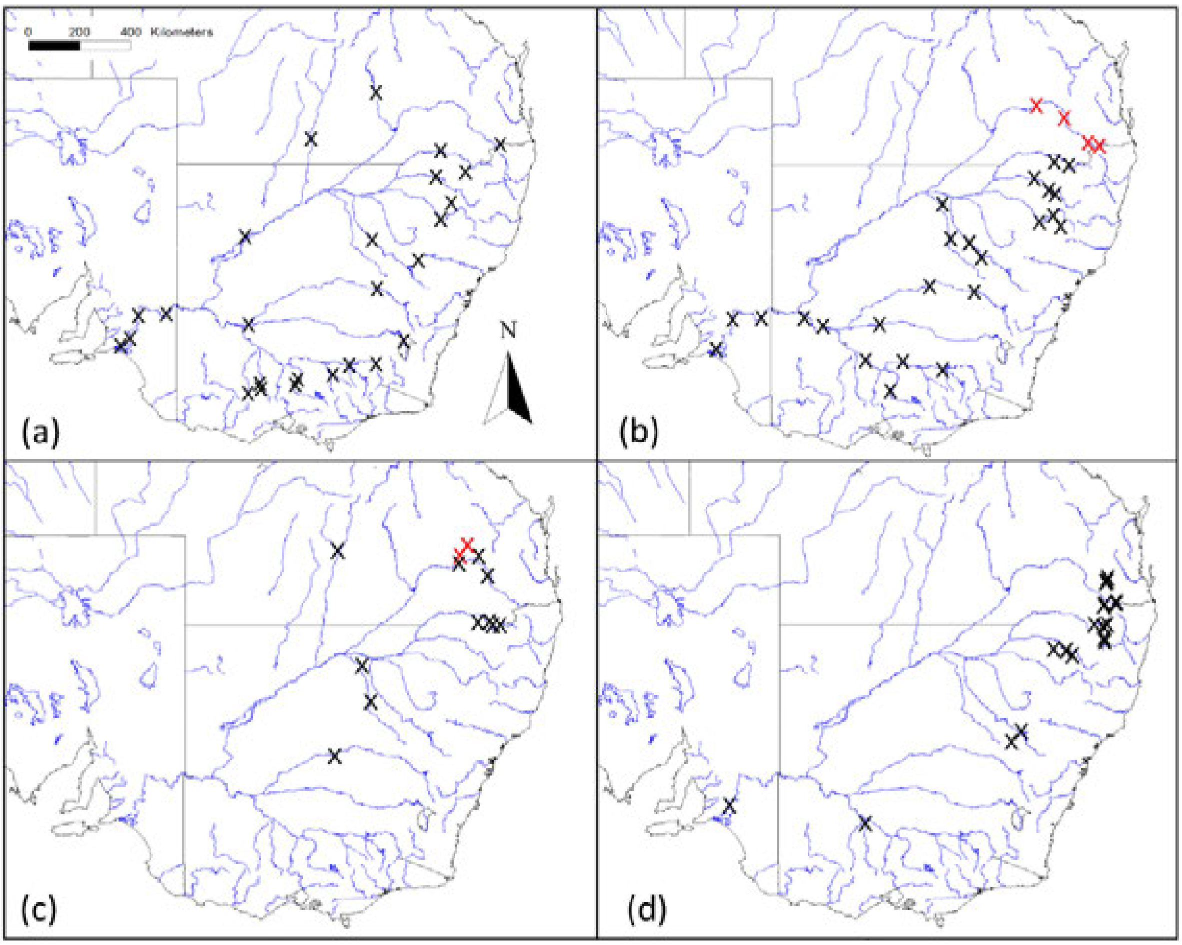
Table 13. Sample size (*N*), number of river valleys, number of populations and the number of variable loci for the four target fish species for the whole MDB and each sub-catchment

Scale	*N*	Rivers	Populations	Loci
Whole of Basin				
Australian smelt	247	17	26	10 095
Unspecked hardyhead	94	11	22	5 288
Olive perchlet	40	6	11	886
Southern purple-spotted gudgeon	247	6	22	1 883
Murray catchment				
Australian smelt	101	8	11	5 754
Unspecked hardyhead	35	5	7	3 115
Olive perchlet	8	1	1	948
Southern purple-spotted gudgeon	79	1	1	588
Darling catchment				
Australian smelt	106	8	11	4 783
Unspecked hardyhead	47	5	12	3 654
Olive perchlet	32	6	10	890
Southern purple-spotted gudgeon	159	4	20	1 445
Lower Murray catchment				
Australian smelt	37	1	4	3 647
Unspecked hardyhead	12	1	3	5 335
Olive perchlet[a]	na	na	na	na
Southern purple-spotted gudgeon	9	1	1	96

na = not applicable

a Not recorded in the lower Murray since 1983.

SNPs are single DNA bases that vary within a sample of individuals. Genome-wide SNP data were collected by the commercial provider Diversity Arrays Technology. Full background and details on their procedures can be found in Georges et al. (2018) and Unmack et al. (2019). Data manipulation was conducted using the R-based application dartR (Gruber et al. 2018). Data are first grouped and labelled by sub-population and river basin. Some analyses are sensitive to missing data, thus any individual samples with higher levels of missing data were removed. Individual heterozygosity values were then checked for outliers, both within the whole dataset and in some cases within population, with between one and seven individuals being removed from each dataset. A second issue related to higher heterozygosity can arise due to introgression from fish sub-populations from outside of the MDB. Frequently fish species from the Burnett River have a strong interaction with conspecific MDB fish sub-populations in the Condamine River. This resulted in all Condamine sub-populations for unspecked hardyhead and Dogwood Creek sub-populations of olive perchlet being removed. For Australian smelt, there is a hybrid zone present in the South Australian portion of the MDB – this was not excluded, but it was incorporated into interpretation of the results at the Basin scale. Each dataset had all invariant/monomorphic SNP loci removed. This cleaned dataset was used as the starting point for all analyses. The next step was to remove SNP loci with >10% missing data prior to analysis. When subsets of each dataset were examined (e.g. populations from only the Darling-Baaka catchment), they were refiltered from the original cleaned dataset to exclude unwanted individuals, refiltered to remove any monomorphic SNP loci and refiltered to remove missing data by SNP locus at >10%.



Red X indicates populations that were excluded due to introgression.

Figure 4. Map of each fish species sampled: (a) Australian smelt, (b) unspecked hardyhead, (c) olive perchlet, (d) southern purple-spotted gudgeon.

Genetic similarity of individuals and sub-populations was visualised using ordination via principal coordinates analysis (PCoA). This provides an easy way to interpret the relationships between populations than does examining complex tables of numbers, although assessing the levels of divergence is difficult, with interpretation required. The percentage of the variation explained on each axis is indicative of genetic distinctiveness, with numbers around 5–10% often being indicative of only smaller to moderate differences; differences over 10% are major and under 5% are minor. These are only an approximate guide and need to be interpreted carefully. Sub-populations that separate in PCoA tend to be those that either are quite low in genetic diversity or have quite different genetic diversity present, which is easily confirmed by looking at the results of other analyses, such as heterozygosity. They also need to be examined in a stepwise manner, with additional insights being provided as outlying populations are removed to reveal patterns at finer scales.

Fst values (the proportion of the total genetic variance contained in a sub-population (s) relative to the total genetic variance (t)) are a more traditional measure of population differentiation. They provide estimates of the genetic differentiation between sub-populations and they vary in value from 0.0 to 1.0, with 0.0 representing no differences, and 1.0 completely different (i.e. no shared alleles). Based on approximate guidelines Fst values up to 0.05 are generally considered to indicate low genetic differentiation (but this is subject to interpretation depending on scale, sample size, number of genetic markers, etc.). Values from 0.05–0.25 indicate moderate genetic differentiation while values above 0.25 represent high levels of genetic differentiation.

Basin-scale comparisons

As may be expected, all species showed a high degree of difference at the Basin scale in the PCoA plots (Figure 5). SNPs show a north–south differentiation between the Darling-Baaka and Murray catchments, with the lower Murray showing a different pattern in each species in the PCoA plots relative to one or the other upstream catchments. Three of the four species had large differences in Fst values (0.233–0.406) between the Darling-Baaka and Murray catchments above their confluence; values were lower in unspecked hardyhead (0.067). For the lower Murray (defined as the section below the Darling confluence), Australian smelt have a complicated pattern due to influence from genetically distinct sub-populations from coastal Victoria; thus, the lower Murray displays a pattern of increased divergence from Murray sub-populations in a downstream progression. lower Murray sub-populations of unspecked hardyhead appear to represent a blend of influences from both the Darling-Baaka and Murray catchments. Southern purple-spotted gudgeon from the lower Murray were most closely grouped with Murray River sub-populations from Victoria in the PCoA plot. However, there were large Fst values between the two populations – 0.158 – highlighting their underlying distinctiveness. No sub-populations of olive perchlet exist today from the lower Murray. The one Murray catchment sub-population from the Lachlan River is well separated in the PCoA plot.

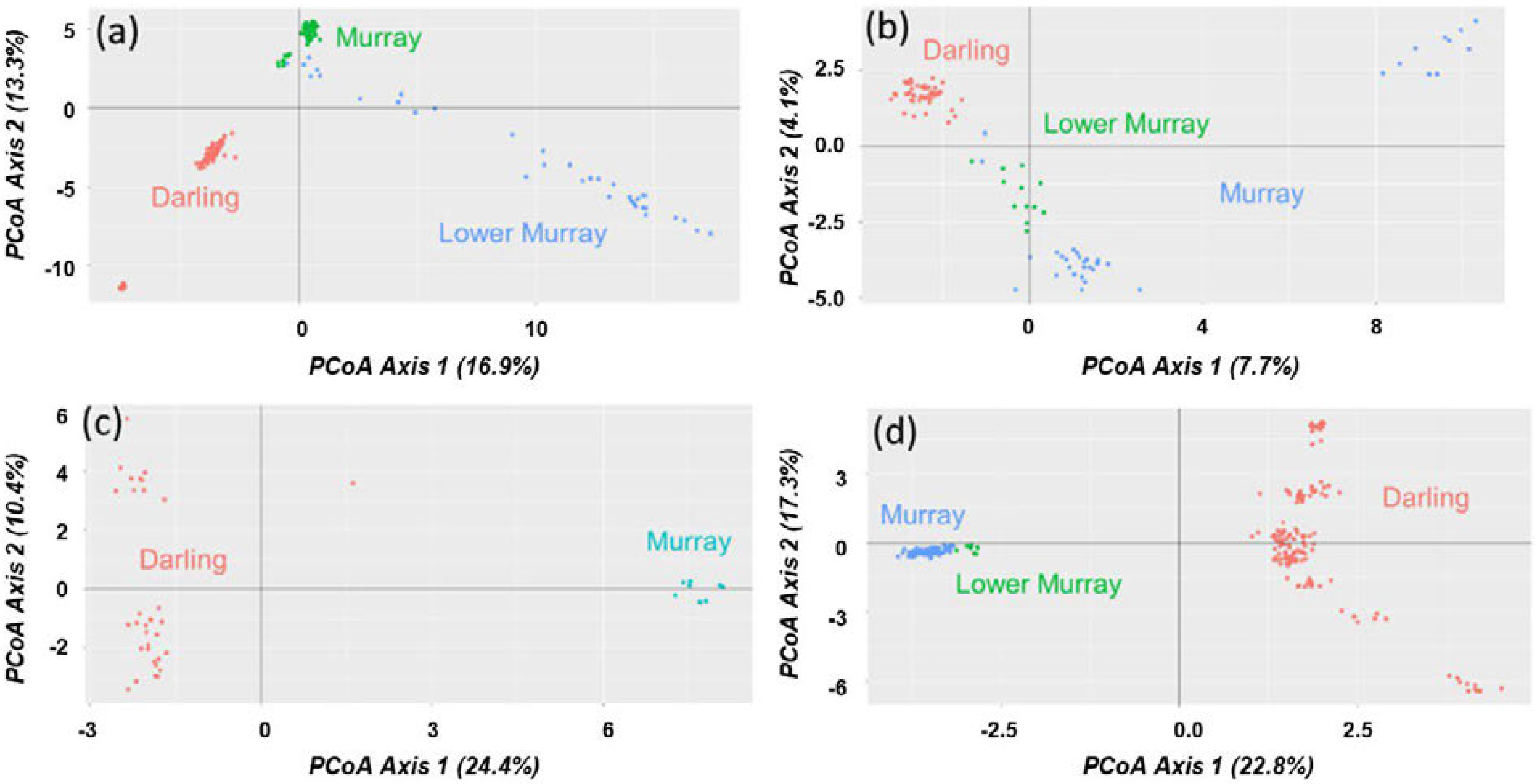
While many barriers exist today in the Darling-Baaka River, prior to the Millennium drought Australian smelt were at least present along much of the Darling-Baaka River, thus potentially providing some more recent gene flow. Unspecked hardyhead tend to be uncommon in the Darling-Baaka River, thus there are less opportunities for gene flow, but there was likely higher gene flow in the recent past based on their lower Fst values. Limited occurrences in the Murray catchment today makes it difficult to interpret differences between the Darling-Baaka and Murray catchment for olive perchlet and southern purple-spotted gudgeon.

These results demonstrate a lack of panmixia across the Basin as a whole and highlight that there is differential movement between the Murray and Darling-Baaka catchment and into the lower Murray.

Between river catchment patterns, excluding the lower Murray River

While all four species were typically widespread across the MDB, only Australian smelt and unspecked hardyhead had high levels of connectivity. All sub-populations were grouped by river catchment, with the Murray River typically split into an upper section (usually above Yarrawonga Weir) and a midsection down to the Darling-Baaka River junction. Any sites that were clearly divergent (based on PCoA results, heterozygosity and high Fst values) were excluded from comparisons between sub-catchments as they have little connectivity.

For Australian smelt, four distinct sub-populations (Figure 6a, b and Figure 7a) were excluded from the Fst results presented. Three sub-populations were from the Darling-Baaka catchment including the Severn River (NSW), which is isolated by waterfalls and has low genetic diversity, the Warrego River, which generally had higher differences, and the Maranoa River (a Condamine tributary), which generally had moderately higher differences. In the Murray catchment, the upper Murrumbidgee River sub-population was excluded as it was quite divergent in the PCoA plot (Figure 7a, b) and had slightly higher heterozygosity. Australian smelt generally had similar patterns in the Darling-Baaka and Murray rivers, Fst values ranged from 0.031–0.085 (average = 0.056) and 0.004–0.100 (average = 0.043) respectively. Typically, sites that were further apart in terms of river kilometres tended to have higher Fst values. Once distinct populations were removed, PCoA plot axes mostly had lower values for the percentage of variation explained (Figure 6a, b and Figure 7a, b).



PCoA = principal coordinate analysis

Figure 5. Separation of sub-populations based on PCoA plots at the Basin scale for (a) Australian smelt, (b) unspecked hardyhead, (c) olive perchlet and (d) southern purple-spotted gudgeon

Four unspecked hardyhead sub-populations from the Condamine River were excluded due to likely introgression from Burnett River sub-populations. Unspecked hardyhead generally showed evidence for higher connectivity in the Darling-Baaka catchment, with Fst values ranging from 0.029–0.074 (average = 0.055) (which were similar to Australian smelt). In the Murray catchment, there were greater differences, with Fst values between 0.027–0.267 (average = 0.133) respectively, although these higher values were largely driven by the more distinct Lachlan sub-population (Lake Forbes and the Lachlan River at Lake Cargelligo). Excluding the Lachlan gave values of 0.027–0.139 (average = 0.073). The Goulburn River sub-population (Tahbilk Lagoon) is small and isolated with higher Fst values and separation on the PCoA plot (Figure 4c, d). The remaining three sub-populations from the Murray and Murrumbidgee rivers were more similar, with Fst values from 0.027–0.057. Once distinct sub-populations were removed, PCoA plot axes mostly had lower values for the percentage of variation explained Figure 6c and Figure 7c, d).

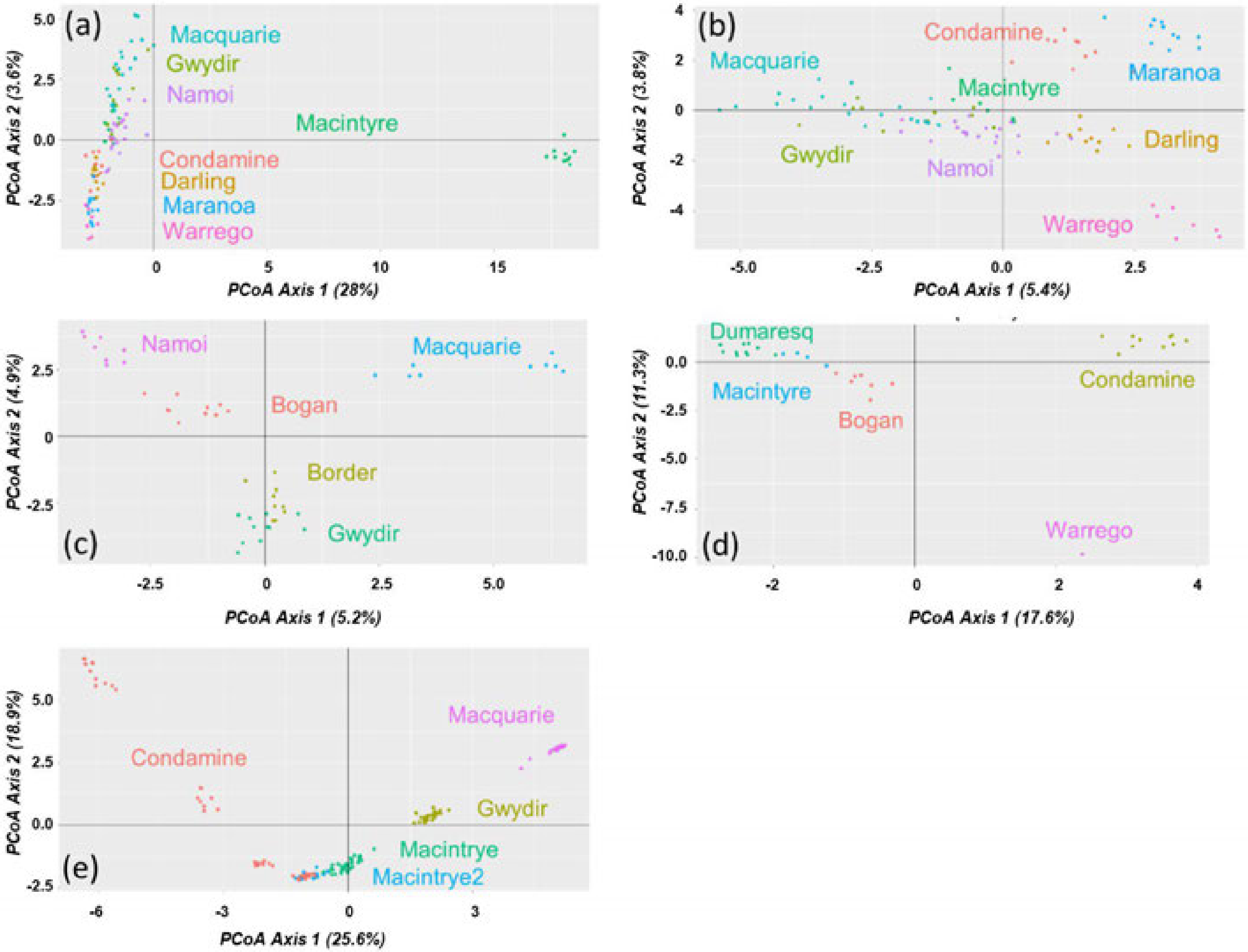
For olive perchlet, sub-populations from the Dogwood Creek sub-population in the Condamine catchment were excluded due to likely introgression from Burnett River sub-populations. In the Darling-Baaka catchment, all rivers were separated by large Fst values, with the Warrego being highly different, but with a sample size of one, which likely inflates those values. Excluding the Warrego, Fst values varied between 0.097 and 0.261 (average = 0.164), which are consistent with minimal gene flow. PCoA plot axes mostly had higher values for the percentage of variation explained (Figure 6d). The value for the X-axis remains at 18.1% even when the Warrego and Condamine sub-populations are removed (plot not shown).

Southern purple-spotted gudgeon has a slightly complicated pattern in the Darling catchment, with three sub-populations in the Condamine catchment from Oakey Creek (by Toowoomba) having much higher heterozygosity than any others in the MDB. There has also been an exchange between the Condamine and Tenterfield Creek; thus, the Macintyre catchment was split into two segments to represent this pattern (Figure 6e). Southern purple-spotted gudgeon are highly fragmented and often have quite low numbers of variable loci and low heterozygosity values. All these characteristics contribute to high Fst values, which ranged from 0.124–0.550 (average = 0.303) but increasing to a maximum of 0.778 when Macquarie catchment individuals are included. PCoA plot axes mostly had higher values for the percentage of variation explained (Figure 6e).

Finer scale patterns

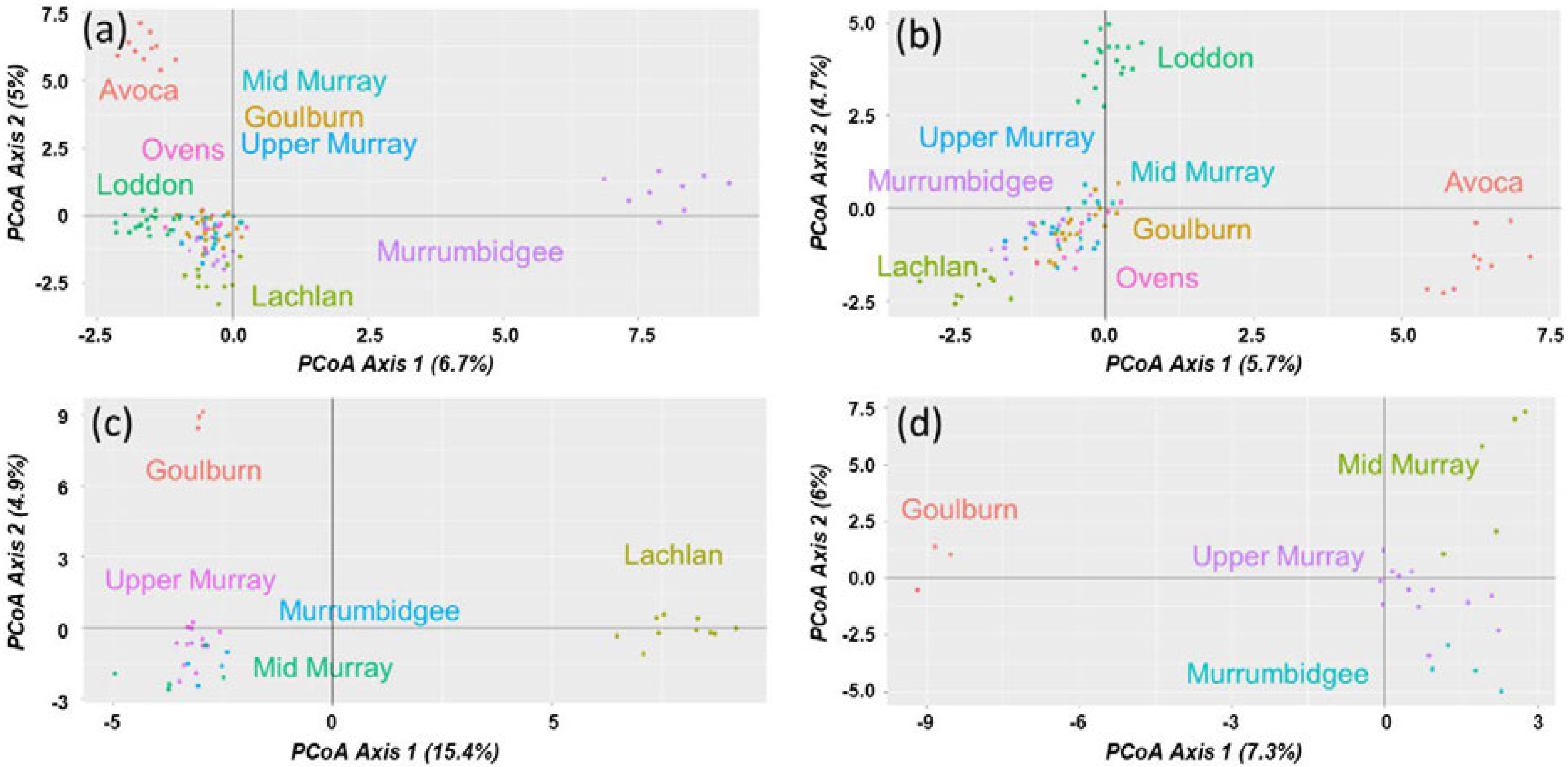
Much of the population sampling used in this study tended to be represented by sub-populations that were deliberately distant from one another. In a few cases, sub-populations in closer proximity were examined, which allows for a glimpse into finer scale patterns.

Australian smelt had the lowest Fst values between sub-populations in Murray catchment, between the upper Murray above Hume Dam, Albury, the Ovens and Goulburn rivers. These Fst values varied from 0.003 to 0.015. Note that gene flow from each of these sub-populations into the Murray River above Hume Dam has not been possible since 1936.



PCoA = principal coordinate analysis

Figure 6. Separation of sub-populations in the Darling-Baaka catchment based on PCoA plots at the river catchment scale for (a) Australian smelt, (b) Australian smelt excluding the Severn River (NSW), (c) unspecked hardyhead, (d) olive perchlet and (e) southern purple-spotted gudgeon



PCoA = principal coordinate analysis

Figure 7. Separation of sub-populations in the Murray catchment based on PCoA plots at the river catchment scale for (a) Australian smelt, (b) Australian Smelt excluding the upper Murrumbidgee River (NSW), (c) unspecked hardyhead, (d) unspecked hardyhead excluding the divergent Lachlan catchment

Unspecked hardyhead were generally sampled more densely at the sub-population scale, but with smaller samples sizes (typically 3–5 per population). Seven sub-populations along the Murray River from Albury to Lake Alexandrina were sampled and most nearby sites, and some more distinct sites, had Fst values from 0–0.01, which is indicative of higher gene flow. A few pairs of sites in the Darling-Baaka catchment had lower Fst values as well: three Gwydir sites from Keera Creek, Bingara and Pallamallawa had values between 0.005 and 0.014, two Namoi sites from Manilla and Gunnedah had Fst = 0.004, two Bogan sites from Nyngan and Gongolgon had Fst = 0.010, and Bonshaw on the Dumaresq River and nearby Yetman on the Macintyre River had Fst = 0.005.

A few sites for olive perchlet were in closer proximity and had lower Fst values, such as Bonshaw and Mingoola on the Dumaresq River (Fst = 0.000) two Bogan sites from Nyngan and Gongolgon (Fst = 0.014 – although sample size for Nyngan was low), and Condamine River at Condamine and Charleys Creek (Fst = 0.016).

Southern purple-spotted gudgeon sub-populations all had high Fst values between them. The closest sites were separated by just over 1 km between Deepwater River and Yoongan Creek and had an Fst value of 0.011; the next-nearest site downstream from Deepwater River, the Dumaresq at Mingoola, had an Fst value of 0.090 relative to Deepwater River. In the Condamine catchment, Farm and Emu creeks had an Fst value of 0.057. In the Gwydir catchment, Keera and Hall creeks had an Fst value of 0.060. Many of these higher Fst values are likely driven by fragmentation and smaller sub-population sizes causing the loss of alleles, but they are still indicative of gene flow being limited even at smaller scales.

Key messages

All species examined showed genetic structure at larger scales, but we expect this in all but the most extreme migratory species due to the vast distances of river length and the constraints of movement in dendritic systems (Fagan 2002). The two common species today had a higher degree of genetic similarity across the MDB than the two rarer species, despite all four species being historically widespread. The common species probably had larger population sizes though historically, which contributes to their higher genetic diversity today.

The key question, which is difficult to answer at this stage with the data at hand, is at what scale does genetic connectivity shift to lower differences. We cannot quite answer this yet, but it is clear that gene flow between many rivers is not frequent, and in some cases there’s little gene flow between sub-populations within river sub-catchments too.

Genetics provides a powerful tool for measuring gene flow. It is important to recognise that animal movement itself does not mean gene flow has been achieved (e.g. Waters 2011). Genetics also identifies sub-populations that have issues, either due to introgression from outside of the MDB (either naturally, or via introductions) or by having low genetic diversity or connectivity. Introgressed sub-populations need special consideration as to their use in conservation programs and sub-populations with low genetic diversity could potentially benefit from translocations.

There is currently a lack of knowledge and the samples required to assess the genetic health and connectivity of most MDB species. High-quality, liquid nitrogen-preserved genetic samples suitable for comparison over time in the MDB are rarely collected. Genomics has opened up new opportunities but requires investment for its full potential to be realised, such as conducting the research to establish linkage maps (e.g. inbreeding individuals for two generations and genotyping parents and offspring) to examine recent changes in sub-population size. Thus, it is currently not possible to answer the question of whether or not genetic diversity has changed over the past 20 years (e.g. in response to drought, blackwater events, barriers or other factors), but it could be feasible with the right investments.

4.5 Key findings – species distribution

Key findings

Potential status assessment questions were identified in Cottingham et al. (2022) and refined in consultation with the Native Fish Recovery Strategy Technical Advisory Group (see Appendix 1, Table 18) for each attribute; however, some questions are not addressed due to scope and data limitations.

A dedicated, targeted and comparable long-term monitoring program is required for threatened fish.

Has the distribution of species increased, decreased or remained stable?

No overall change detectable in distribution of species at Basin scale measured as species presence (from 2010 point of reference), other than a range extension for silver tandan into the MDB during floods and the loss of the Yarra pygmy perch.

The total fish species recorded before and after 2010 declined by one species, from 48 to 47 species (noting that the undescribed Wimmera River blackfish, Goulburn two-spined blackfish and short-headed lamprey were omitted from the database used for assessment). However, there were further differences in the species present in the pre- and post-2010 periods (e.g. record of silver tandan and loss of ornate galaxias and estuary perch in the post-2010 period).

Trend in species distribution is variable at valley scale (from 2010 point of reference*), not many realistic increases, but some apparent loss of sub-populations in the Paroo (e.g. silver perch, Murray cod, freshwater catfish).

Differences in the species present in the pre- and post-2010 periods were also recorded in each river valley; that is, there were instances where species were lost or gained post-2010. However, the differing length of the two time periods means that it is possible that the records of species being lost to particular river valleys post-2010 could be inflated.

*There is no centralised data repository for fish distributional records within the MDB. The current status assessment relies on a collation of records that was compiled for another purpose (broad distribution mapping, not valley-by-valley assessment across set time periods) and does not include all records.

Are species sub-populations connected or fragmented?

Varies by species, with some fragmentation evident. Golden perch, olive perchlet and spangled perch have moved into the Southern Basin during flood events, but there have been decreases as well. Olive perchlet and spangled perch are considered vagrants into the Southern Basin.

Improvement in and widespread use of eDNA detection methodology will greatly improve presence reporting in the coming years, particularly for rarer species.

Using genetics to examine patterns of population connectivity in the Murray–Darling Basin will also be useful in the future, for example by identifying fragmentation and barriers to the mixing of sub-populations of individual species.

Results for four species, Australian smelt, unspecked hardyhead, olive perchlet and southern purple-spotted gudgeon, demonstrate a lack of panmixia (i.e. random mating across the entire population is not possible) across the Basin as a whole and highlight that there is differential movement between the Murray and Darling-Baaka catchment and into the lower Murray.

Only Australian smelt and unspecked hardyhead had high levels of connectivity. All sub-populations were grouped by river catchment, with the Murray River typically split into an upper section (usually above Yarrawonga Weir) and a midsection down to the Darling-Baaka River junction.

Gene flow between many rivers is not frequent, and in some cases there’s little gene flow between sub-populations within river sub-catchments too.

5 Population dynamics

5.1 Background

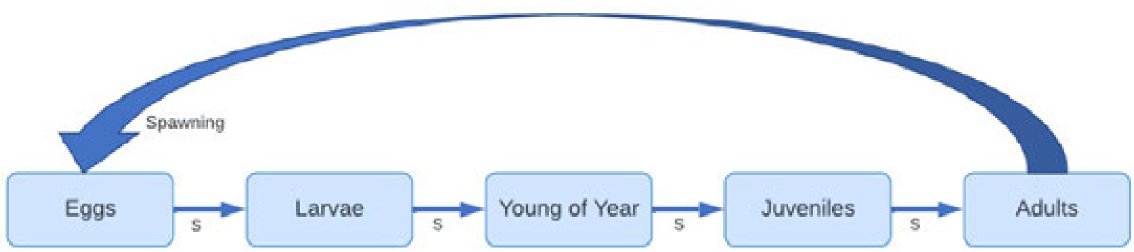
Population dynamics can include elements like recruitment, abundance (population and sub-populations), population structure (e.g. size and age structure, length-frequency histograms, cohort analyses), growth, survival and mortality, movements and migration, and fish condition and health. The study of a species' population dynamics usually seeks to answer questions such as: how are the life stages of a population changing over time or space? And what factors are causing fluctuations in abundance?

A fish population at any future time period may be described by an equation (Koehn et al. 2020a):

> Population being considered = original population size + recruits – deaths + immigration – emigration

The number of new fish entering a population or a sub-population in a given time is termed recruitment. Recruitment to the adult population is the combined survival through life stages (eggs, larvae, young of the year, juveniles and adults) conceptually outlined in Figure 8. There are of course a range of environmental factors (e.g. spawning triggers, spawning habitat, suitable food and nursery areas, predation of young) that all impact survival rates for each life stage. Further exploration of these important factors is beyond this assessment. Reproduction is also a combination of the species fecundity (which may include fish condition) and the number of adults (an important monitoring variable, particularly in the assessment of conservation status) contributing to spawning (number of eggs; Figure 9). The time taken for this to occur varies between species according to their age at maturity (e.g. Murray hardyhead matures in less than a year and may only live to 2 years of age, whereas Murray cod matures at about 5 years and lives to almost 50 years; Koehn et al. 2020a).

While 'true' recruitment is addition to the adult (breeding) population, this term is also used to describe interim, early life stages (e.g. to the post-larval life stages, such as age 0+ fish). That is the definition used in this assessment. Populations may also be artificially enhanced by actions such as fish stocking and/or translocations.



S = survival

Figure 8. A simple fish species life cycle. S = survival rate between the life-cycle stages.

For monitoring, measuring adult fish abundance is more of an indicator of the culmination of this full life cycle into adulthood, which in the case of long-lived and late-maturing species, significantly delays access to data useful to managers. Determining spawning (presence of larvae) or recruitment of young fish is more of a leading indicator; this helps managers predict how the population may change in the future. Larval sampling has occurred for few species, and is generally not consolidated into Basin-wide datasets. Fish condition may be an indicator of impending spawning success or a precursor/measure of fish stress (such as during drought) and likely higher mortality; as may indicators of fish health.

This chapter will present a narrative on species abundance (adults and juveniles where measured), recruitment, biomass (where available), size-class distribution, and spatial extent or distribution based on frequency of occurrence or occupancy of river kilometres.

5.2 Assessment approach

This assessment initially focuses on analysis of abundance, extent and recruitment but also includes other factors that influence population dynamics. We start with a large-scale population trends using contemporary research analysing the Sustainable Rivers Audit and Murray–Darling Basin Fish Survey (SRA/MDBFS) datasets, then use some case studies for several key species types and conclude with a discussion of monitoring limitations and factors influencing current and future data collection and analyses. Species used are listed in Table 13 and types of species are explained in Box 1.

Box 1 – Fish guilds that aid in interpretation

The SRA categorised fish in the MDB into one of three life-span categories, long-lived (generally more than 5 years maximum age), intermediate-lived (3 to 5 years life span) and short-lived (up to 3 years) species. We use the same categories here to aid in interpreting trends in extent and/or recruitment of species that have some traits in common.

Another commonly used grouping of fish is to classify each species as large or small bodied. These categories are not independent of the life-span categories but do allow for an uncomplicated interpretation for a wider audience – as larger-bodied species in particular are well known and sometimes iconic to the community.

5.2.1 MDBFS and SRA datasets

The MDBFS (2014–present) and the SRA (2005–2013) monitoring programs were designed to allow for biodiversity assessment estimates at the large scale (whole of MDB) with high confidence, and each MDB catchment/valley with less confidence. The SRA sampled more intensively, but less frequently, while the MDBFS samples more frequently but less intensively:

- SRA = every MDB valley sampled once every 3 years, 14–28 sites per valley
- MDBFS = every MDB valley sampled once every year, four to eight sites per valley. *With the exception that the MDBFS only sampled 50% of the MDB each year in the 2019 and 2020 sampling years

The MDBFS has a permanent sampling frame and revisits the same sites each sampling round. The SRA had a more flexible sampling frame and revisited up to 50% of sites each sampling round.

The sampling methodology is predominantly electrofishing, but sampling effort is dictated by the habitat in the sampling site, to either boat only, backpack only or a mix of boat and backpack. Fish are counted, measured (length and weight) and released, making site estimates of abundance and biomass possible. The sites are a standard length, with the sites selected using stratified random sampling, with two to four elevation-based zones (referred to hereafter as strata[6]) sampled within each of the 23 valleys and a total of 68 strata sampled. Each of these strata has at least seven sites per survey (SRA) and two sites per survey (MDBFS). As every one of the strata has a different stream length (and hence used a different sampling frame when selecting the site locations) the site selection probability is different between strata and this needs to be accounted for in analyses. All sites are the same physical length regardless of stratum but have different widths[7] (i.e. channel width) which is approximately related to stream order and consequently associated with the elevation strata. In summary, the area of habitat sampled is different between sites and the universal rule is to treat all sites within each stratum as equal in sampled area. Data from all electrofishing shots are treated as from a standard site for point (site) scale analyses, but when aggregating to higher scale assessments (strata or catchment), site parameters are weighted by length of the available strata in the sampling frame when the site was initially selected. Assessments are thus better interpreted as 'river kilometres' (e.g. fish/km or kg/km) rather than as 'site averages'.

[6] Strata are sampling subgroups used in stratified random sampling, in this instance elevation-based zones – montane, slopes, lowland etc.

[7] Thalweg is the lowest elevation point in the channel, typically measured in the middle of the channel.

Table 14. Fish species analysed for the population dynamics status assessment in 2022

Species	Common name	Large-bodied population status	Extent of ubiquitous species	Recruitment of long-lived species	Recruitment of intermediate-lived species	Status of small-bodied threatened fishes
Ambassis agassizii	Olive perchlet					✓
Bidyanus bidyanus	Silver Perch			✓		
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead		✓			
Craterocephalus fluviatilis	Murray hardyhead					✓
Cyprinus Carpio	Common carp	✓				
Gadopsis bispinosis	Two-spined blackfish		✓		✓	
Gadopsis marmaratus	Northern river blackfish		✓		✓	
Galaxias olidus	Mountain galaxias		✓		✓	
Galaxias oliros	Obscure galaxias		✓			
Galaxias rostratus	Flat-headed galaxias				✓	✓
Hypseleotris spp.	Gudgeon complex		✓			
Leiopotherapon unicolor	Spangled perch		✓		✓	
Maccullochella macquariensis	Trout cod	✓		✓		
Maccullochella peelii	Murray cod	✓	✓	✓		
Macquaria ambigua	Golden perch	✓	✓	✓		
Macquaria australasica	Macquarie perch	✓		✓		
Melanotaenia fluviatilis	Murray–Darling rainbowfish		✓			

Species	Common name	Large-bodied population status	Extent of ubiquitous species	Recruitment of long-lived species	Recruitment of intermediate-lived species	Status of small-bodied threatened fishes
Mogurnda adspersa	Southern purple-spotted gudgeon				✓	✓
Nannoperca australis	Southern pygmy perch		✓			✓
Nannoperca obscura	Yarra pygmy perch					✓
Nematalosa erebi	Bony herring		✓		✓	
Neosilurus hyrtlii	Hyrtl's tandan				✓	
Philypnodon grandiceps	Flathead gudgeon		✓			
Retropinna semoni	Australian smelt		✓			
Tandanus tandanus	Freshwater catfish	✓	✓	✓		

There are some caveats (Box 2) and limitations (Box 3) on the analyses of these data for this chapter.

Box 2 – Caveats on the analyses

We define sampling round as a sampling period taken to sample the entire MDB. The SRA (9 years, 3 rounds) was designed to allow statistically reliable assessments of trend after 15 sampling rounds of data collection. When combined with the MDBFS (8 years, 7 rounds), the data now cover 10 sampling rounds, presenting a preliminary opportunity to analyse large-scale trends for extent, abundance and biomass for riverine species that are ubiquitous and/or abundant in the dataset.

The SRA/MDBFS datasets allow estimates of trends in population relative abundance and biomass for several species at the whole-of-Basin scale. Note that the assessments are of trends in the populations through time, not necessarily the absolute values of the populations and not compared to a reference or baseline. For example, one may say that biomass of a particular species has decreased or increased by 10% but should never say that it has increased or decreased by 20 kg/ha. It should be noted that the data did not include the fish death event of 2023 in the Darling-Baaka, so Basin-wide trends may not be consistent across all valleys.

Box 3 – Zeroes in the dataset

As the sampling is broadscale and does not target any specific species, there is generally a lot of zeroes in the dataset. That is, many species will not be present in a lot of the sites and a lot of zeroes can limit the statistical options available. Options commonly used to reduce the number of zeroes and make the statistical analyses more stable include aggregating the data to a higher scale (e.g. converting site data to valley data); modelling the zeroes as a secondary response variable; removing sampling sites that are not relevant to some species (e.g. removing highland sites when assessing lowland species); analysing only prevalence (abundance when present) or; selecting species that have fewer zeroes (ubiquitous species).

The MDBFS and SRA datasets offer medium-term data covering the whole of the MDB with standardised sampling effort for riverine fish. The data collected are adequate for estimating relative abundance and biomass for abundant or ubiquitous species that are susceptible to electrofishing. This includes most large-bodied species and species that have a wide distribution in the MDB, even if not locally abundant. Notably, silver perch are not well collected using this method (Lyon et al. 2014). Wetland and off-channel residents are also not included in these data sets.

5.2.2 Status and trends in large-bodied fish populations

Crook et al. (2023) analysed the relative abundance of six large-bodied species in the NSW part of the MDB using monitoring data between 1994 and 2022. This research incorporates data from 142 research projects and includes the NSW Rivers Surveys from 1994 up to the start of the SRA, and through to the current MDBFS. The species included are Murray cod, golden perch, silver perch, Macquarie perch, freshwater catfish and carp. Preliminary results are included, with permission, in Section 5.3.1, and reports status and trends in:

- abundance
- biomass
- size distribution.

The analyses included generalised additive mixed models and to improve modelling efficiency and relevancy of the results, Crook et al. (2023) only included sites where the species is known to occur at least once in the dataset, and only used relative rather than absolute measures. These approaches moderate the imbalance between the distribution of sites and effort in the strata. Full analysis details are in Crook et al. (2023).

5.2.3 Spatial extent of ubiquitous fish populations

Robinson et al. (in prep.) assessed the spatial distribution of ubiquitous riverine fish species between 2004 and 2022 in the SRA/MDBFS datasets, and explore the status and trends between, by describing the extent and spatial distribution of ubiquitous species as estimated by the relative number of river kilometres each species was detected in.

Although not assessing abundance directly, the spatial extent is presented as an alternative measure for abundance, as more abundant species are always detected in more sites. Even though abundance estimates are affected by electrofishing detection efficiency, detecting the presence of a ubiquitous species within a strata is not (Robinson et al. 2019). Hence, the approach of Robinson et al. (in prep) improves efficiency and relevance of results by aggregating data to the strata or valley scale before analyses. Only species that were detected in at least 20% of the 68 MDB defined strata are included in the spatial extent analyses. Analyses only includes valleys where the species was historically known (Lintermans 2023) and sites where the species has been detected by the SRA/MDBFS program at least once since 2004. When assessing the change in extent of each species, results should consider the proportion of 'river kilometres' where the fish were detected in. Three of the long-lived species analysed for extent by Robinson et al. (in prep) (Murray cod, golden perch, freshwater catfish) were also analysed for trends in abundance in the large-bodied species by Crook et al. (2023).

5.2.4 Status of key small-bodied threatened freshwater fishes

Whiterod et al. (2019, 2021c) investigated the status of six small, short-lived native fish species in the Southern Basin. Their narrative assessment included descriptions of historic trends in populations and sub-populations, as well as statements on the status of the individual species as of 2021. This work is a good example of using expert opinion to assess the status of fish species in circumstances where there is limited available data. A summary of their findings has been included to complement that from assessment using the SRA/MDBFS and other datasets.

5.2.5 Status of key species in the Coorong, Lower Lakes and Murray Mouth

While many freshwater habitats are missed by the MDBFS (no wetland or ephemeral streams are sampled) The Living Murray (TLM) has been able to report on key estuarine and migratory species in the Coorong, Lower Lakes and Murray Mouth (CLLMM) icon site. In this status assessment we paraphrase from annual TLM reports to document trends in the commercial catch of black bream, greenback flounder *Rhombosolea tapirina* and Murray hardyhead between 2008 and 2021.

5.2.6 Recruitment of long-lived and intermediate-lived species

The community-scale recruitment assessment counts the presence of juvenile or young of the year (YoY) from 14 ubiquitous native fish taxa present in each site in the SRA/MDBFS dataset (Table 15). The count is compared to a benchmark value and each site is then assessed as having compliant levels of recruitment or not. The benchmark is the 90th percentile of all 1 873 site surveys in the dataset. In other words, a compliant site is in the top 10% of all time surveys. Note that adults do not contribute to the index and there are no short-lived species in the assessment, as only adults are collected by the current protocol. Intermediate or long-lived species are assessed separately to aid in interpretation.

5.2.7 Narratives for select large-bodied native species

Narratives drawing from multiple independent research studies conducted over numerous study sites and timeframes are given for Murray cod, trout cod and silver perch.

5.3 Results – population dynamics

5.3.1 Status and trends in large-bodied fish population – NSW MDB, 1994–2022

When assessing species status across the whole Basin, by necessity generalisations must be made. It is important to point out, however, that there are complex spatial patterns and temporal trends in relative abundance and biomass both within and among species at the Basin scale that also need to be considered. The following results are summarised from Crook et al. (2023).

Overall, **Murray cod** (Figure 9) relative abundance increased sharply from a low level in the mid-late 1990s and peaked around 2008, before falling until 2012. Abundance then recovered and remained relatively stable from 2015 to 2022. The relative biomass of Murray cod also increased sharply from a low level in the late 1990s, peaked around 2003 and declined until 2008, coincident with a decrease in the median size of fish. Biomass and median size of Murray cod increased from 2008 to 2017 before declining again between 2018 and 2022. There have, however, been recent declines in the Barwon–Darling and Gwydir river systems.

Golden perch (Figure 9) relative abundance increased across the study period, with a peak in 2010–12 that coincided with dominant cohorts of small fish (<20 cm) in 2011 and 2012. Biomass of golden perch fluctuated considerably with peaks in 1994, 2003 and 2019, and troughs in 1998, 2010 and 2022. The troughs in biomass occurred in years in which the population had a relatively high proportion of small fish.

Overall **silver perch** relative abundance was low and highly variable in the 1990s. Abundance rose to a peak around 2010, declined sharply until 2015, then declined more gradually through to 2022. Relative biomass of silver perch remained relatively stable across the time series but had wide confidence intervals because of small sample sizes. There was evidence of occasional juvenile recruitment prior to 2000, after which the population was dominated by larger fish, with very few fish <20 cm total length (TL) present. Population structure appears healthier (greater abundance and recruitment in the Murray and Murrumbidgee rivers) with those populations being the stronghold for this species (see also Yen et al. 2021a), Trends in the Border rivers are less encouraging with a declining trend, low numbers and limited recruitment in northern NSW. Captures in the NSW portions of the Paroo and Warrego rivers) are not presented (presumably too little data), so status and trend in these valleys cannot be assessed.

There was no clear trend in the relative abundance and biomass of **Macquarie perch**. Population structure varied substantially among years[8] with some years dominated by adults and other years dominated by small fish <20 cm TL.

The relative abundance estimates of **freshwater catfish** showed a consistent upward trend across the study period, while there was an accompanying decreasing trend in relative biomass. Large confidence intervals for these trends prevented determining statistical significance with low capture numbers in several river systems. The population structure of freshwater catfish oscillated between periods dominated by adult fish and periods dominated by small fish.

The relative abundance of the introduced **common carp** showed no clear general trend over the time series and was characterised by distinct peaks and troughs, with a major peak associated with a large recruitment event occurring in 2010–12. There was an overall declining trend in the biomass of common carp punctuated by a sharp increase following the surge in the number of recruits in 2011–13, followed by a sharp decline in biomass after 2019. The population structure of common carp alternated between periods dominated by either adults or small fish <20 cm TL.

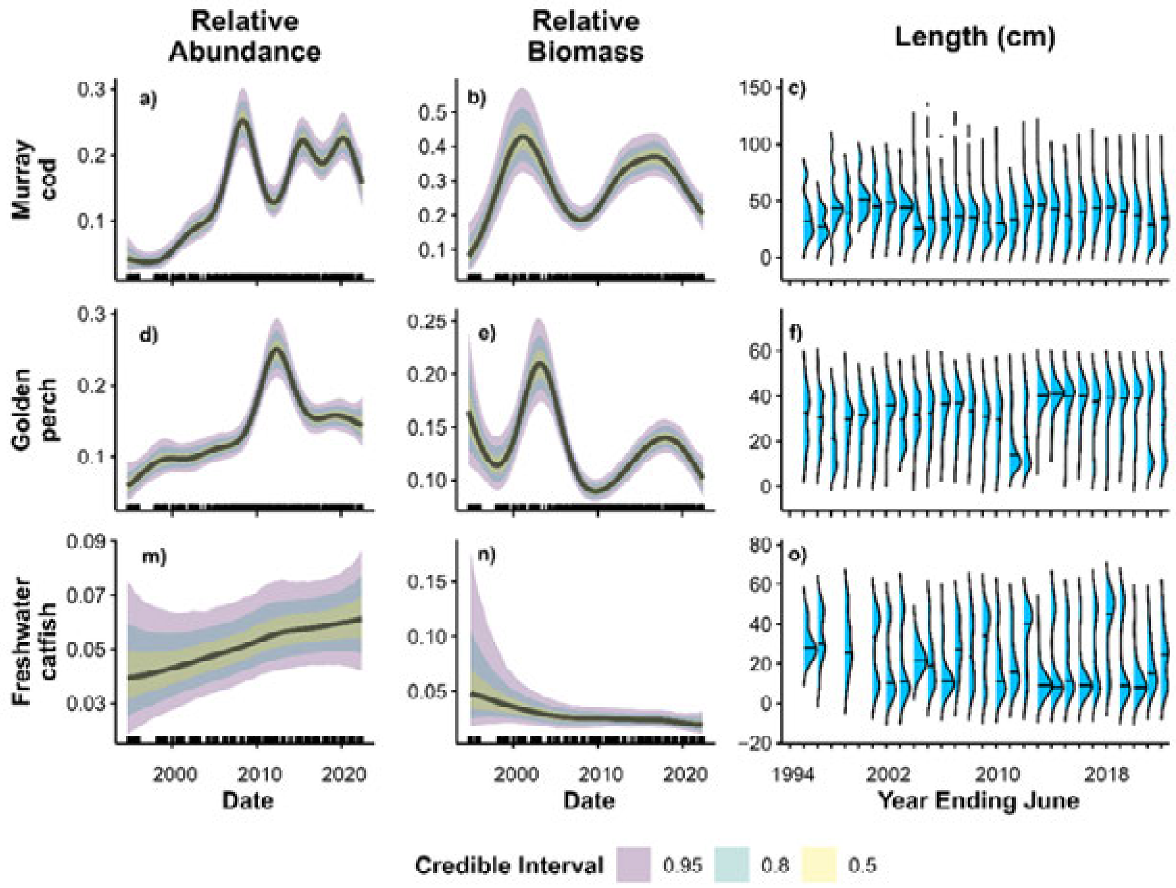
Box 4 – Caveats for length distributions

A major restriction on assessing fish size or age distributions at scales larger than the sampling site is the protocols of current sampling programs. That is, most current program methods do not target recruits and – most importantly – the sites are generally selected using a spatial sampling protocol. Thus, the data are from a cluster sample (Nelson 2014) and the sampling site is only one data point in any analyses requiring independent data. To collect fish from different sites and pool the length data to estimate the size distribution will produce a biased size curve. Results from pooled samples, as in Figure 9, should be treated as a guide only where trends may reflect real trends, but absolute values of the trends should not be considered actual values.

Crook et al. (2023) provides an excellent illustration of the need to conduct monitoring and analyses on a river, sub-population, valley basis to ensure correct interpretations for management. While the Basin-wide population for silver perch indicates no discernible trend, individual catchments in the Northern Basin (Barwon–Darling, Macquarie–Castlereagh, Namoi and NSW Border Rivers) show very low abundances with limited recruitment. There is also the possibility that the presence of small silver perch may be from hatchery stocking rather than natural recruitment. In addition, the lower Darling-Baaka River has been subjected to large fish kills, and other Northern Basin rivers in Queensland have had marked declines in abundance (M. Hutchison,

[8] Electrofishing alone does not represent size distributions well in Macquarie perch, with smaller individuals (<18 cm) missed or poorly represented (see Lintermans 2016; Box 4) and further work is required to adequately characterise population trend in this species.

pers. comm.) There are similar issues with the assessments of Macquarie perch within the Murray and Macquarie–Castlereagh rivers.



Plots were generated using draws from the posterior predictions, excluding random effects, for a sampling duration of 90 s of electrofishing. Length (cm) distributions are pooled by year (July–June) to give annual distributions. The length-density plots are adjusted such that the area under each curve was equal among years to control for differing annual sample sizes. The horizontal line in the length-density plots represents the median length. Note that the y-axes vary among species. Rug plots (tick marks) on the x-axes show distribution of sampling events through time from 1994 to 2022.
Source: Crook et al. 2023, used with permission

Figure 9. Fitted trends in relative abundance and relative biomass, and length distributions of Murray cod, Golden perch and Freshwater catfish in the NSW part of the MDB, 1994–2022

5.3.2 Spatial extent of ubiquitous fish in the MDB, 2004–2022

Twenty-one species that were detected in at least 20% of the MDB fish strata were analysed for extent; these included 15 native taxa (note: several *Hypseleotris* species were combined for the analyses because of taxonomic resolution difficulties in the early years of the programs) (Table 15) and six alien species. The analyses are separated by species life guild (long, intermediate and short-lived species) to aid in interpretation. Even though some species are ubiquitous when judged at the Basin scale (e.g. Australian smelt), declines at valley level may be significant (e.g. only two records of smelt since 1997 in the Paroo).

Table 15. Ubiquitous native species in the MBFS/SRA dataset between 2004 and 2022 (native species that were detected in more than 20% of the 68 fish strata are included)

Species	Common name	Life guild	Number of MDB zones collected in
Bidyanus bidyanus	Silver perch	Long lived	21
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead	Short lived	22
Gadopsis bispinosa	Two-spined blackfish	Intermediate lived	19
Gadopsis marmorata	Northern river blackfish	Intermediate lived	24
Galaxias olidus	Mountain galaxias	Intermediate lived	27
Galaxias oliros	Obscure galaxias	Intermediate lived	21
Hypseleotris spp.	Gudgeon complex	Short lived	52
Leiopotherapon unicolor	Spangled perch	Intermediate lived	23
Maccullochella peelii	Murray cod	Long lived	43
Macquaria ambigua	Golden perch	Long lived	51
Melanotaenia fluviatilis	Murray–Darling rainbowfish	Short lived	24
Nannoperca australis	Southern pygmy perch	Short lived	15
Nematalosa erebi	Bony herring	Intermediate lived	32
Philypnodon grandiceps	Flathead gudgeon	Intermediate lived	22
Retropinna semoni	Australian smelt	Short lived	53
Tandanus tandanus	Freshwater catfish	Long lived	29

Source: Robinson et al., in prep.

5.3.3 Long-lived native fish species – SRA/MDBFS dataset, 2004–2022

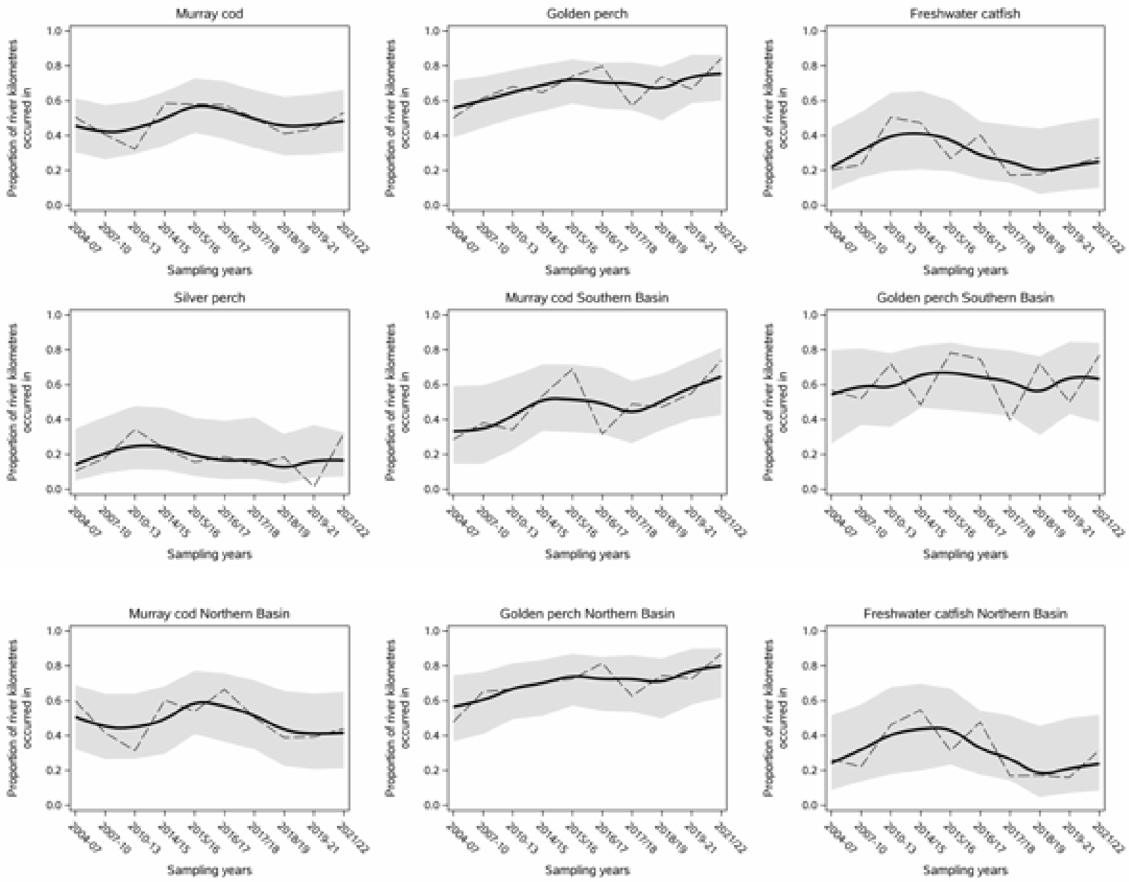
Four long-lived native fish species had sufficient data for extent analysis. Murray cod had an overall non-significant increase from 41% to 46% of contemporary distribution during the study and overall estimated average extent in 41% of their contemporary distribution (Figure 10). The Murray cod trend complement the Crook et al. (2023) abundance results, as they show, low extent prior to 2013 followed by stability of extent over the past six sampling rounds.

Golden perch showed a general but not significant (Tau = 0.47, $p < 0.07$) increase in contemporary spatial extent during the data set, averaging 68% overall and increasing to 75% in the most recent three rounds (Figure 10).

Freshwater catfish averaged 29% throughout the study with occasional dips to 17% and highs up to 51%. Silver perch were only collected in about 20% of historic river kilometres throughout the sampling rounds. Further information on these and other iconic species is presented in Section 5.3.7.

The general trends for Murray cod and golden perch (Figure 10) are similar to those in the abundance plots of Crook et al. (2023) for the NSW part of the MDB (Figure 9). However, while freshwater catfish extent was considered steady overall (Figure 10), the abundance was deemed to be increasing by Crook et al. (2023) (Figure 9). This may reflect the patchiness of the distribution of the species in NSW relative to the entire Basin.

The patterns for each species were similar when compared at the scale of the Northern and Southern Basins (Figure 10), noting that catfish are less common in the Southern Basin (Figure 10). Whilst the overall trends remain similar, the estimated extent for Murray cod and golden perch are more variable between years in the Southern than Northern Basin. Silver perch were not caught in the Northern Basin enough times to create a trend graph, and the Southern Basin trend mirrors the overall trend in Figure 10.



Solid line is the 3-year moving average and grey shade indicates the moving average 95% confidence interval. The dashed line is the actual survey proportion. Top row gives whole-of-Basin scale, lower rows Southern and Northern Basins.

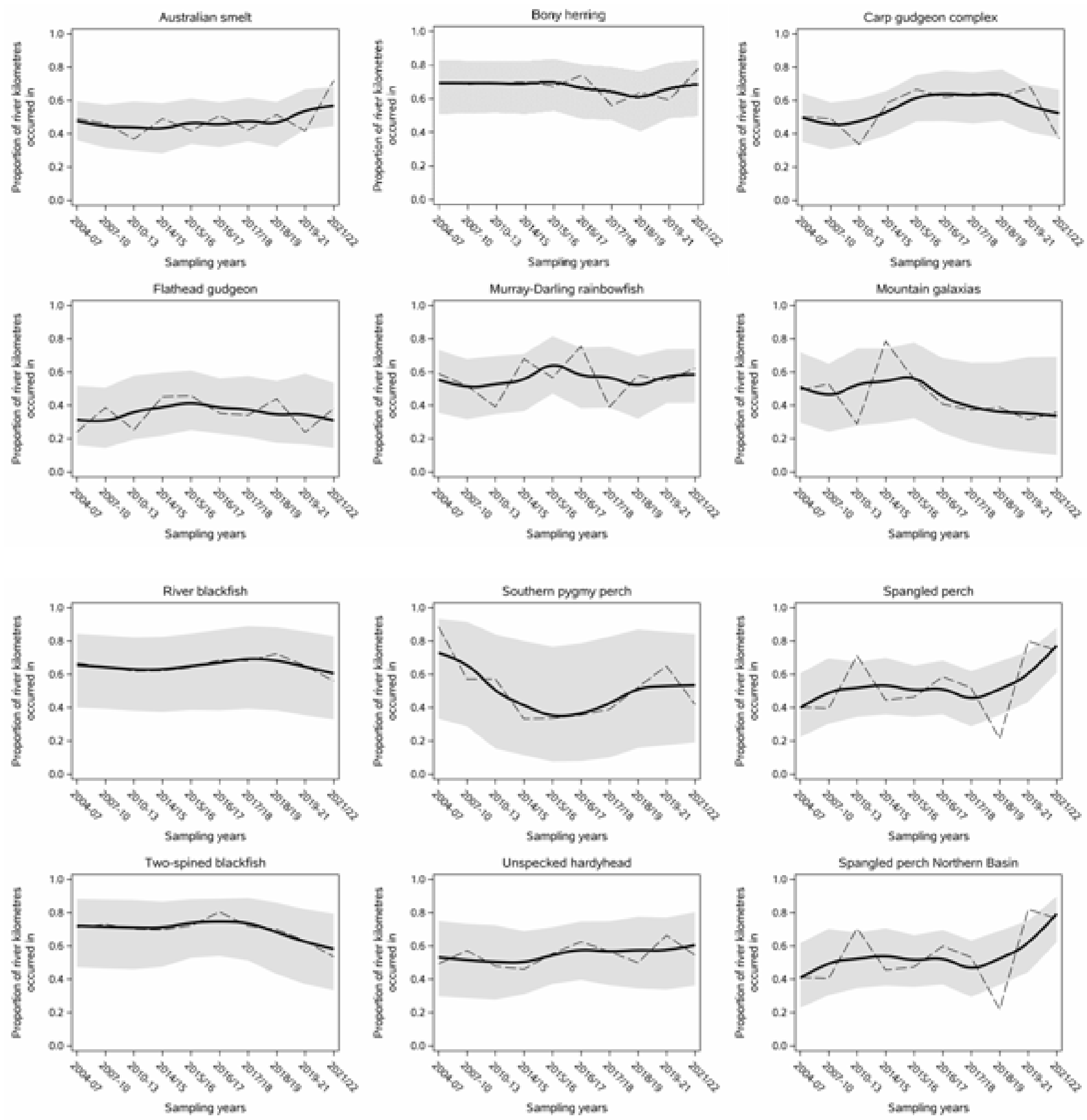
Figure 10. Estimate of proportion of river kilometres inhabited by three long-lived native fish species in the MDB, 2004–2022

Intermediate and small fish species–SRA/MDBFS dataset (2004–2022)

There was no continuous trends in the estimated extent[9] during the study period for the short or intermediate-lived native fish species assessed in the MDBFS and SRA datasets between 2004 and 2022 (Figure 11). Mountain galaxias (averaged 45%) and river blackfish (65%) showed slight non-significant declines in their current extent, both trending downwards in the last few years of the data (Figure 11). The remaining species tended to either remain very stable in their distribution, were highly variable, or displayed short-term peaks and troughs in spatial distribution, but returned to a long-term stable distribution within one or two years (Figure 11). For example, the occurrence of spangled perch appears to be increasing at the Basin scale, but the variability in data is such that this trend is not statistically significant (but see below for the Northern Basin). Bony herring had the highest contemporary spatial extent index of all native species and varied between 62% and 92% between sampling rounds (Figure 11). Two-spined blackfish were also relatively common and consistent in contemporary extent, estimated to occur in approximately 70% of river kilometres through time (Figure 11). Flathead gudgeon were also very consistent in their estimated contemporary spatial extent, averaging 35% through time but spangled perch were highly variable occurring between in 21% and 80% of contemporary river kilometres in the study (Figure 11). Notably they had significantly lower extent in the first, second and eighth rounds than in the third, ninth or tenth rounds ($p < 0.02$).

Examination of trends for each species in the Northern and Southern Basins separately, undertaken for this project, was problematic due to highly variable data as a result of the reduced sites per valley in the MDBFS since 2014. For example, there are only eight sites per annum that are expected to have northern river blackfish in the Northern Basin, which is an insufficient sample size to estimate annual status nor detect regional trends with any confidence. Additional data for individual species are required to identify statistically significant trends at the scale of the Northern and Southern Basins. In particular, further data are needed to confirm the negative trajectory for northern river blackfish in the Northern Basin; as they were common during the first three sampling round but rarer in the last three years of sampling. Conservation concern for northern river blackfish has been raised previously (Hammer et al. 2014, Turschwell et al. 2017). Spangled perch extent in the Northern Basin is not a statistically significant consistent trend through time. During the last three rounds, spangled perch occurred in an average of 61% of river kilometres in the Northern Basin, a 28% increase from during the first six rounds of surveys (48% of river kilometres).

[9] Remember: while not assessing abundance directly, the spatial extent is interpreted as an alternative measure for abundance as more abundant species are always detected in more sites in the SRA/MDBFS datasets.



Solid line is the 3-year moving average and grey shade indicates the moving average 95% confidence interval. The dashed line is the actual survey proportion.

Figure 11. Estimate of proportion of river kilometres inhabited by 11 short- or intermediate-lived native fish species in the MDB, 2004–2022

5.3.4 Small-bodied threatened freshwater fishes in the Southern Basin

The following is summarised from the status assessments undertaken by Whiterod et al. (2019, 2021c), which considered the status of each species following the Millennium drought and more recently in light of various management efforts for some of the species.

Flathead galaxias:

- While there is no quantitative information on population trends in the species, it is considered to have experienced substantial declines in distribution and abundance, much of which occurred prior to the Millennium drought.
- The species is now assumed extinct across much of its former range and only irregularly recorded in extremely low numbers in other areas.

- While there has not been any greater insight provided on the status of flathead galaxias since the Millennium drought, the decline of the species is presumed to be continuing.

Murray hardyhead:

- The species experienced significant declines as a consequence of river regulation and the associated alteration and loss of well-vegetated shallow, saline wetland habitat, exacerbated by critical water shortages during the Millennium drought.
- The post-drought conservation of Murray hardyhead has benefited from the establishment of backup sub-populations. Since the end of the drought, there has been some fragmented recovery of wild sub-populations, in part due to active management (environmental watering and reintroductions), and all known sub-populations of the species have persisted since 2019.
- Murray hardyhead persist across a number of locations, often supported by strategic environmental water delivery. The persistence of recently rediscovered and reintroduced sub-populations has improved the outlook for the species (Ellis et al. 2022).

Olive perchlet:

- Once occurring more broadly across the MDB, the species has experienced widespread historical decline and is now considered extinct in Victoria (last record 1922) and South Australia (last record in 1983). It was considered absent from the NSW section of the southern MDB before it was rediscovered (after a 47-year absence) in large numbers in the Lachlan River catchment. Abundances in the Warrego and other Queensland MDB rivers have declined significantly in the last two decades.
- Recent surveys have confirmed that the single known Southern Basin sub-population in the Lachlan River catchment has been maintained although its distribution remains restricted.

Southern purple-spotted gudgeon:

- Historically, southern purple-spotted gudgeon was broadly distributed across coastal areas of Queensland and NSW as well as patchily occurring in the MDB. In the southern MDB, it was once widespread and common in wetland and fringing river habitat in the Lachlan, Murrumbidgee and Murray catchments (including lower Murray) but has since experienced substantial decline. Sub-populations in some Queensland MDB valleys have declined in the last two decades.
- The future of the species remains precarious in the southern MDB but has been improved with its rediscovery in the Kerang Lakes region in late 2019.
- It is only known from few locations, which are mostly sites used for reintroductions. In the lower Murray, it does persist but has yet to re-establish a self-sustaining sub-population. In NSW, reintroductions have not been successful within the southern MDB; however, there has been the successful establishment of an additional population within the Castlereagh River in the Northern Basin. Encouragingly, healthy backup populations are maintained for the species.

Southern pygmy perch:

- Historically, the species occurred in the Southern Basin in the Murrumbidgee and Murray catchments.
- Loss of habitat and the Millennium drought resulted in widely distributed sub-populations becoming fragmented, with local extirpation occurring from middle and upland Murray catchment sites.

- Since the Millennium drought, the range of the species has continued to decline across the southern MDB, but in the 2 years to 2021 the overall status of the species remained stable.

Yarra pygmy perch:

- Found mainly in coastal catchments, Yarra pygmy perch were restricted to the lower reaches of the southern MDB.
- Its habitat in the Lower Lakes and tributaries was severely reduced during the Millennium drought and the species became extinct there, the last being detected in February 2008.
- Small-scale backup populations persist, and genetic rescue is being trialled, but the situation for the species remains dire.

5.3.5 Trends in selected CLLMM fish species

Monitoring undertaken as part of The Living Murray initiative of the MDBA includes the annual catch of two long-lived species (black bream and greenback flounder) and one short-lived species (smallmouth hardyhead, *Atherinasoma micorsoma*) from 2008 to 2021 (Ye et al. 2022). Trends reported for these species are not statistically modelled as the results are total catch without quantifying effort. Nevertheless, the results summarised below can be interpreted as higher catch occurring in years when the species occurs in a higher abundance.

Long-lived species

The annual catch of black bream in the Coorong has been less than 3.3 tonnes (t) in every year since 2004–05, well below the target of 8 t, which was the mean annual catch between 2000–01 and 2005–06 set for this species (Figure 12). The population condition[10] remained poor or very poor up until 2016 before improving to moderate condition by 2021. Further, long-term commercial fishery catch shows that more than 90% of the annual catch was from the estuary during the Millennium drought between 2002 and 2010, but typically is 50% each from the estuary and the Coorong in years where the Coorong barrage flows are substantial (Ye et al. 2022).

The annual catch for greenback flounder has shown a similar pattern to that for black bream (Figure 12), having largely remained below the target level (24 t, based on mean annual catch between 1995–96 and 2001–02) set for the species since 2002–03 (the exception being 2011–12). The greenback flounder sub-population condition was extremely poor at the end of the Millennium drought (2008–2010), improved to moderate condition in 2014, then declined again to be in poor condition in 2016, but then recovered to be in good condition in 2021 (see Ye et al. 2022). Greenback flounder catch was predominantly from the Coorong in most years, but mostly from the estuary for 3 years following high flows through the barrages.

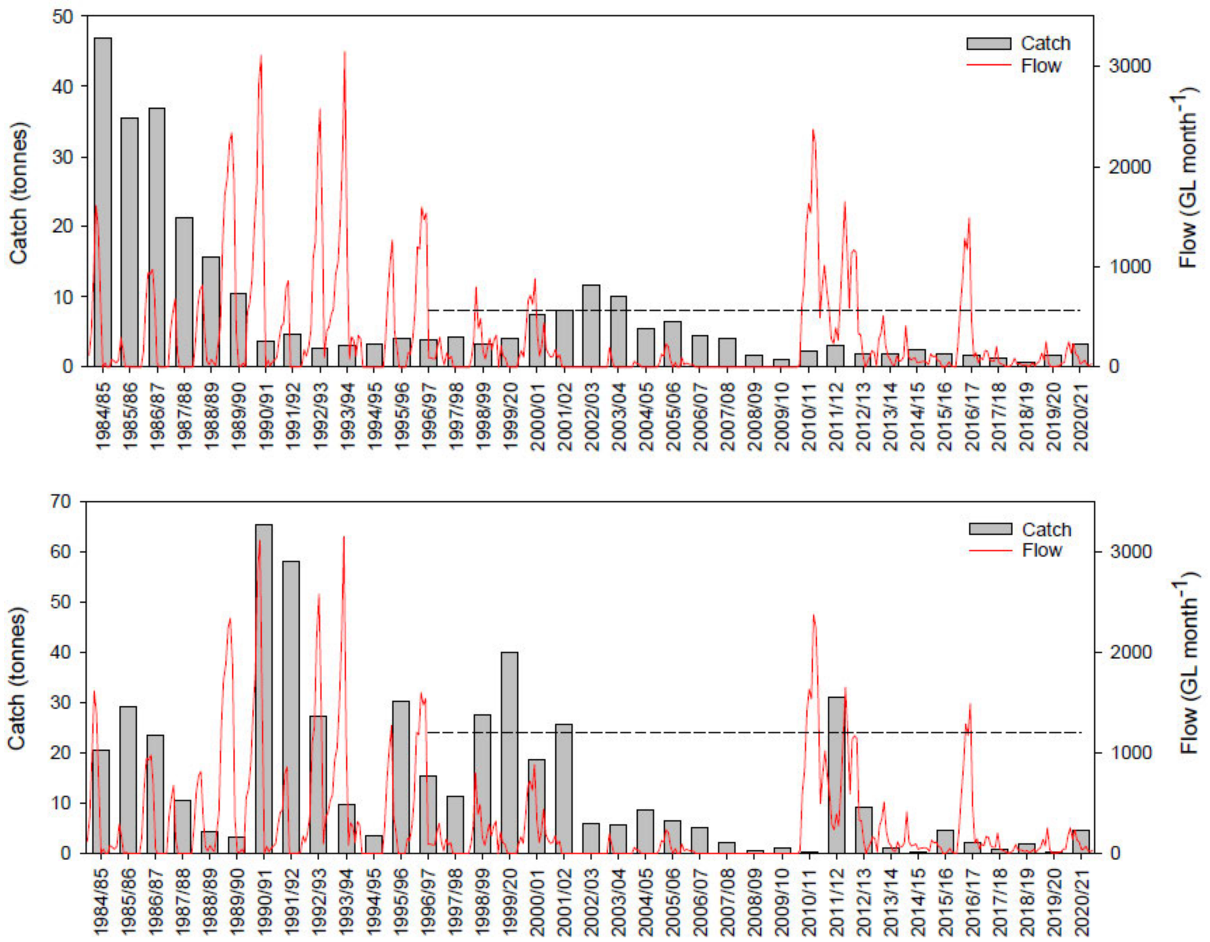
Overall, both species have annual catch below targets that are based on historical averages and both species have undergone expanded distributions in response to increased barrage flows from higher Murray River discharge (Ye et al. 2022). Interestingly, Figure 12 shows much higher catch rates in the 1980s (black bream) and 1990s (greenback flounder) than in the last two decades. This is a good reminder of the need to account for 'shifting baselines' or our perception of more

[10] Ye et al (2022) assigned condition rankings based on scores for (1) relative abundance, (2) distribution, (3) age structure and (4) recruitment.

recent averages; that is, while we might detect contemporary trends (e.g. increases) in population metrics, it is important to compare such trends against historic as well as contemporary measures to fully understand how populations have changed over time. In this case, of these two species, these contemporary measures of condition and abundance indicate a substantial decline relative to earlier assessments.

Short-lived species

Adult smallmouth hardyhead abundances are extremely variable and there are no easily discernible trends through time. Extraneous factors affected sampling timing each year, so the presence and relative abundance of adults or juveniles in the samples must be treated with caution. Nevertheless, recruitment was intrinsically related to upstream floods and increased freshwater flows to the system (Ye et al. 2022). Overall, the extent of the species has been strong since 2009, with detection in 75% to 100% of survey sites each time; however, within-site abundances are generally low and the species is only considered in moderate condition.

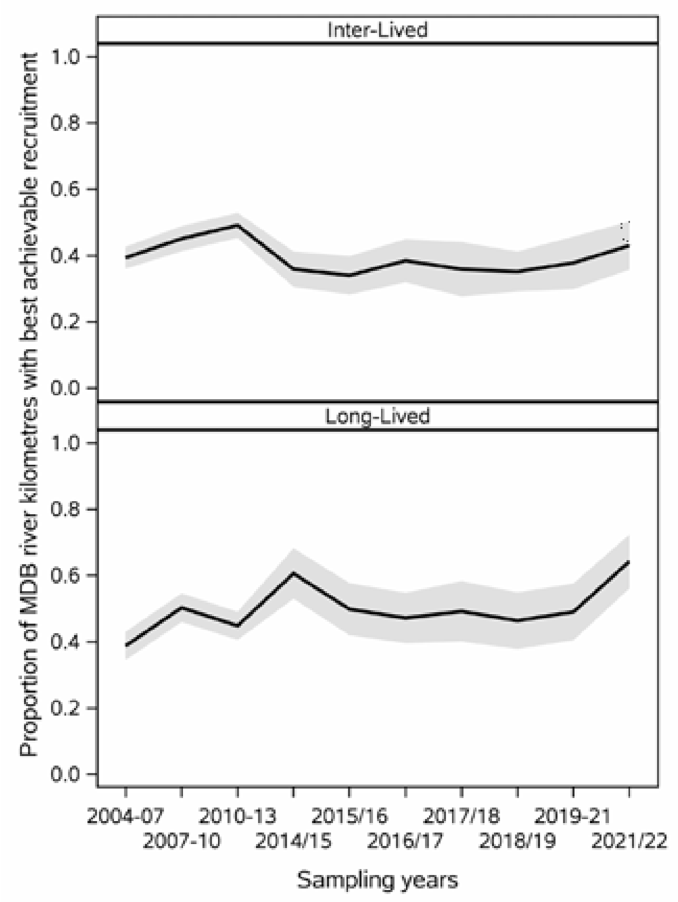


Red solid line is discharge to the Coorong (GL/month; right-hand axis). Horizontal dashed lines give the targets (8 t for black bream and 24 t for greenback flounder).
Source: Ye et al. 2022

Figure 12. Annual commercial catch of black bream (top) and greenback flounder (bottom) from the Coorong, 1984–2021

5.3.6 Recruitment of long- and intermediate-lived fish in the MDB, 2004–2022

Both lifeform indexes showed non-statistically significant ($p > 0.05$) relationships across the 10 years. There was always between 40% and 60% of river kilometres where best achievable recruitment occurred between 2004 and 2022 (Figure 13). Intermediate species recruitment peaked in the 2010 to 2013 sampling period, whilst the long-lived species peak in recruitment came one to two years later. In other words, both communities appeared to recruit in response to flood events of 2010 and 2011. Similarly, the 2021 and 2022 data showed an upturn in recruitment from the previous two years for both intermediate and long-lived species (Figure 13). Ecologically speaking, recruitment condition is considered stable for the intermediately lived and large-bodied (long-lived) species. (Figure 13).



Grey shade indicates the 95% confidence interval.

Figure 13. Proportion of river kilometres that have the best achievable recruitment levels by intermediate- and long-lived fish species in the MDB, 2004 to 2022

Overall, recruitment among long-lived fish species had a significant positive trend across the MDB over the past two decades (there are more YoY and/or recruits per site on average). Intermediate-lived species were more variable in recruitment levels from year to year and may have had a slight decreasing trend in the last 20 years were it not for increased recruitment levels in 2020–21 and 2021–22.

5.3.7 Narratives for three large-bodied native species

Murray cod

Murray cod remains widely distributed throughout most of its natural range (most of the MDB) but there have been some localised extinctions (such as the Paroo River; Sarac et al. 2011) and considerable declines in abundance over the long term (Cadwallader and Gooley 1984, Rowland 2005, Mallen-Cooper and Brand 2007, Ye et al. 2000, Ye and Zampatti 2007, Zampatti et al. 2014). Murray cod once supported a considerable commercial fishery across its southern range (Reid et al. 1997, Rowland 2005, Humphries and Winemiller 2009) but there were concerns about overfishing and declining catches from the early 1900s (Dannevig 1903, Dakin and Kesteven 1938, Rowland 1989, 2005). Declines in catches eventually saw all commercial fisheries closed by the early 2000s (Rowland 2005). Murray cod are widely produced in hatcheries and stocked for recreational fishing (Ingram et al. 2011, Rowland 2005, Forbes et al. 2015a, 2015b, Hunt and Jones 2018). There has been partial recovery of populations in some areas, with the species now not considered threatened in the latest International Union for Conservation of Nature Red List assessment (Gilligan et al. 2019b, Woinarski et al. 2023), but there have also been numerous large-scale fish death events in the past two decades (King et al. 2012, Thiem et al. 2017, Vertessy et al. 2019). While there has been no MDB-wide, dedicated, long-term Murray cod–specific monitoring, it is a key species considered under broadscale monitoring such as the SRA (2004–2010) (Davies et al. 2008, 2010a, b) and the MDBFS (2015–2018) (MDBA, unpubl. data, Gwinn et al. 2019, 2020) as well as state monitoring programs. The stock status across the MDB, however, remains described as poorly understood and undefined (Ye et al. 2018).

Gwinn et al. (2019) showed that Basin-wide abundance of Murray cod declined by over 50% between 2010 and 2013. Crook et al. (2023) found that the relative abundance of Murray cod in NSW increased sharply from a relatively low level in the mid-late 1990s and peaked around 2008, before falling until 2012. Abundance then recovered and has remained relatively stable from 2015 to 2022. The biomass of Murray cod increased sharply from a relatively low level in the late 1990s peaking around 2003, declining until 2008, increasing from 2008 to 2017 before declining again between 2018 and 2022.

The overall abundances of Murray cod appeared to remain variable but stable across the Basin in the past two decades There are concerns for some populations, especially in the Northern Basin (e.g. Paroo River; M. Hutchison, Qld DPI, pers. comm.). Numbers are especially impacted by the large fish death events due to hypoxic blackwater that have occurred, especially in the Murray and lower Darling-Baaka rivers (King et al. 2012, Thiem et al. 2017, Vertessy et al. 2019).

Key message:

Murray cod is showing some signs of a population increase at the scale of the whole Basin, although this may not be uniform across their range. While recruitment of Murray cod appears to be generally stable through time, mortality from fish death events has probably resulted in many of the population troughs and declines in some sub-populations (e.g. lower Darling-Baaka River). There has been widespread stocking of hatchery fish and considerable harvest by anglers.

Trout cod

First listed as threatened in the 1980s and reduced to one truly natural population in the mid-Murray River, progress over three successive national recovery plans (spanning 18+ years) have increased the number of sub-populations and their extent. There have been a wide range of recovery actions employed (see Section 3.4), including successful establishment of new sub-populations using hatchery stocking, with the stocking strategy and adaptive management approach outlined by Bearlin et al. (2002) and Todd et al. (2004). New, abundant, self-recruiting trout cod sub-populations have now been successfully established over 100+ km in the Ovens, Goulburn and Murrumbidgee rivers (Ebner et al. 2007, 2009, Lyon et al. 2012, Koehn et al. 2013).

While the expansion of the remnant Murray River sub-population and establishment of new sub-populations have reduced the extinction risk, and there is cautious optimism for the future of this species, there has been reduced recovery activity in the past decade when the establishment of further sub-populations could have reduced the conservation listing of this species.

The recovery of trout cod sub-populations is a success story for this threatened species, although more work is needed to further expand and maintain sub-populations before its conservation status can be downlisted.

Silver perch

Silver perch was once widespread across most MDB lowland river reaches but is thought to have suffered substantial declines in abundance and range in recent decades (Lintermans 2007, 2023, Trueman 2011), especially in the mid-Darling-Baaka River (G. Butler, NSW DPI, pers. comm.) and Northern Basin (M. Hutchison, Qld DPI, pers. comm.) where it is now rare (Clunie and Koehn 2001a) and there is concern for its future. Fish abundance varies in both the Northern Basin (Warrego–Condamine, Macquarie, Namoi, Border rivers), and Southern Basin (Edward–Wakool, lower Darling-Baaka, Murrumbidgee, Loddon, Campaspe, Goulburn and lower Murray River reaches) (Tonkin et al. 2017, 2019). Crook et al. (2023) showed silver perch relative abundance in NSW to be low, with high variability in the 1990s. A low abundance rose to a peak around 2010, before declining sharply until approximately 2015. It has then declined more gradually through to 2022. Predicted biomass of silver perch was characterised by high error in the 1990s and remained relatively stable across the time series. There was evidence of occasional recruitment of small fish prior to 2000, but the sub-populations were dominated by larger fish after this time, with very low numbers of fish <20 cm TL. This was especially so in the Barwon–Darling, Macquarie–Castlereagh, Namoi and Border Rivers (Crook et al. 2023). While Crook et al. (2023) did not find evidence of population decline at the NSW Basin scale, Todd et al. (2022) used a stochastic metapopulation model to assess silver perch sub-population trajectories in the MDB. Results indicated that the species is likely functionally extinct (unlikely to be able to recover through natural recruitment) in the Northern Basin and has had a long-term decline in the Southern Basin. These predictions are supported by observed Basin-wide population decline (Clunie and Koehn 2001a, Lintermans 2007, 2023, Tonkin et al. 2019, Koehn et al. 2020b), and extremely low numbers in the Northern Basin (Lintermans 2022a, 2023).

The mid-reaches of the Murray River support the highest relative abundances of silver perch (11-year period to 2016) in the MDB (Tonkin et al. 2017), even though the population is likely to have substantially declined from documented historical levels (e.g. 94% reduction at the Euston fishway catches over the past 50 years; Mallen-Cooper and Brand 2007). Recruitment in the mid-Murray occurred almost every year, including under both low within-channel flows and overbank floods during a period that encompassed extremes in discharge (drought and flood). The strongest year classes of silver perch were associated with low-to-average river discharge and high water temperatures during November and December, and that preceded a year of extended high flows and widespread flooding. Large flow events appear to significantly improve survival of juvenile fish (spawned the previous year). Years subject to broadscale, flood-induced blackwater events are perhaps the only years that will not produce significant increases in year classes. Despite spawning in most years, however, the maximum age recorded for silver perch – 27 years

(Mallen-Cooper and Stuart 2003) – is now known not to be reached in the main Murray River sub-population, where very few fish are older than 7 years (Tonkin et al. 2019).

Tonkin et al. (2019) suggested that movements by silver perch were an important component of population dynamics, with movement of both juveniles and adults likely to be higher during both within-bank river rises and during flooding, being greatest during periods of high magnitude and extended flooding. Silver perch are using the Murray fishways, commonly undertaking extensive longitudinal migrations (Mallen-Cooper and Stuart 2003, I. Stuart, CSU, unpubl. data). As silver perch are highly reliant on riverine connectivity to complete migrations as adults and juveniles, a river reach such as the mid-Murray, with perennial flowing water extending over a broad spatial scale (>300 km), appears to allow recruitment in most years and a range of movements. For example, the attraction of silver perch from the Murray River into Victorian tributaries is a key mechanism for improving broader population resilience through migration and subsequent increased availability of habitat for feeding and reproduction, especially in the year after large flows events in the Murray River (Tonkin et al. 2019). This highlights the importance of multiyear flows to freshwater fish populations and the importance of large-scale connectivity to allow for population stability and resilience. The study also suggested off-channel floodplain habitats, which are rarely sampled for silver perch, have the potential to act as recruitment and nursery grow-out zones, where juvenile fish can undergo rapid growth before returning to the main river following reconnection events (King et al. 2013).

Key messages:

- Silver perch has suffered major declines in their sub-populations, particularly in the Northern Basin, where there is significant concern for their future.
- Despite regular spawning over the past decade, recruitment levels remain relatively low, as evidenced by the low proportion of fish greater than 7 years of age.

5.4 **Case study** – Connectivity between the Coorong and Lower Lakes via the barrage fishways

South Australian Research and Development Institute has collected data on diadromous fish migration and estuarine fish assemblage structure since 2006. The data are used to inform against specific ecological objectives and targets within the Lower Lakes, Coorong and Murray Mouth Icon Site. Here we use the summary from Bice et al. (2021), to inform the status assessment of diadromous migratory native fish and variability between 2006 and 2020. Data are from fishway trapping on six barrage structures in the CLLMM region, including Goolwa Barrage, Goolwa vertical-slot, Tauwitchere rock ramp, Tauwitchere vertical-slot, Tauwitchere small vertical-slot and Hunters Creek vertical-slot fishways.

This case study focuses on the relative abundance of catadromous fish (congolli, *Pseudaphritis urvillii*, and common galaxias, *Galaxias maculatus*) and anadromous fish (pouched lamprey, *Geotria australis*, and short-headed lamprey, *Mordacia mordax*) attempting to migrate upstream at the CLLMM barrages from 2006–2007 to 2020–2021. Migration is a key component of population dynamics and one rarely considered in general assessments of population change.

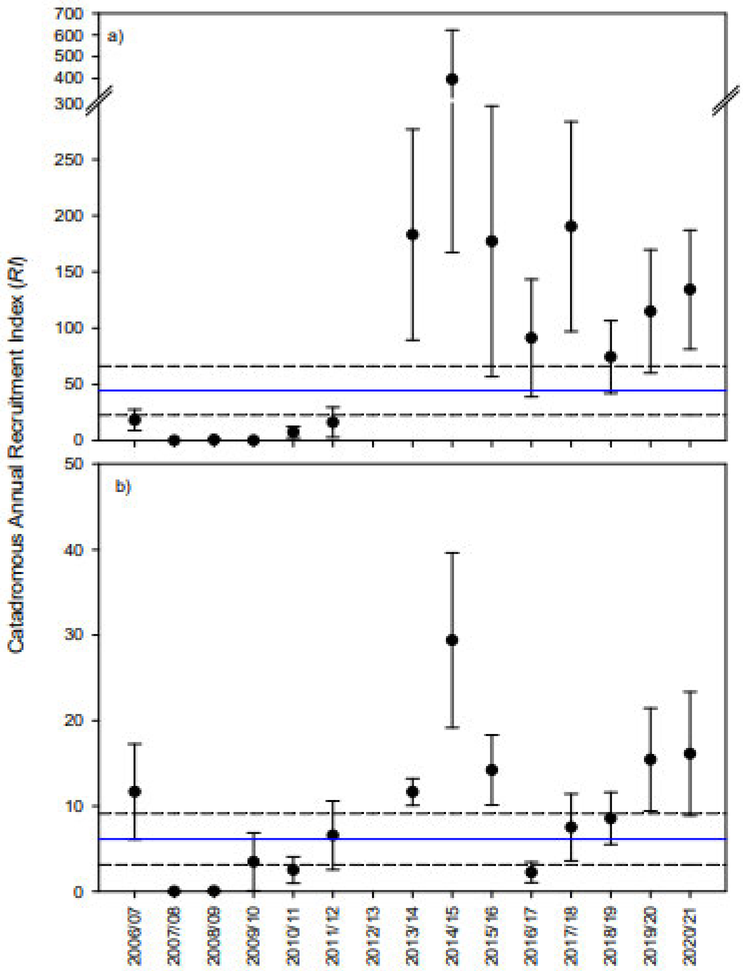
Migrating fish abundances moving through the CLLMM barrages from 2006 to 2020

Among the barrage sites, there were consistent patterns of temporal variability in fish assemblages from 2006–07 to 2020–21, characterised by relationships with freshwater discharge via the barrages. These are:

- Millennium drought (2007–2010), with no freshwater discharge to the Coorong
- depauperate assemblages during this extended period when marine species and some medium- to large-bodied estuarine species were dominant, and diadromous and freshwater species were absent or in low abundance
- years of low discharge (e.g. 2006–07, 2018–19), causing low overall fish abundance, but high diversity, with moderate abundances of catadromous species
- years of high discharge (2010–11, 2011–12 and 2016–17), giving high overall fish abundance, and high species-specific abundance for freshwater species
- years of moderate discharge (2013–2016, 2017–18, 2019–2021), giving total fish abundances intermediate between the two previous groupings, including moderate abundances of freshwater species, but typically high abundance of catadromous species.

Migration by catadromous fish species at the CLLMM barrages

The number of upstream migrating juvenile congolli was healthy (i.e. above reference condition – see Bice et al. 2021) for all surveys after 2013–14, after being poor from 2006 through the Millennium drought up to 2010–11 (Figure 14). Similarly, the numbers of upstream migrating common galaxias juveniles have been consistently healthy since the poor years of 2007–08, 2008–09, 2010–11, except for a drop in 2016–17.



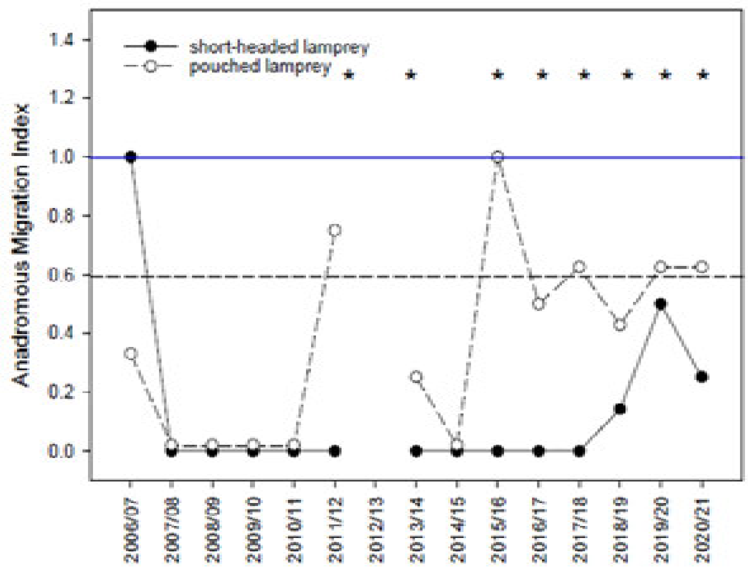
The reference value is indicated by the blue solid line and half confidence intervals indicated by dashed lines.
Source: Bice et al. 2021

Figure 14. Catadromous annual recruitment index (RI, number of upstream migrating YoY/hour) and half confidence interval for: (a) congolli and (b) common galaxias, 2006–07 to 2020–21 (no sampling was conducted in 2012–13)

Migration by anadromous fish species at the CLLMM barrages

Short-headed lamprey were absent from fishway sampling (i.e. they were not migrating upstream) between 2007 and 2018, and only appeared in low numbers from 2018 to 2020 (Figure 15).

Pouched lamprey was only collected from one site in 2006–07, followed by absence from monitoring and failure to meet the target from 2007 to 2011. Individuals were sporadically collected in 2011–12 and 2013–14 then in 2014–15. Since 2015–16, pouched lamprey upstream migration at the CLLMM barrages has been consistent, albeit below the long-term target (the number of sites it was detected in in 2011–12).

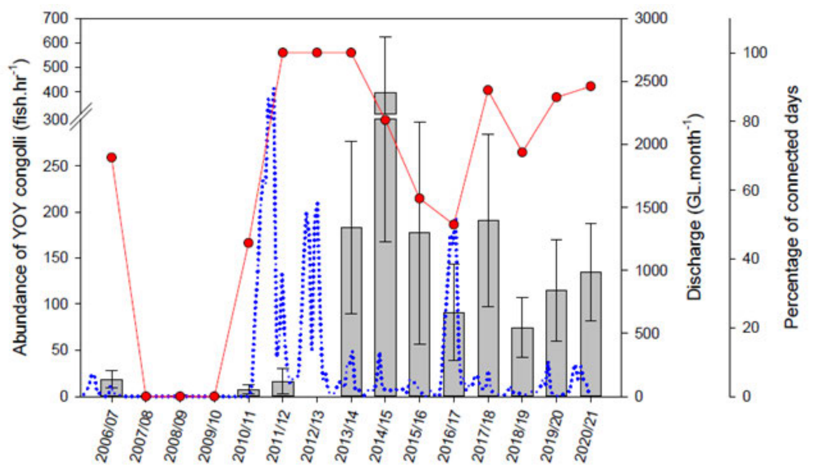


The blue solid horizontal line is the long-term target abundance for a healthy population and the dashed line is a target for managers. * indicates targeted sampling for both species occurred during the migration period.
Source: Bice et al. 2021

Figure 15. Index of migration (abundance standardised for effort) for the two native anadromous fish species monitored at the CLLMM barrages, 2006–2020

Summary of connectivity and migration for diadromous fish species in 2020

All four species studied underwent severe declines in abundance and reduced ability to migrate during the Millennium drought but recovered in the years since the drought to current levels. Recovery in the species was undoubtedly related to improved hydrological connectivity, and abundance of reproductive adults in each population (Bice et al. 2021). For example, recruitment and subsequent YoY abundance for congolli steadily increased from low numbers between 2010 and 2013, following the return of hydrological connectivity in 2011 (Figure 16). The lag in abundance increase following increased connectivity after the drought was most likely related to the period taken for younger fish to reach sexual maturity after connection was restored (Bice et al. 2021). Hence, maintaining connectivity and improving our understanding of the life cycles of these species is critical for their future.



The blue dotted line is the monthly discharge rate and the solid red line is the percentage of annual days of connectivity between freshwater, estuarine and marine environments.
Source: Bice et al. 2021

Figure 16. The abundance of YoY congolli sampled across all CLLMM barrages, 2006 to 2020

5.5 Key findings – population dynamics

Additional findings on the usefulness, limitations and future requirements for monitoring in order to improve future status assessment of population dynamics are presented in Chapter 6.

Key findings

Potential status assessment questions were identified in Cottingham et al. (2022) and refined in consultation with the Native Fish Recovery Strategy Technical Advisory Group (see Appendix 1, Table 18) for each attribute; however, some questions are not addressed due to scope and data limitations.

Declines in MDB native fish populations have previously been recorded over multiple decades (e.g. Reid et al. 1997, Cadwallader 1981, Cadwallader and Gooley 1984). Thus, it is important to remember that assessment of recent (either post-1994 (Crook et al. 2023) or post-2004 more generally for this assessment) trends in fish occurrence and abundance (such as this one) represents changes from a relatively low base when compared with historical levels. There are a range of additional aspects of information (e.g. conditions, detection rates) that can be added to further strengthen analyses of population dynamics for many species.

Recruitment

- What is the current population structure of species; has the proportion of recruits/adults changed over time (e.g. post-2004 as per recruitment in Figure 13)?

Population structure is variable dependent on antecedent conditions, management interventions (i.e. stocking), species and location.

Recruitment and age/length distributions for most species are not well analysed or reported on using current large-scale fish assessment monitoring program data. Levels of recruitment that can be identified show that long-lived species may be resilient and can maintain populations via recruitment through highly variable antecedent conditions. Intermediate and short-lived species are less resilient in the short term and take longer to recover from perturbations.

There are a number of threatened short-lived wetland species that remain at risk and the loss of Yarra pygmy perch from the MDB and the more recent loss of southern pygmy perch from localised regions in the Southern Basin is of great concern.

While analysis of population dynamics was not possible for Murray crayfish and river mussel populations they have been affected by large-scale disturbances, such as drought and blackwater events. Their recovery is likely to take a long time.

- Has recruitment been occurring?

Assessment of this question was limited by the available monitoring data and narrative approach to the status assessment. Measurement of recruitment has been identified as a key data gap, and is outside of the current scope and resources of this status assessment.

- Can we follow cohort survival in populations over time – are there examples where cohorts are being impacted (e.g. harvest, fish deaths)?

This was outside the scope of the current assessment.

- Has the number of sub-populations of wild stock increased, decreased or remained stable?

This was outside the scope of the current assessment. Stocked fish data was not accessed; however, it is acknowledged that the impacts of harvesting, stocking and fish death events need to be taken into consideration in future assessments.

- Are populations fragmented? Narrative about how important connectivity is to each species?

All of the nationally listed fish species populations are considered to be fragmented.

Fish movements and habitat connectivity play a major role in population dynamics, and allow the completion of life cycles for key migratory species, and recruitment levels may take years to recover from perturbations. Connectivity is crucial for diadromous species that need to pass through the CLLMM marine and freshwater interface to complete their life cycles. It is, however, also a key component of changes to the populations of many other species (e.g. golden perch; Lyon et al. 2010).

Abundance

- What is the population abundance (or relative abundance) trend for key species and case study species?

Although native fish populations in the MDB remain degraded and face numerous ongoing or even escalating threats (e.g. due to climate change effects), recent increases in the abundance of some native species are an encouraging sign that restoration efforts can improve the outlook for native fish.

The nature of the datasets used for this assessment, together with the often highly variable relative fish abundance for many species, means that care is needed in analysing and interpreting results.

However, Murray cod, golden perch and Murray–Darling rainbowfish have shown general positive trends in occurrence and abundance over the past two decades. Spangled perch abundance and distribution in the Northern Basin has also shown an upward trend.

Abundance of several species is decreasing, particularly in the Northern Basin (from 2010 point of reference). Unfortunately, there has been a significant recent downward trend in mountain galaxias abundance across the MDB, as well as that for northern river blackfish in the Northern Basin. There have also been troubling declines in silver perch abundance in the Northern Basin. Other species assessed have had relatively stable populations in recent times.

Other species assessed have had relatively stable populations in recent times (from 2010 point of reference).

Biomass

- Assessments of biomass should be undertaken for the species overall and for key sites or populations?

Trends in relative biomass of six long-lived species in NSW varied by species (Crook et al. 2023):

✧ Murray cod: three periods of increasing trend followed by declines, currently in a decline.

✧ Golden perch: fluctuated considerably with strong peaks in 6 years and 3 years with troughs that were characterised by a relatively high proportion of small fish.

✧ Silver perch: relatively stable but with low confidence, and some sub-populations declining.

✧ Macquarie perch: no trend evident but with low confidence.

✧ Freshwater catfish: decreasing trend.

✧ Carp: decreasing trend followed by increase in 2011–13, and sharp decline post-2019.

Spatial extent and distribution

The expanded distribution and abundance of trout cod is an important success story for this threatened species, although more work is needed before its conservation status can be downlisted.

Mountain galaxias and river blackfish showed slight declines in their current extent, both trending downwards over the last few years.

6 Spiny crayfish and mussels

There are three families of freshwater crayfish, two being restricted to the northern hemisphere and the other, Parastacidae, only found in the southern hemisphere (Whiting et al. 2000, Richman et al. 2015). There are 148 native species of freshwater crayfish in Australia (Richman et al. 2015) with 53 species of *Euastacus* spiny crayfish recognised across Australia, 13 of which occur within the MDB (Ahyong 2014, van der Wal et al. 2022, Austin et al. 2022). *Euastacus* is considered the most threatened genus of freshwater crayfish in the world, with 80% of its currently described species listed under International Union for Conservation of Nature threat categories (Austin et al. 2022). This chapter only considers the spiny crayfish; future assessments will be expanded to include other genera, such as *Cherax*.

Most spiny crayfish species occupy montane or headwater habitats; species such as Murray crayfish and Sutton's crayfish are more broadly distributed across slope and lowland habitats in the Southern Basin and the Border Rivers region of the Northern Basin, respectively (Austin et al. 2022). Several *Euastacus* species that occur in the Basin have been shown, based on molecular genetic data, to include divergent species. The named species, which likely include cryptic species, are *Euastacus claytoni, E. rieki,* and *E. spinichelatus* (Austin et al. 2022).

The Murray crayfish (Figure 17) occupies both upland and lowland areas of the Murrumbidgee and Murray River catchments, including the mid-Murray River anabranches and tributaries such as the Mitta Mitta, Kiewa, Ovens and Goulburn rivers (Gilligan et al. 2007). Although thought to be the result of translocations, new evidence suggests that outlying sub-populations in the Lachlan and Macquarie River catchments may be remnant (Austin et al. unpublished).

The distribution and abundance of Murray crayfish, in particular, has declined over many decades due to factors such as river regulation, pollution, over-harvesting, and the effects of forest fires and poor water quality (e.g. low dissolved oxygen in blackwater events) (Gilligan et al. 2007, NSW DPI 2019, Legge et al. 2021). Murray crayfish traits such as being long-lived, slow to mature and breed, and having limited dispersal suggests that the species is vulnerable to environmental disturbance, and opportunities for large-scale dispersal and recolonisation are likely to be limited.

Source: Nick Whiterod

Figure 17. Murray crayfish (*Euastacus armatus*)

Freshwater mussels are one of the most globally imperilled freshwater species (Böhm et al. 2021, Aldridge et al. 2023, Nakamura et al. 2023). Freshwater mussels are an important but often neglected part of aquatic food webs across the MDB. They are a food source for native fish such as Murray cod as well as terrestrial animals including birds and rakali (water rat), and are important ecosystem engineers – for example, they improve water quality by filtering sediments and organic matter from the water column (Walker 1981, Aldridge et al. 2023). Mussels have long been important to Aboriginal peoples of the MDB, previously being an important source of food and tools; mussels continue to be an important part of cultural practices and integral to the concept of Country (Langloh Parker 1905, Frawley et al. 2012, Noble et al. 2016, DNRME 2019).

Recent assessments of Northern Basin freshwater mussel sub-populations suggest significant and widespread loss during recent (2017–2019) drying conditions (Sheldon et al. 2020), which is a cause for concern given the longevity of mussel individuals and limited evidence of widespread recent recruitment.

Currently there are 13 species of freshwater spiny crayfish and five freshwater mussels found in the MDB. Along with their current conservation status, they are listed in Table 16. Note that nine of the 13 spiny crayfish are currently undergoing assessment for EPBC listing (see Chapter 4, Table 5). Case studies that describe some of the known distribution and population dynamics of Murray crayfish and freshwater mussels are presented in the following sections.

Table 16. Freshwater spiny crayfish and freshwater mussels of the Murray–Darling Basin

Type	Scientific name	Common name	Occurrence	Environmental zone	Conservation status
Freshwater crayfish	*Euastacus armatus*	Murray crayfish	Southern Basin	Montane Slopes	NSW: Vulnerable Vic: Vulnerable ACT: Vulnerable
	Euastacus claytoni	Clayton's crayfish	Southern Basin	Montane	
	Euastacus crassus	Alpine spiny crayfish	Southern Basin	Montane	Vic; Endangered ACT: Protected
	Euastacus gamilaroi	Gamilaroi crayfish	Northern Basin	Montane	
	Euastacus jagara	Jagara hairy crayfish	Northern Basin	Montane	Qld: Critically Endangered
	Euastacus maccai	Terrestrial crayfish	Northern Basin	Montane	
	Euastacus rieki	Riek's crayfish	Southern Basin	Montane	ACT: Protected
	Euastacus simplex	Simple crayfish	Northern Basin	Montane	
	Euastacus spinichelatus	Small crayfish	Northern Basin	Montane	
	Euastacus sulcatus	Mountain crayfish	Northern Basin	Montane	
	Euastacus suttoni	Sutton's crayfish	Northern Basin	Montane Slopes	Qld: Protected
	Euastacus vesper	Cudgegong giant spiny crayfish	Northern Basin	Montane	
	Euastacus woiwuru	Central highland spiny crayfish	Southern Basin	Montane Slopes	
Freshwater mussels	*Alathyria condola*	Freshwater mussel	Mostly[a] Southern Basin	Slopes Lowlands	
	Alathyria jacksoni	River mussel	Basin-wide	Uplands	Qld: Regulated

Type	Scientific name	Common name	Occurrence	Environmental zone	Conservation status
				Lowlands	
	Alathyria pertexta pertexta	Purple nacre mussel	Northern Basin (very small numbers)	Headwaters Uplands	Qld: Regulated
	Velesunio ambiguus	Billabong mussel	Basin-wide	Slopes Lowlands	Qld: Regulated
	Velesunio wilsonii	Wilson's mussel	Northern Basin	Slopes Lowlands	Qld: Regulated

a Found in the Lachlan, Macquarie and Murrumbidgee rivers, NSW. There is unconfirmed evidence that the species has spread towards the Murray River through the channels of the Murrumbidgee Irrigation Area (Ponder et al. 2022).
Sources: MDBA 2020a, Austin et al. 2022, Ponder et al. 2022

6.1 **Case study** – Murray crayfish

Prepared by Peter Cottingham with contributions from Nick Whiterod

The Murray crayfish is a large (up to 174 mm carapace length), long-lived (up to 25 years), late-maturing (8–9 years) freshwater crayfish endemic to the MDB in south-eastern Australia (Morgan 1997, Gilligan et al. 2007). It is a traditional food source for Aboriginal communities and a popular target for recreational fishing (commercial fishing for the species is banned).

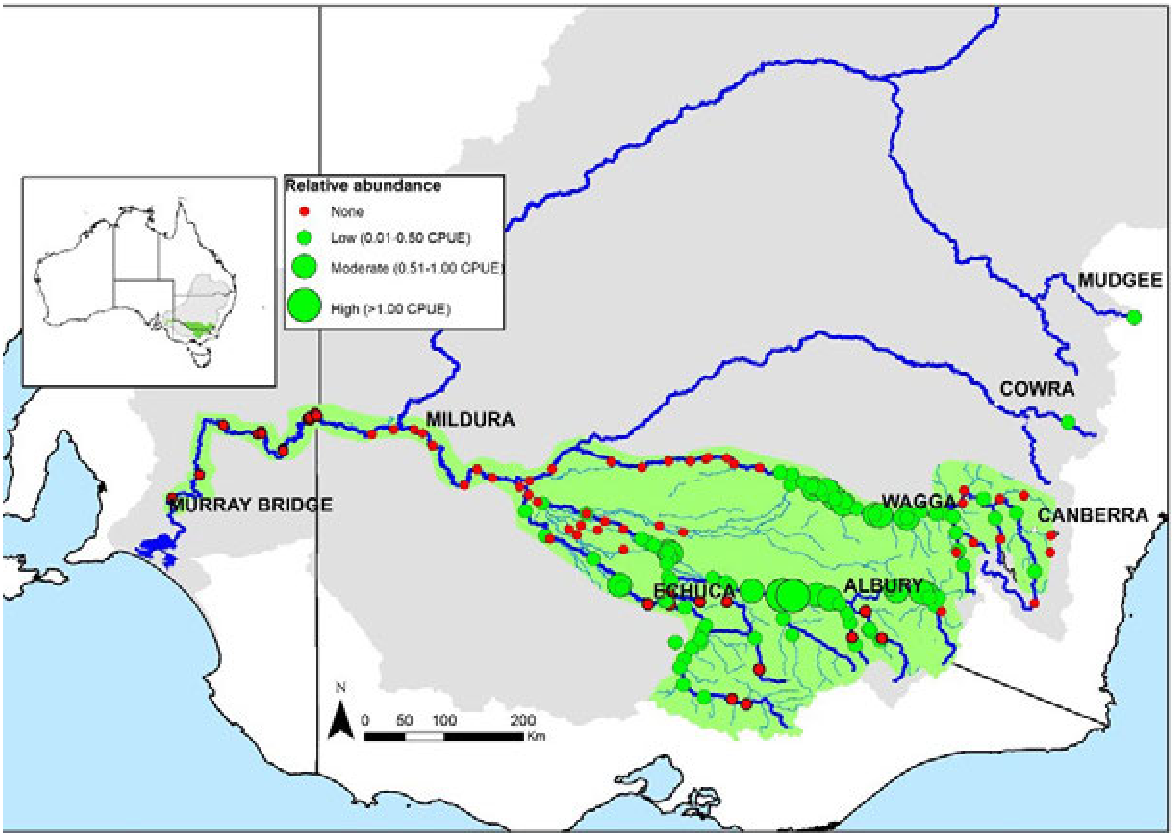
Murray crayfish is a benthic riverine specialist with preference for relatively cool (up to 30 °C), oxygenated (dissolved oxygen concentrations >2 mg L^{-1}) and flowing (>0.25 to 0.30 m s^{-1}) water with physical structure (Gilligan et al. 2007). A genetic analysis by Whiterod et al. (2017) found evidence of panmixia across much of the species' range, and despite low levels of gene flow in hydrologically connected waterways, this was considered sufficient to maintain population sizes and genetic diversity. However, evidence of local genetic structuring, coupled with biological traits (e.g. slow growing, late maturing), suggests that the species is vulnerable to environmental disturbance, and opportunities for large-scale dispersal and recolonisation are likely to be limited.

This case study focuses on the status of Murray crayfish, given its importance to the broader community and as it is the most studied of the spiny crayfish species in the Basin. The plight of Murray crayfish is reflected more broadly in all Australian freshwater spiny crayfish, as 80% of species are listed as threatened and are the focus of action plans (Whiterod et al. 2022).

Assessment approach and findings

Murray crayfish is the most widely distributed species in the *Euastacus* genus but it is evident that the current distribution and abundance of the Murray crayfish (Figure 18) are both small compared to its historical distribution and abundance (Forbes et al. 2020, Geddes et al. 1993, Gilligan et al. 2007, Noble and Fulton 2017, O'Connor 1986, Raymond et al. 2017, Walker 2001, Whiterod and Zukowski 2017, Whiterod and Zukowski 2019, Whiterod et al. 2018, Zukowski et al. 2018). Most of the declines are believed to have occurred before the 1950s and up to the 1980s, with the species now considered rare or absent from the Murray River downstream of Mildura and the Murrumbidgee River downstream of Darlington Point, and patchy across parts of its contemporary range.

Historical declines have been attributed to a range of threats including river regulation, habitat destruction, pollution, invasive species and overfishing, although impacts vary across different parts of its range (Furse and Coughran 2011, Furse 2014, Richman et al. 2015, Gilligan et al. 2007). Some threatening processes that may have resulted in declines in the past are no longer impacting Murray crayfish sub-populations, while others continue to have ongoing impacts. For instance, the impact of habitat loss persists (e.g. Noble and Fulton 2017) along with hypoxic blackwater disturbance. Varied impacts of climate change are likely to contribute to future decline.



Source: Reproduced with permission from Whiterod and Zukowski 2019.

Figure 18. The historical range (pale-green shaded) of Murray crayfish (*Euastacus armatus*) across the southern Murray–Darling Basin (light-grey shaded)

There has been increasing survey of the species since the 1980s, but a long-term monitoring program does not currently exist. As such, existing data are patchy over time, across rivers and regions, and differing sampling methods have been employed across surveys. In total, more than 600 site surveys (many of the same site over time) have been undertaken across the range of the species from 1981 to 2022 (NSW DPI and Aquasave-NGT, unpublished).

Compilation of existing data (with similar methods) allows for some assessment across eight sections of the species' range, including mid-Murrumbidgee River; upper Murrumbidgee River tributaries of the Goobarragandra and Goodradigbee rivers; open and closed to recreation harvest sections of the Murray River and mid-Murray tributaries, including the lower Ovens River, Wodonga Creek and the Goulburn River. For the mid-Murrumbidgee River and Ovens River sections, relative abundance increased from the 1980s before dropping considerably between 2003 and 2010 and has since increased over time to be comparable with the 1980s. For upper Murrumbidgee River tributaries of the Goobarragandra and Goodradigbee rivers, a 91% decline in Murray crayfish was observed between samplings in 2009 and 2015 (Noble and Fulton 2017). No obvious trend was observed in the relative abundance in Lake Nagambie (Goulburn River) and Wodonga Creek between 1986 and 2017. Similarly, in the section of the Murray River open to recreational harvest, relative abundance has remained relatively stable since 2010. In contrast, in the section of the Murray River closed to recreational harvest, the magnitude and prolonged nature of the 2010−11 blackwater event (Whitworth et al. 2012) led to an 81% reduction in Murray crayfish relative abundance in impacted areas of the Murray River (McCarthy et al. 2014, Whiterod et al. 2018). Similarly, in Murray River tributaries such as in the Edward/Kolety–Wakool system, the Murray crayfish's range contracted from widespread prior to the 2010–11 blackwater event to largely patchy or absent in 2020 (Whiterod 2021b). It was only in areas with relatively free-flowing conditions at the top of the system (e.g. Edward/Kolety River near Deniliquin) where Murray crayfish could still be found consistently.

Overall, the species remains in decline across sections of its range, while relative abundance in other sections remain relatively stable. It will be important establish a long-term monitoring program to track the temporal trends in the status of Murray crayfish across the Murray–Darling Basin.

Management recommendations

Many gaps in our understanding of Murray crayfish exist, which hampers the ability to manage the species. The key management needs for the species are:

- ongoing and regular monitoring of the status of the species across its range
- improved understanding of habitat and flow requirements and influence of threatening processes, such as river regulation, habitat alteration, blackwater disturbance, and impacts of alien fish species (including salmonids and common carp) to inform management
- coordinated management and regular evaluation of the recreational fishery in the two jurisdictions (Victoria and NSW) where it remains permitted, plus effective enforcement of fishery regulations across both fisheries
- expanded programs of reintroduction to areas where sub-populations are currently in low abundance or locally extinct, and exploration of captive breeding techniques
- given the species has a clear susceptibility to hypoxic blackwater events, emergency response plans should be developed and implemented to limit the impact on exposed sub-populations.
- investigation of the cultural value and Traditional Knowledge for the species.

The monitoring of Murray crayfish sub-populations has increased over the past two decades, but a key recommendation remains the establishment of a long-term monitoring program for the species. This would enable tracking of the trajectory of the species, which would help to periodically evaluate the status of the recreational fishery. Several of the identified knowledge gaps for the species (Gilligan et al. 2007) have been addressed but understanding of habitat and flow requirements and impacts of threatened processes remain lacking. The impacts of the 2010–11 hypoxic blackwater disturbance (Whitworth et al. 2012) as well as limited recovery from previous disturbances (see discussion below), led to amendment of the restrictions on recreational fishing for Murray crayfish in 2013, including a restricted season (June–August), and limits on the size (through a harvest slot length limit (HSLL) of 10–12 cm occipital carapace length) and number (2) of crayfish that can be taken per day or held (4) at any one time in NSW and Victoria (https://www.dpi.nsw.gov.au/fishing, https://vfa.vic.gov.au/recreational-fishing). Population modelling indicated the HSLL of 10–12 cm afforded the greatest population sustainability (i.e. lowest population risk, least skewed sex ratio and highest spawning potential) while achieving the highest harvest potential (i.e. number of individuals potentially harvested), supporting the HSLL included in NSW and Victorian fishing rules (Todd et al. 2018). More recent modelling raises some concern with the HSLL (Raymond and Todd 2020), so further investigation is warranted. Flexibility in the fishery regulations may also be required.

Reintroductions of Murray crayfish are now being used to supplement existing populations or reintroduce the species to areas where it had become locally extinct. Notably, reintroduction of more than 1 000 crayfish over 5 years, has helped to re-establish the species in a section of the Murray River impacted by the 2010–11 blackwater event (Whiterod 2021a). Keys to the success have been a sound, defensible framework to implement and assess the reintroduction and strong collaboration and support by multiple partners and stakeholders. Engagement of recreational fishers was useful to achieve broader support for the reintroduction. The exploration of captive breeding techniques and an expanded reintroduction program may be necessary to help recover the species in other parts of its range. Furthermore, short-term emergency rescues (and releases when conditions improve) are now taking place and may be increasingly needed to combat hypoxic blackwater disturbance events.

Although it appears that Murray crayfish does not have a totemic role within indigenous groups (Gilligan et al. 2007), a significant sense of sustainable fishery management for Murray crayfish appears to be a strong part of traditional indigenous culture. Collaborative actions with First Nations peoples will be an important input to the conservation and management of the species.

Key messages:

- The distribution and abundance of Murray crayfish has declined over many decades due to factors such as river regulation, pollution, over-harvesting and poor water quality (e.g. low dissolved oxygen in blackwater events).
- The species is long lived, slow to mature and breed and has limited dispersal capabilities, making it vulnerable to environmental disturbance, and opportunities for large-scale dispersal and recolonisation are likely to be limited.
- Management interventions, such as limits on recreational fishing and translocation of Murray crayfish from existing sub-populations to areas with suitable habitat are being trialled to reverse the negative trends in distribution and abundance.
- As with other *Euastacus* spiny crayfish species in Australia, greater effort is needed to mitigate threats and implement actions, incorporate species into management strategies and actions, redress knowledge gaps, implement ongoing population monitoring programs, implement translocations, engage stakeholders and raise the species profile.
- Lack of a systematic monitoring program means that assessing population status and trend is currently difficult.

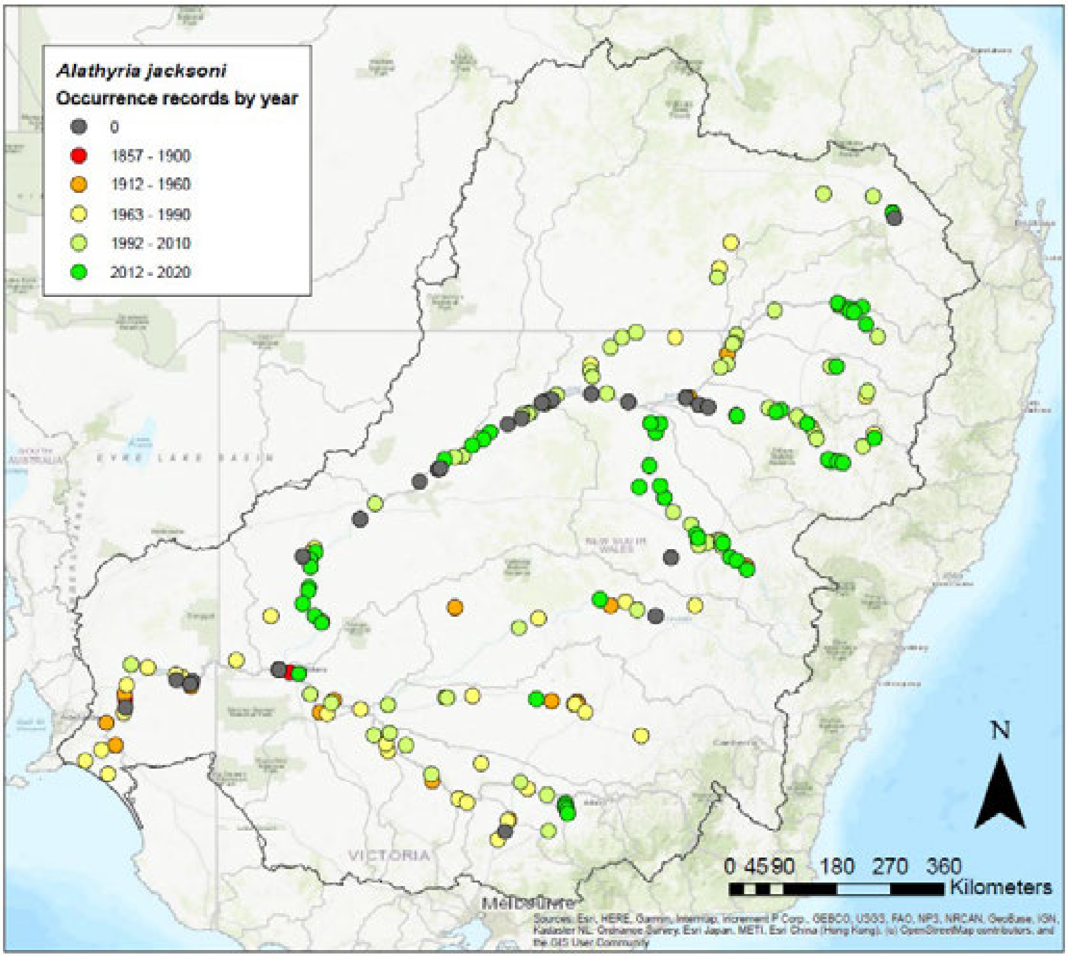
6.2 **Case study** – Freshwater mussels

Prepared by Peter Cottingham with contributions from Michelle Hobbs and Fran Sheldon

Approach and findings

This case study focuses on the work of Sheldon et al. (2020), who reviewed existing knowledge on environmental water requirements, life history, physiological tolerances and habitat requirements and cultural significance of freshwater mussels in the MDB. This was to improve baseline understanding of distribution and population structure of freshwater mussels in the Northern Basin and make recommendations for land and water management to protect freshwater mussel sub-populations based on an improved understanding of their flow and habitat requirements. Similar assessments have not been undertaken in the Southern Basin, with no targeted field collections in the past decade.

Five species of freshwater mussel (Unionoida: Hyriidae) occur across the MDB (Sheldon et al. 2020, MDBA 2020a). The most common are the river mussel (*Alathyria jacksoni*) (Figure 19) and freshwater mussel (*Alathyria condola*) found in riverine systems, and the smaller billabong mussel (*Velesunio ambiguous*) found on floodplains (Walker 1981, Sheldon et al. 2020) (Figure 20). The river mussel is widely distributed across the rivers of the MDB, while the freshwater mussel is restricted in range; the billabong mussel likely occurs more frequently in the lower, floodplain wetland regions of the tributaries and restricted floodplain habitats along the Barwon–Darling-Baaka mainstem (Sheldon et al. 2020).



0 = no date for that record

Source: Reproduced with permission from Sheldon et al. 2020.

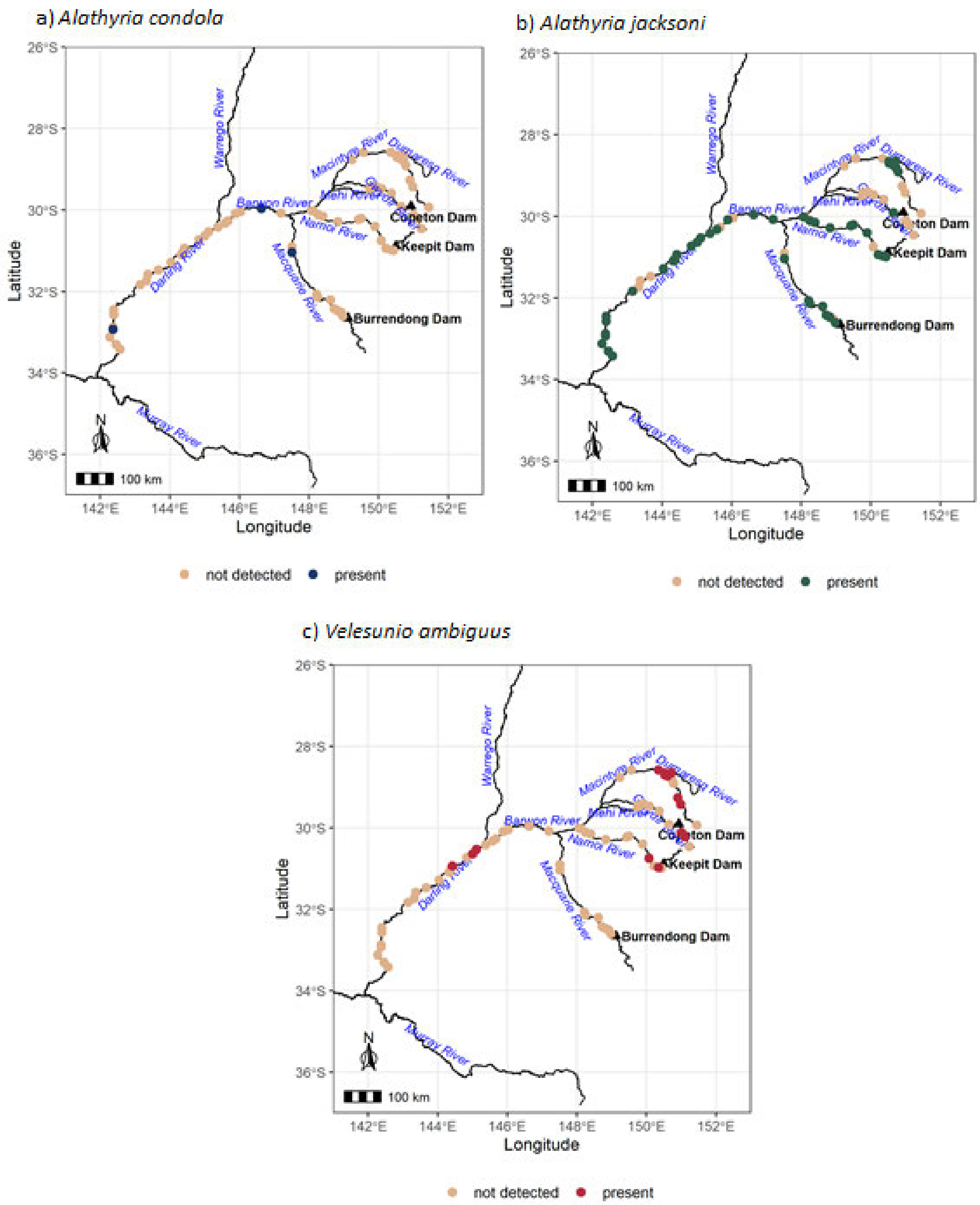
Figure 19. Spatial distribution of the *A. jacksoni* occurrence records in the Murray–Darling Basin that were used for development of a species distribution model

Sheldon et al. (2020) developed a species-habitat distribution boosted regression tree model to predict the likely distribution of the river mussel beyond existing survey and environmental data. The model predicted that the river mussel was likely to occur broadly across the mid-to-lowland reaches of the Barwon–Darling-Baaka River and its associated north-eastern and eastern tributaries and is likely absent from the westerly Warrego and Paroo rivers.

Field sampling between February and July 2020 found evidence (either as presence of shells or live animals) of one or more of the three mussel species being present at 53 of the 90 sites sampled (billabong mussel at 17 sites, river mussel at 45 sites and freshwater mussel at 3 sites).

There was evidence of the river mussel in reasonable abundance in all rivers except the Gwydir and Macintyre; where in these two systems evidence of billabong mussel was more obvious, predominantly dead/shells in the Macintyre and both alive and dead in the Gwydir. Despite the evidence of river mussel throughout most tributaries, most records were of deceased mussels and at no site were only live mussels observed. The greatest abundance of river mussel, both alive and dead, was observed in the lower Darling-Baaka below Menindee. At some sites in this region, thousands of dead mussels were surveyed, with site mortality estimates of 20–100% across the Northern Basin.

Length-frequency distributions were also compiled for each species from 927 shells collected at sites in the Darling-Baaka, Macquarie, Namoi, Gwydir, Macintyre and Dumaresq rivers. The limited number of small shells collected (see Sheldon et al. 2020) may imply limited recent recruitment.



Rivers targeted include the Barwon–Darling-Baaka, Warrego, Gwydir, Macintyre, Namoi and Macquarie rivers. Dots represent all sites surveyed. Presence was defined as the presence of either sham (empty shells) or live mussels. Source: Reproduced with permission from Sheldon et al. 2020.

Figure 20. Presence of (a) freshwater mussel (*Alathyria condola*) (b) river mussel (*Alathyria jacksoni*) and (c) billabong mussel (*Velesunio ambiguus*) in the northern Murray–Darling Basin

Key messages

Overall, the findings of Sheldon et al. (2020) suggest that the loss of river mussel populations across the Northern Basin resulting from the drying conditions of 2017–2019 was significant and widespread. This is a cause for concern given the longevity of individual mussels (maturing at 3–4 years and living up to 30 years or more; Walker 2001) and the limited evidence of widespread recent recruitment. This led to the following recommendations:

- that further research needs to be undertaken to understand the biology of freshwater mussels in the northern MDB, including their reproduction, recruitment, growth patterns and diets, as well as their role in the ecosystem of the Northern Murray–Darling Basin rivers – not least because, besides fish, they were historically the dominant animal by weight in these rivers
- that a focus be made on monitoring freshwater mussel recovery in both the short- and long-terms. This should include an understanding of which fish species act as hosts and what conditions are required for successful recruitment and establishment of juveniles
- that the importance of low flows and refugial habitats, reaches and waterholes, be formally recognised for freshwater mussels in the northern MDB and the flow requirements of freshwater mussels be incorporated into flow management plans
- that the role of refugial reaches and waterholes in the landscape persistence of mussels and fish be recognised and the flow required to maintain the integrity of these physical places in the channel network be understood and incorporated into flow management plans. This would require a Basin-wide perspective of the water sharing plans and water resource plans to ensure the critical area of the Barwon–Darling River has adequate flows for long-term population survival
- that a specific freshwater mussel recovery plan be developed in consultation with the communities of the northern MDB and this plan dovetails with Fish Recovery Plans.

7 Summary of findings

This is the first attempt at preparing a status assessment of native fish in the MDB using available data (MDBA 2020a). Assessing the status of all freshwater native fish in the MDB is a complex and challenging task, but it is an important exercise that has highlighted a number of data and knowledge gaps which need to be addressed to ensure future, scientifically robust assessments. A summary of each of the attributes is presented for each species in Appendix 4.

While there have been numerous native fish projects implemented across the MDB in recent decades, relatively few, if any, were established to assess the status of native fish at the scale of the MDB. Most projects have been tailored to local conditions to answer evaluation questions at smaller spatial and temporal scales than is required to assess the status of native fish across the MDB over time. However, many projects, particularly state jurisdiction fish monitoring programs, are now at the stage where the combination of data and expertise can be used to contribute to future status assessments, particularly where there is greater coordination of projects.

Ultimately the approach to assessing the status of native fish will depend on the level of supporting data/information and resources available from which to establish an appropriate baseline or point of reference and measure spatial and temporal changes in native fish attributes. The overall approach adopted in this assessment is predominantly qualitative narrative as outlined in Figure 22 in Appendix 1. The intention for future assessment is to move to a more quantitative assessment.

7.1 Summary statement

7.1.1 Status of native fish, spiny crayfish and mussels in the MDB as of July 2023

In the early 2000s, an expert panel concluded that MDB native fish populations overall were at about 10% of their pre-European levels, and established an overarching management goal of returning them to 60% over 50 years. It took many decades for the fish community to decline, and recovery will take as long or longer. In 2020, an updated expert reassessment concluded that in the face of many stressors, native fish populations had further declined and were now likely to be lower than this original figure (i.e. <10%; MDBA 2020a). Both assessments utilised available data from historical baselines, expert opinion and distributions and abundances elicited from the considerable recent (post-1990) monitoring programs. There was, however, no quantitative assessment of data. This 2023 status assessment reinforces that assessment and concludes that native fish populations in the Basin have continued to decline. There is still much to be done to restore native fish to sustainable and secure levels.

MDB fish management

Fish management in the Basin over that last two decades has had many notable successes, at both local, regional and species-specific scales (not necessarily an exhaustive list).

Basin-wide:

- In 2003, the MDB Native Fish Strategy (MDBC 2004) commenced a concerted and coordinated multi-jurisdictional program to improve fish populations; it ran for 10 years.
- Recent decades saw the establishment and implementation of the Basin Plan (Commonwealth of Australia 2012), environmental watering strategies and regional watering plans.
- Significant monitoring has occurred, including The Living Murray monitoring (2006–ongoing), Sustainable Rivers Audit (SRA; 2005–2013) and Murray–Darling Basin Fish Survey (MDBFS; 2015–ongoing).
- The Native Fish Recovery Strategy commenced in 2020 (MDBA 2020a) after the 2019 lower Darling-Baaka River fish death events.
- Significant, Basin-scale environmental water monitoring began, as did evaluation and research programs including the Commonwealth Environmental Water Office's long-term monitoring, evaluation and research program, the Murray–Darling Water and Environment Research Program (MD-WERP).
- Numerous Basin state programs commenced, including the Victorian Environmental Flows Monitoring and Assessment Program and Wetland Monitoring and Assessment Program, South Australia's Coorong, Lower Lakes and Murray Mouth monitoring, the Healthy Coorong Healthy Basin program, NSW's Basin Plan Environmental Outcomes Monitoring, and the Queensland Environmental Flows Assessment Program (King et al. 2022).
- Woody habitat reinstatement, carp biomass assessment, pump screening, changes to angler regulations, and stocking regimes and other initiatives all took place.
- The period saw an astonishing output of quality science from targeted research and investigations (Barrett et al. 2013, Fenton et al. 2020, Koehn et al. 2020b).

Northern Basin:

- The commencement/acceleration of a fishway program in the Northern Basin allowed fish to navigate weirs and barriers in the Darling-Baaka, Barwon and connected tributaries.
- Freshwater catfish were successfully translocated into the Gwydir catchment (NSW).

Southern Basin

- Twelve fishways in the Sea to Hume fishway program on the Murray River were constructed, and opened 2 225 km of fish passage.
- This included fishways at the barrages that allowed populations of diadromous fish (such as lampreys and congolli) to migrate between marine and freshwater habitats in the lower Murray, Coorong, Lower Lakes and Murray Mouth.
- Significant new sub-populations of some threatened fish species were established through stocking or translocations, including:
  - Macquarie perch in the Ovens River (Victoria), and Retreat River (NSW)
  - trout cod in the Ovens, Goulburn and Murrumbidgee rivers
  - Murray hardyhead in Little Frenchman's Creek, an environmentally watered wetland in far western NSW
  - southern pygmy perch translocated into multiple small locations.
- Breeding and translocation programs for small-bodied fish such as olive perchlet, southern purple-spotted gudgeon, Murray hardyhead, southern pygmy perch were begun, including limited releases in South Australia, Victoria and NSW.

- Developments continued in Macquarie perch captive breeding.
- Rescue programs were undertaken for many fish populations affected by drought and fire in 2019–20.

MDB environmental conditions

Aquatic ecosystems in the Basin have also faced significant and, for many, unprecedented challenges over this timeframe, including:

- the Millennium drought (1997–2010)
- severe flooding and blackwater fish death events in 2011–2016 and 2022–2023
- severe drought in the Northern Basin in 2017–2019
- the lower Darling-Baaka fish death events in 2018–2019 and 2023 across the Southern Basin
- mega-fires in 2019–20, followed by catastrophic sediment inputs to streams following rainfall on severely burnt catchments.

These extreme events, along with ongoing stressors of water abstraction, flow regulation, continuing habitat loss and expanding alien fish populations have all impacted native fish populations. Fish death events within the MDB are becoming more frequent and severe and are having increasing impacts on fish populations in terms of distribution, abundance and population dynamics. These events increase the risk to species, populations and the success of programs such as the Basin Plan. Monitoring plays an important part of quantifying the losses and impacts, as well as population recovery trajectories. Quantitative assessments of fish death event losses are very rarely undertaken (Koehn 2022) and additional monitoring is required to determine the immediate loss of fishes (for each species) and the effects on population structure. These data should then be included in the interpretation of future status assessment monitoring data and management actions.

The status of native fish populations

Basin-wide:

- It must be recognised that native fishes have suffered very considerable declines before this study.
- Approximately 47% of the Murray–Darling Basin's freshwater fish species and populations are now considered rare or threatened under national and state lists.
- No threatened fish have had their conservations status delisted and several new species have been listed (stocky galaxias, bald carp gudgeon); others have had their status downlisted, and more species are currently under consideration for listing under the EPBC Act.
- Yarra pygmy perch is now extinct in the wild in the MDB.
- Many species are now restricted in their ranges and have been reduced to small, fragmented sub-populations.
- An increase in Murray cod population abundance has been documented in NSW, and is likely in Victoria.
- Despite considerable year-to-year variations, probably related to flow conditions, golden perch population abundances increased in NSW over the assessment period.

- Small-bodied fishes (in off-channel habitats and small streams) are poorly monitored, with several likely eligible for listing as threatened at the Basin scale (e.g. olive perchlet, southern purple-spotted gudgeon).
- There has been a significant downward trend in mountain galaxias abundances.
- Spiny crayfish have been poorly monitored, and several species were significantly affected by the bushfires and blackwater events. Five species are currently being considered for national listing as threatened within the MDB.

Northern Basin:

- There is considerable concern for silver perch populations in the Northern Basin.
- Murray cod and freshwater catfish appear to have been lost from the Paroo valley, and Australian smelt are now extremely rare there.
- Silver perch is now in very low numbers and recent population modelling has considered it to be functionally extinct in the Northern Basin.
- Purple-spotted gudgeon and olive perchlet have declined in Queensland.
- River mussel populations have been declining in the Northern Basin over decades, with significant mass deaths in the Darling-Baaka River over the summer of 2019–2020.

Southern Basin:

- Macquarie perch and other species have been severely impacted by the 2020 bushfires in southern NSW, the ACT and north-east Victoria.
- Trout cod populations in the Ovens and Murray rivers have been impacted by fish death events.
- The numbers of Murray crayfish, and the areas they can live in, have declined due to the loss of free-flowing river habitat, and blackwater events following the Millennium drought and 2022–23 floods.
- Silver perch populations in the mid-Murray region appear stable.
- Murray cod populations in the Murray River and lower Darling-Baaka River have been impacted by numerous significant fish death events. This is also so for bony herring and golden perch in the lower Darling-Baaka River.

Limitations

With the data and resources available to this status assessment, the continuing decline and current level of the fish community cannot be fully quantified with confidence and for many sections is presented predominantly as a narrative. The most significant constraints on undertaking a quantitative status assessment include:

- lack of comprehensive, purpose-built coordinated monitoring programs to assess native fish population and conservation status – most species are not adequately monitored or have insufficient data for quantitative assessments
- lack of a rigorous coordinated threatened fish monitoring program
- lack of inclusion of many datasets – such as interventions monitoring programs and consultant reports
- lack of a centralised data assessments and sharing system

- lack of a Basin-scale knowledge exchange program to synthesise and share information on
  - fish distribution and abundance
  - the magnitudes, trends and trajectories of major threats (Koehn and Lintermans 2012)
  - management actions to address these threats, and their successes and outcomes.
- lack of leadership and resources to ensure cross-agency and cross-jurisdiction coordination to deliver complementary programs rather than the current fragmented approach
- lack of actual analyses of existing datasets
- low population numbers for some species, which makes it difficult to obtain adequate data to undertake quantitative population status assessments
- lack of sampling and analysis of recruitment – although this can be improved to provide better understanding of future population trends
- lack of quantification of losses during major fish death events; impacts on small-bodied species particularly poorly known
- gaps in data and ecological knowledge, which have hampered the interpretation of results. Lack of data about movements, fish deaths, stocking, angler harvest, angler regulations and species' detection rates for different sampling methods and conditions all impose greater uncertainties on data analysis conclusions.

Spiny crayfish and mussel status

There is even less information available for spiny crayfish and mussel populations than for fish.

- *Euastacus* is the most threatened genus of crayfish in the world.
- Approximately 69% of Basin spiny crayfish are currently of conservation concern and under assessment for listing under the EPBC Act.
- In the Basin, distribution and abundance of all but one spiny crayfish (Murray crayfish) are poorly understood.
- There are a number of cryptic species of spiny crayfish in the Basin, with further taxonomic investigation likely to increase the total number of species in the Basin as well as those of conservation concern.
- River mussel (*Alathyria jacksoni*) sub-populations in the Northern Basin are showing declines post-2017–2019 drying, with thousands of dead mussels surveyed and site mortality estimates of between 20 and 100% across the Northern Basin.
- There is no coordinated Basin-wide monitoring program for any mussel or spiny crayfish species.
- Information on the ecology, habitat requirements, refugia, and impacts of major stressors such as river regulation, drought, blackwater and fire for freshwater spiny crayfish and mussels is severely limited.

7.2 Considerations

7.2.1 Status assessment improvements – monitoring

Monitoring programs are all designed for a particular intended purpose and their sampling methods, coverage and frequency have different efficiencies and limitations. Not all methods catch all species or life stages with the same efficiency (e.g. electrofishing versus netting), and effectiveness varies with species, site and environmental conditions (e.g. water depth and turbidity). Hence not all data are equal. Given that data are not often collected for undertaking assessments of species' populations across the whole MDB, there will always be limitations on how it can be used – and hence the data must be used carefully and accompanied by considered interpretations and caveats. There are also considerable gaps in monitoring programs, especially for small fishes (i.e. small species and juveniles), small streams and wetland ecosystems (Davies et al. 2010a, b). This is despite floodplain specialists having the lowest population health index.

A targeted, robust monitoring approach across all habitat types (i.e. not just generic river-only monitoring) is needed assess the status of native fish species and sub-populations, particularly threatened species (Scheele et al. 2019). Such an approach should seek to make best use of existing monitoring programs in terms of use of existing data to assess current trends in fish population dynamics and inform future status assessments, but also explicitly consider how analysis will be undertaken.

An integrated monitoring program with multiple objectives will naturally require multiple sampling frames and methodologies. An integrated approach (King et al. 2020) that could be used at a the MDB scale could include:

- broadscale presence/absence monitoring
- focused monitoring of high-priority species, life stages, and populations/assemblages and their habitats.

7.2.2 Status assessment improvements – analysis

Analytical methods, analyst skillsets and preferences, hardware and software capabilities and current trends all influence the types of analyses that can be undertaken to assess the population status of native fish. While there are sufficient skills and capabilities and new and emerging ways of viewing new or historical data, there remain challenges in collecting monitoring data to inform future status assessments:

- To assess widespread and abundant species accurately requires broadscale sampling; however, broadscale sampling is inefficient for rare or cryptic species and life stages, and targeted sampling, which is considerably more effective, is required.
- Fish sampling methods have varying efficacies (e.g. different species and life-stage capture efficiency when electrofishing), depending on the species, life stage and local conditions (e.g. habitat type, salinity, turbidity).
- Sampling for native fish recruits requires different techniques than sampling for presence only.
- Sampling spatially requires selecting individual sites as the sampling unit, which is a different sampling frame to sampling species populations/sub-populations, where individual fish are the sampling units.

Some considerations when designing an integrated monitoring program for fish status assessment include:

- Novel methods for estimating the occurrence and abundance of species. For example
  – a method to provide the first estimate of carp (numbers and biomass) applicable at river reach, basin and continental scales (Stuart et al. 2021) – and a similar approach could be investigated for native fish species

  - including species biomass as a metric
  - assessments of fish health (e.g. prevalence of parasites).

- Obtaining data from as many sources as possible, particularly for assessing species distributions. In addition to MDBA and jurisdiction data bases, data are likely to be held by many other organisations and individuals, including catchment management authorities, university researchers, water corporations and consultants. Under the Nature Positive Plan (DCCEEW 2022a), an independent environmental information office, the Data Division, is being established. It will play a key role in providing a platform for bringing together disparate environmental information held by different organisations and governments, including information gathered as part of environmental approval processes, and biodiversity data collected through government natural resource management programs.

- The inclusion of the catch effectiveness for species by different sampling methods, expressed as detection or capture probabilities for different species under different conditions (Bearlin et al. 2008, Ebner et al. 2008, Lyon et al. 2014), can strengthen the ability of monitoring data to estimate population abundances (Gwinn et al. 2019) and to assess the presence or recruitment status of rare species at local scales (Lintermans 2016).

- The contemporary large-scale fish species monitoring programs (i.e. SRA/MDBFS) do not attempt to use abundance data in assessments. However, these datasets can provide informative assessments of trends in abundance at larger spatial scales by assessing abundance in one of three ways; namely
  - incorporating detection probabilities in abundance estimates at local or higher spatial scales (Lyon et al. 2014, 2019, Gwinn et al. 2019) (note that variation in capture probability in large lowland rivers results in additional uncertainty when estimating population size or relative abundance)
  - assessing abundance in relative terms only and using larger spatial scales (Crook et al. 2023).
  - assessing abundance in relative terms for ubiquitous species at spatial scales where detection inefficiency is negligible (Robinson et al. in prep.).
  - The Lyon et al. (2014) methodology, using mark–recapture data to include migration and angler harvest rates, aspects that influence populations but are not included in current standardised assessment methods (Davies et al. 2010a, b).

- Narratives around analysis and status assessments should be improved to cover limitations and caveats, and be designed to provide knowledge useful to managers.

- Inclusion of stocking records, estimates of harvest, quantification of fish death event losses and habitat condition trends (droughts, fishway openings, reduction of cold water pollution, fish pump screening) and the ecology of each fish species (e.g. current population abundance and structure) and fish condition/health to be incorporated into such assessment narratives.

Use of metrics or indices

Much of the data used for this status assessment were collected for different purposes (e.g. broadscale distributional mapping, river health assessment) and the analyses used here have many caveats. Often, we have used an index to represent the results – for example, as relative abundance or proportion of river kilometres where a species occurs. That is, the actual true abundance or extent of the distribution is not estimable; however, a relative assessment (a comparison through time or between sites) is. Another method is to compare the relative estimate to a reference value or a management target and state whether the relative assessment is meeting the reference or how it compares to previous years. This allows us to estimate trends in the measure of interest without having definitively quantifying the measure. For example, we know that when congolli populations are healthy, they are widespread in the Coorong, Lower Lakes and Murray Mouth region and will be detected at all the barrage fishways. We also know that it is impossible to estimate abundance for this species, so we use the number of barrages at which it is detected as the indicator of healthy populations. However, there may be years when not all barrages are available for sampling, so comparing raw numbers is meaningless. Instead, it is possible to create an index that says, if they occur in all sampled barrage fishways in any year, the population is healthy; then, the analysis of population trends compares the index between years. Other indices to consider may be the relative proportion of alien to native species and observed to expected species.

7.2.3 Status assessment improvements – increased utilisation of existing data

There are a range of other data collected from a variety of projects that could be integrated with existing datasets. This includes many smaller projects, often undertaken by local agencies and/or consultants and not collated. Such data should be collected and evaluated for their usefulness in the questions posed by this project. This includes the extensive flow interventions monitoring datasets. For example, Tonkin et al. (2017) recommended that for fish monitoring in the northern rivers of Victoria, the approach should be to combine both event-based intervention monitoring and condition monitoring to provide a robust link between patterns in population processes (in that case migration) and population demographics. Importantly, these have been underpinned by an up-to-date conceptual understanding of flow links for MDB fishes.

Both stocking and harvest occur across the MDB for some large popular, native angling species (such as Murray cod, golden perch, silver perch and trout cod (stocking only)) (Koehn et al. 2020b). Such actions can influence populations, depending on their extent and the conditions at the time. For example, Crook et al. (2016) found that stocked fingerlings of golden perch increased catch per unit effort and made up high proportions of sub-populations in the Murrumbidgee River, Edward River and Billabong Creek, whereas there was no evidence of recruitment at unstocked control sites in the Murray River. Another example was restocking of Macquarie perch and trout cod within the Ovens River system, which contributed to the re-establishment and expansion of these species (Lutz et al. 2020, DEPI 2014). However, restocking and reintroductions of short-lived threatened species has had mixed results (e.g. Whiterod et al. 2021a).

Angler harvest across Australia has been estimated for many species (Henry and Lyle 2003), although these data need updating. The removal of fish through angler harvest can not only reduce population abundance but also alter population structure (Nicol et al. 2005). Similarly, the stocking of popular species for anglers (especially Murray cod and golden perch) or for conservation purposes (e.g. trout cod) can add to juvenile numbers. Overall, these additions or subtractions need to be considered when making assessment of the reasons for population changes.

Assessments of the effects of management interventions on fishes frequently focus on direct, short-term responses without consideration of underlying population trends that span multiple years. Failing to account for intrinsic population trends led to a combination of plausible and implausible conclusions when assessing management actions (Yen et al. 2021a). That is, short- and long-term changes in populations can be affected by responses to river discharge and overarching environmental conditions and population structure (Todd et al. 2019). For example, fish death events can impact populations, especially Murray cod (Thiem et al. 2019).

Environmental conditions (e.g. flows) not only effect assessments at the time of monitoring but preceding conditions also influence populations (Koehn et al. 2020b, Tonkin et al. 2017). Relative abundance for some MDB fish species is influenced by the duration of drought or flood conditions up to 3 years ago (Robinson et al. 2019).

Nevertheless, 90% of the variability in relative abundance of native fish in the SRA fish dataset from 2004 to 2013 was from variability between sites (Robinson 2015). Variability between sampling periods is always less than 5% of the total variability as is the variability between river valleys. In other words, the relative abundance of native fish between 2004 and 2013 did not change much through time regardless of floods or droughts. This is also seen in the make-up of species in the native fish assemblages, where despite varying climatic and hydrologic regimes (mainly, flow intermittence), significant spatial variability is at the reach scale Whiterod et al. (2015).

7.2.4 Moving from species monitoring to predictive modelling

Determining the status and trends of biodiversity in a form that is easily understood, timely, scientifically rigorous, standardised, relevant, and representative of species populations across species and multiple scales over time (Jetz et al. 2019) is fundamental in responding to global and national initiatives focused on improving conservation of biodiversity. There is a need to better understand fish populations and their trends and likely future directions to provide more useful direction for management. The assessment of monitoring data, by necessity, is largely looking into the past to provide an explanation of what has already happened, often in response to interventions by management agencies. An increasingly common approach is to use predictive modelling to look forward to what may happen to populations into the future, given antecedent conditions and scenarios of potential future conditions. Such approaches rely on monitoring data and the latest understanding of a species' ecology to provide trends and predictions that help managers be proactive in their management planning.

Population models can use the latest ecological knowledge, link key population processes (especially spawning, recruitment and movements) to environmental (often flow) components and be informed by data (e.g. Todd et al. 2020). Population models are now being used for management of a range of species in the MDB, including Murray cod (Koehn and Todd 2012); trout cod (Todd et al. 2005); golden perch (Todd et al. 2023); Macquarie perch (Todd and Lintermans 2015); silver perch (Todd et al. 2020, 2022); southern pygmy perch (Todd et al. 2017a), two-spined blackfish (Todd et al. 2017b); carp (Stuart et al. 2021) and Murray crayfish (Todd et al. 2018,Yen et al. 2021b).

As there will always be some uncertainties within the models, it is the modelled trends rather than the absolute model outputs that are important for consideration. As models are imperfect, they need to be validated, but examples of validation of such models are rare. Hale et al. (in prep.) undertook such validation by testing model assumptions and outputs against independent, empirical datasets. Results showed correlations between fish population sizes and growth rates as predicted by the model and observed in independent empirical datasets for several populations, but the strengths of these correlations varied among populations, and across observed hydrological conditions. Predicted and observed fish movement rates were strongly correlated. Such studies demonstrate that: (1) validation can identify model strengths and weaknesses;
(2) observed datasets often have inherent limitations that can preclude robust validations;
(3) validation is likely be more common if appropriate observed datasets are available; and
(4) validation should consider the purpose of modelling.

The use of predictive population models, based on the latest ecological knowledge and data for the species in questions, will be a part of the quantitative assessments proposed for future status assessments. Additional efforts should be made to include assessments of recruitment and to integrate monitoring data with population modelling to provide more predictive information for managers regarding likely population trends.

7.2.5 Use of eDNA and population genetics

The discussion in Chapter 4 highlighted the difficulty of assessing the distribution of individual species across the MDB in the absence of a program dedicated to this. The case study presented in Section 4.4 also highlighted that many species are fragmented across their existing range, whether naturally or due to barriers to movement and migration. This is where emerging technologies, such as eDNA metabarcoding and population genetics, can assist future status assessments.

eDNA metabarcoding

eDNA metabarcoding is increasingly being used as a tool to detect the presence of aquatic species and thus species richness. For aquatic environments, DNA is extracted from water or sediment samples and amplified using general or universal primers in a polymerase chain reaction. DNA sequencing is then used to detect species presence. The value of eDNA for detecting species richness compared to standard methods is influenced by the overall diversity. For example, McElroy et al. (2020) showed that for systems with less than 100 species eDNA was better at species detection than standard methods. A limitation of eDNA is that empirical studies have shown that eDNA degrades quickly in most aquatic environments (Lahoz-Monfort and Tingley 2018). While still being developed as a practical application for monitoring in aquatic ecosystems, the use of eDNA to detect species is expected to become commonplace in coming years. Only a few studies have been undertaken to date in the MDB (e.g. Bylemans et al. 2018, Rojahn et al. 2021a, b); however, the potential for using eDNA metabarcoding should be explored for future native fish status assessments.

Population genetics

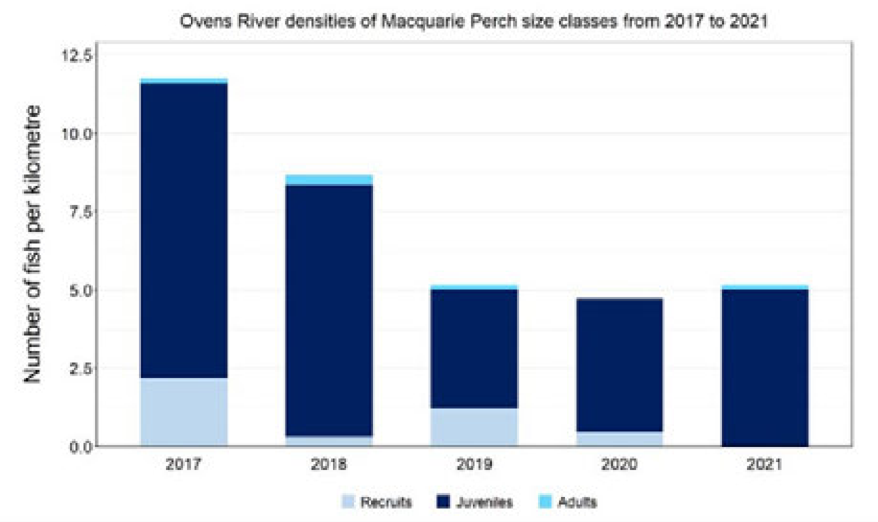
The case study on four native fish species highlighted the ability to examine genetic structure at varying scales across the MDB. The use of population genetics provides a powerful tool for measuring gene flow, allowing us to identify populations that have issues, such as low genetic diversity/connectivity. This information is invaluable to conservation programs and the management of populations with low genetic diversity.

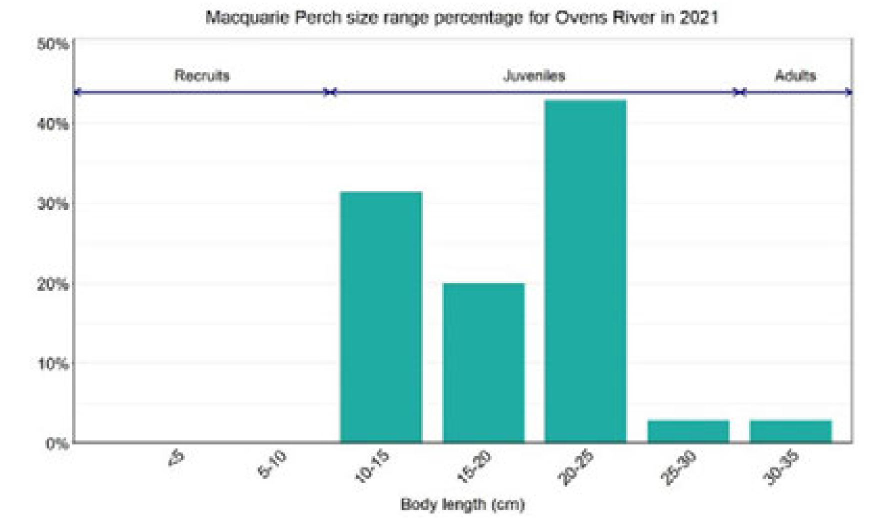
There is currently a lack of knowledge and the samples required to assess the genetic health and connectivity of most MDB fish species. Assessing population genetics is a specialised undertaking, requiring such things as liquid nitrogen-preserved genetic samples suitable for comparison over time. While genomics has opened up new opportunities for assessing population genetics, it requires investment for their full potential to be realised.

Assessing recruitment

The number of new fish entering a sub-population at a given time is nominally termed ‘recruitment’. For a whole population, the term recruitment generally applies to the number of new individuals entering via reproduction or immigration and surviving to reproductive age (Figure 21). In many species, recruitment strength is established during the early life stages and hence 'recruitment' is judged to be when individuals survive into the juvenile or young-of-the-year (YoY) cohort, and into adulthood (King et al. 2013, van der Veer et al. 2000). The importance of regular recruitment events differs between short-lived and long-lived species.

The detection of young recruits within a population can provide an indication of likely population trends. Determining the absolute age of small fish is not usually possible during field sampling as it requires terminating the fish. However, the likely lengths for YoY or fish age at maturity (LAM) for fish in the MDB (e.g. Rourke and Robinson 2022) have been used by major sampling programs as a substitute. This is an important component of such monitoring, but it must be recognised that regional differences in growth rates (especially Northern versus Southern Basin) can occur. For example, differences in golden perch growth rates (Koehn et al. 2020b, Wright et al. 2020) highlighted uncertainties with this approach and the need to consider age and growth data (and perhaps other variables such as fecundity) at finer spatial scales, rather than considering them as being homogenous across MDB. Such growth differences also occur across temporal scales with differing environmental conditions (e.g. post-flooding productivity or cold water releases; Whiterod et al. 2018) and for other widespread species such as Murray cod (Rowland 1989, G. Butler, NSW DPI Fisheries, unpubl. data). The accuracy of such parameters can be important as they support our understanding of population processes (Todd et al. 2017a).





Source: ARI 2021

Figure 21. Densities and size range of Macquarie perch in the Ovens River

To date, the use of size classes to indicate population structure has generally been underutilised (especially for most species) in analyses. There are, however, several useful metrics that can be utilised relatively easily to use existing data to illustrate important aspects of this, including the estimates of size at age, or size at maturity (Table 17), which can also be expressed as an index for the occurrence of juvenile or YoY fish in each population. Other approaches include a summary of key population health indicators on an annual basis as a 'yes' and 'no' descriptor; for example, as an indication of recent recruitment, presence of multiple size classes, and the presence of mature fish (ARI 2021). Crook et al. (2023) used changes in average size as a general indicator of whether the size distribution within the population was changing. A more nuanced break breakdown of length-frequency data expressed as the percentage of population assessed as YoY recruits, juveniles or adults could, however, be more informative at larger spatial scales (Figure 21). This can also be visualised from length-frequency histograms, which can then be quantified by various forms of cohort analysis (e.g. Kolmolgorov-Smirnoff to determine differences between years, or other tests). The inclusion of length-frequency histograms over a range of years is very instructive for following recruit cohorts between sites and from year to year. This is, however, more difficult for short-lived, fast growing species and later year classes for longer lived species where differences in growth rates mean that the overlap in size/age classes becomes greater. The MDBA and management agencies should require better analyses of data to meet their management needs. For example, assessing the percentage catch of legal-size fish as an indicator may be useful for fishery managers.

To better assess fish population structure and allow accurate assessments of recruitment, future fish monitoring in the MDB should include a program that allows targeted sampling of recruits, or age assessment, and the sampling program should be designed to sample fish populations, rather than river kilometres.

Table 17. Example length at maturity and length at 1 year for native fish in the Central Murray region of the MDB

Scientific name	Common name	Species origin	Life guild code	Central Murray LAM	Central Murray YoY
Ambassis agassizii	Olive perchlet	Native	Short lived	35	35
Bidyanus bidyanus	Silver perch	Native	Long lived	288	101
Craterocephalus fluviatilis	Murray hardyhead	Native	Short lived	40	40
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead	Native	Short lived	39	39
Gadopsis marmorata	River blackfish	Native	Intermediate lived	80	70
Galaxias olidus	Mountain galaxias	Native	Intermediate lived	30	30
Hypseleotris spp.	Gudgeon	Native	Short lived	35	30
Macquaria ambigua ambigua	Golden perch	Native	Long lived	230	118
Macquaria australasica	Macquarie perch	Native	Long lived	127	75
Maccullochella macquariensis	Trout cod	Native	Long lived	150	115
Maccullochella peelii peelii	Murray cod	Native	Long lived	235	115
Melanotaenia fluviatilis	Murray–Darling rainbowfish	Native	Short lived	45	39
Mogurnda adspersa	Southern purple-spotted gudgeon	Native	Intermediate lived	49	49
Nannoperca australis	Southern pygmy perch	Native	Short lived	31	31
Nematalosa erebi	Bony herring	Native	Intermediate lived	145	67

Philypnodon grandiceps	Flathead gudgeon	Native	Intermediate lived	58	50
Philypnodon sp.	Dwarf flathead gudgeon	Native	Short lived	30	28
Retropinna semoni	Australian smelt	Native	Short lived	37	37
Tandanus tandanus	Freshwater catfish	Native	Long lived	360	102

LAM = length at maturity; YoY = young of the year
Source: Rourke and Robinson 2022

7.2.6 Knowledge gaps

There are a range of knowledge gaps that inhibit monitoring, assessments and interpretation of data for MDB fishes. Obvious gaps already mentioned include the monitoring coverage for MDB fish species and their habitats (e.g. small fishes, newly described species, wetland and floodplain species). There is acknowledgement of the lack of data and ecological studies for many species in the Northern Basin (Koehn et al. 2019a). The lack of incorporation detection and capture efficiency of the various survey methods also hinders progress to interpretation of estimates of 'true' populations and their trends.

There are also ecological knowledge gaps that hinder interpretation of results and their application into population models. These have been identified for freshwater fish in the MDB: survival rates of life stages, and recruitment to adults (population dynamics), especially small species, movement (especially for larvae and juveniles), growth and condition (Koehn et al. 2017, 2019a). Understanding population dynamics can help with the prediction of trends and the assessment of likely outcomes of management interventions. This is particularly important with respect to changes in environmental conditions, especially flows, and changes in these trends, perhaps caused by climate change. Monitoring data (especially long-term datasets) can help assist with filling some of these knowledge gaps if the collection and analyses are undertaken with the appropriate parameters (see Section 7.2.1).

7.3 Recommendations

7.3.1 Improving collaboration

There must be considerable commitment from all levels of government to improve the efficiency and effectiveness of monitoring and analyses/utilisation of fish data in the MDB. Going forward, there is now a need to either improve existing collaborative processes, or where missing establish such processes, in order to implement the detailed recommendation in this report. It is recommended that the MDBA initiates a workshop (or series of workshops) involving jurisdictional, science, management, First Nations and stakeholder representatives to address the recommendations listed below.

Recommendation 1: The MDBA, federal and state agencies, research institutes and First Nations collaborate to establish a process to undertake detailed, quantitative assessments of native fish status using appropriate long-term datasets and fish population modelling to assess attributes such as species conservation status, species distribution, and existing and likely future population dynamics (e.g. existing, and likely future population trends).

7.3.2 Improving the assessment method

Many of the needs to improve future status assessments of populations of native fish in the MDB rely on refinements to the approach used in this current assessment. To shift to a more quantitative method will require additional, coordinated collection and analysis of data. In particular, fit-for-purpose monitoring and improved analytical approaches to status assessment will be essential. The scope of future status assessments should be expanded to capture complementary data and address management needs. Future status assessments should include the development of standardised reporting metrics for alien fish distribution and abundance, as alien species are a major threat to many fish species and a constraint on threatened fish recovery (e.g. existing and likely future populations trends).

Recommendation 2: The MDBA and its partners refine more targeted approaches to status assessment, particularly for habitats, species and life stages that are under-represented in current Basin-scale monitoring programs. Current priority monitoring and status gaps include off-stream and small-stream species, recruitment metrics (young of the year, spawning) and the status of Murray cod, silver perch, freshwater catfish and Australian smelt in the Paroo valley. Notably, silver perch are poorly surveyed by electrofishing and should be a priority species for targeted sampling in multiple valleys.

Recommendation 3: Use the findings of this assessment to refine a more targeted, quantitative approach to status assessment:

- Integrate additional variables in analyses and undertake new and novel analysis methods to enhance the presentation and interpretation of results.
- Include calculations of fish biomass and fish condition as standard metrics in data analysis.
- Develop standardised reporting metrics for alien fish distributions and abundances, as alien species are a major threat to many fish species.
- Address knowledge gaps to assist in data analysis, predictive population modelling and interpretation for managers.

Recommendation 4: Articulate the key management questions for which these data will be used and progress from status data modelling to predictive population modelling to better assist management decision making.

Recommendation 5: Include data on angler harvest, hatchery stocking, fish death events and other relevant management actions that may influence populations in species' status assessments. At the very least these should be included in the interpretation of results (out of scope in the current assessment).

Recommendation 6: Future status assessments should include greater consideration of alien species including assessment of trends in number of species, abundance and distribution (see recommendation 18).

Recommendation 7: Continue support for research that relates to distribution, conservation status and population dynamics that can provide knowledge for improved analysis and interpretation of monitoring results.

7.3.3 Data management

The establishment, collation, curation and management of an accessible MDB-wide fish database through a centralised hub that incorporates all of the major datasets (e.g. intervention, condition, threatened species monitoring) is an urgent requirement.

Recommendation 8: That the MDBA and its partners establish a database which includes all relevant metadata (e.g. data source, project name, sampling locations, methods, frequency, effort) to house native fish data from all Commonwealth- and state-funded programs (and other programs, such as those undertaken by universities and research institutions) including intervention, condition, threatened species monitoring.

7.3.4 Monitoring priorities

Underpinning future status assessments is the need to establish targeted, sound monitoring program(s) that are generating fit-for-purpose data. It should inform monitoring needs at multiple scales and for multiple purposes. Maintaining, and where required expanding existing programs – to ensure longevity of datasets, curation, custodianship and open access – is essential to the management and recovery of native fish in the MDB. Key needs should be to address knowledge gaps for key species, adopt appropriate spatial coverage and sampling methods and the establishment of a threatened species monitoring program.

Recommendation 9: Develop a revised, more rigorous fish monitoring program that addresses key gaps and deficiencies of current monitoring programs. This should specifically target wetland species, threatened species, newly described species (e.g. *Galaxias* species, *Gadopsis* species), and recovery of populations from fish death events (including population trends), at appropriate spatial and temporal scales.

Recommendation 10: That a Basin-wide threatened species monitoring program be established, including fit-for-purpose sampling methods and frequency (e.g. annual) that can produce standardised reporting metrics on individual threatened species populations and their status across jurisdictions.

Initial target species for monitoring include those which lack significant information on population dynamics which are essential for assessing conservation status (extent of occupancy, area of occupancy, number of adults in the population, number of sub-populations, key threatening processes). This includes:

- recovering species: Murray cod (and other species) following fish death events
- MDB species and sub-populations of concern: freshwater catfish, short-headed lamprey, southern purple-spotted gudgeon, Murray–Darling rainbowfish, olive perchlet, southern pygmy perch, Darling River hardyhead (*Craterocephalus amniculus*), river blackfish (*Gadopsis marmorata*), barred galaxias (*Galaxias fuscus*)
- declining species: mountain galaxias, mussels, Murray crayfish, silver perch (Northern Basin), threatened short-lived and wetland species.

Recommendation 11: Investigate the drivers of decline in key species in river valleys identified as of particular conservation concern. This includes the Paroo which is seemingly losing at least two large-bodied threatened fish species: Murray cod and freshwater catfish, with silver perch now being extremely rare, and considered functionally extinct.

Recommendation 12: Undertake additional monitoring to quantify the immediate loss of fishes (abundance for each species) and the effects on populations due to fish death events.

Recommendation 13: Support supplementary sampling in existing programs to better assess population structures for key species within known ranges. For example, the current broadscale electrofishing-based surveys do not target habitats where many recruits may be present. Additional sampling of eggs, larvae or small fish using other methods may also be needed. Develop recruit-specific sampling methodologies and analysis for species and sites as appropriate.

Recommendation 14: Undertake an audit of key fish habitat attributes across the MDB, with monitoring of habitat amount/condition and other threats included in the interpretation of data and status assessment for each species.

Research and management needs

Recommendation 15: Improve and support taxonomic understanding of cryptic diversity in Murray–Darling fishes and crayfishes. This is essential for management and accurate assessment of species and community status and trend and should be enhanced and continued. It will also be needed for future assessments of conservation status.

Recommendation 16: Undertake a Basin-wide inventory of threatened fish management interventions and their success; this will allow synthesis and analysis of strengths and weaknesses of current management approaches to common threats.

Recommendation 17: Undertake a Basin-wide inventory of the prevalence of key threatening process to native fish populations and required management responses to these threats (e.g. riparian restoration extent, riverine fencing, environmental flows). Characterisation of changes in threat distribution and intensity will assist with interpretation of changing fish, mussel and spiny crayfish status.

Recommendation 18: Develop a Basin-wide alien fish management strategy to be implemented under the Native Fish Recovery Strategy; it must include:

- an alien fish surveillance program, for example using eDNA followed with conventional sampling.
- protection of priority locations inhabited by threatened native species.

Program evaluation

This 2023 status assessment indicates that native fish populations in the Basin have continued to decline. There is still much to be done to restore native fish to sustainable and secure levels. As the most threatened group of vertebrates, and with an ongoing decline in populations of many species, there is a need to undertake regular assessment of the status and trends of native fish in the Basin. This assessment is based on a limited number of existing available datasets and is narrative in nature. Future assessments must include quantitative modelling approaches using full datasets across whole of MDB (where applicable).

Recommendation 19: The frequency of future status assessments should be at 5-year intervals. Targeted assessments may be required at shorter intervals for key or at-risk species. The next assessment should improve on collaborative approaches, be quantitative in nature and make best use of available data, expertise, and interpretation.

8 The way forward

8.1 Context

It is critical to acknowledge that many of the findings of this assessment are not unexpected and reiterate findings from several past programs and publications.

However, native fish in the MDB continue to be in decline.

There have been several previous calls to address the data and knowledge gaps identified in this report (e.g. Barrett et al. 2013, Fenton et al. 2020, Koehn et al. 2019a, King et al. 2022). Coordination and integration of approaches, research and monitoring data are essential steps to improve outcomes for native fish in a resource constrained policy setting.

There are strong policy and legislative imperatives that require the establishment of a coordinated Basin-scale program, as outlined in Sections 8.1.1–8.1.3.

8.1.1 Contribution to Basin Plan and MDB Outlook

Basin Plan objectives, targets and outcomes under Chapter 8, Schedule 7 and the Basin-wide Environmental Watering Strategy (BWS) all require data on native fish attributes measured in this assessment. This assessment provides outputs at river valley and whole-of-Basin scale for target species listed in the BWS and will directly contribute to the MDB Outlook project providing the best available assessment of the status of native fish in the Basin. The MDBA will deliver the first MDB Outlook at the end of 2023 which will (King et al. 2022):

- report on the current condition and recent trend of environmental, social, economic and cultural values in the Basin using key indicators
- assess risks and threats to these values, including external influences to water, such as land management
- provide insight into the future condition of the water dependent ecosystems, economies and communities in the Basin under a range of climate scenarios.

8.1.2 Contribution to nature positive commitments

Under the Nature Positive Plan released in December 2022, the Commonwealth Government's primary principle is to better protect Australia's environment and prevent further extinction of native plants and animals. The plan defines nature positive as a term used to describe circumstances where nature – species and ecosystems – is being repaired and is regenerating rather than being in decline.

Under the proposed new legislation, all Matters of National Environmental Significance (including listed species and communities, Ramsar sites) and other matters will be subject to National Environmental Standards. This will include a new National Environmental Standard for First Nations Engagement and Participation in Decision-Making will be developed as a priority to enable First Nations views and knowledge to be considered in all project approvals and planning decisions under national environmental law.

8.1.3 Opportunity to coordinate and integrate major programs

There is a current window of opportunity to take advantage of the evaluation and review of The Living Murray due in December 2023 and re-design of the Commonwealth Environmental Water Office's long-term monitoring, evaluation and research program commencing in the second half of 2023.

8.2 The way forward

To improve the efficiency and effectiveness of monitoring and analyses/utilisation of fish data in the MDB there must be considerable commitment from all levels of government. Going forward, there is now a need to either improve existing collaborative processes or, where missing, establish such processes, to make progress on the detailed recommendation in this report. We suggest that the MDBA initiates a workshop (or series of workshops) involving jurisdictional, science, management, First Nations and stakeholder representatives to address key areas, such as:

- developing a revised, more rigorous fish monitoring program that addresses key gaps (e.g. wetland species, threatened species, fish deaths, spatial and temporal scope)
- establishing, collating, curating and managing an accessible MDB-wide fish database through a central hub that incorporates of the major datasets (e.g. intervention monitoring)
- addressing knowledge gaps to assist in data analysis, predictive population modelling and interpretation for managers
- initiating a program of works that undertakes rigorous analyses of fish data to provide status assessments, including additional species, parameters, methods, presentation of results and interpretation
- articulating the key management questions for which these data will be used and the progression from status data modelling to predictive population modelling to better assist management decision making.

As water monitoring and management becomes increasingly sophisticated, so must the management of MDB fishes in order to protect this key resource. This places more importance on the collection and utilisation of data to inform management decisions. This assessment provides the basis from which improvements in the status of fishes, their protection and population recovery can occur.

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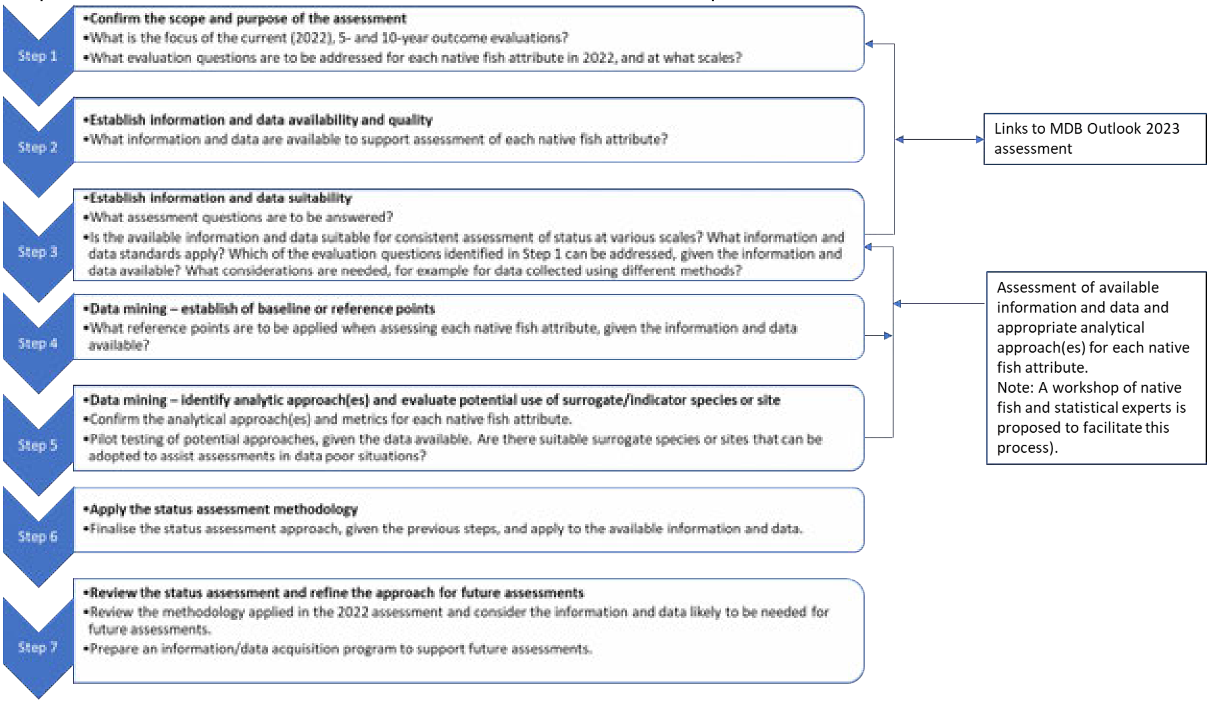
Appendix 1 – General approach to the status assessment

Overview of the status assessment approach

The overall approach, approved by the Technical Advisory Group established for the project, is outlined in Cottingham et al. (2022) and illustrated in Figure 22. The evaluation questions used to guide this status assessment are presented in Table 18 and were developed based on the guidance in Cottingham et al. (2022) and approved by the Technical Advisory Group, and are to be considered wherever feasible. Not all questions and outputs have been addressed in the current assessment due to scope, data and resources limitations.



Source: Cottingham et al. 2022

Figure 22. Overview of the 2023 native fish status assessment process

Table 18. Potential status assessment evaluation questions developed at outset of current status assessment

Potential evaluation question by attribute	Spatial scale	Potential outputs
Number of species		
• What is the total number of native fish species (i.e. fish; spiny crayfish and mussels pending sufficient data)? • Has the total number of species increased, decreased or remained stable? Why has this occurred (e.g. new discoveries or taxonomic changes)? • Has the total number of alien species increased, decreased or remained stable?	Basin scale (Northern and Southern Basins), river valley (e.g. including wetland or headwaters for rare species)	• Tables and supporting text. • Text on any species new to the Basin or lost to the Basin • Text on species complexes • Case studies (e.g. spiny crayfish and mussels)
Conservation status		
• What is the current conservation status of each species or genetic management unit? • Has the number of threatened species increased, decreased or remained stable (compared with a refence point)? • Are there yet-to-be-listed species whose decline is of concern?	International, national, Basin scale, jurisdiction	• Tables of conservation status for each species • Case studies of species/sub-populations trending towards threatened or otherwise imperilled
Distribution		
• Has the distribution of species increased, decreased or remained stable? • Are species sub-populations connected or fragmented? Case study as an example.	Basin scale (Northern and Southern Basins), river valley	• Species distribution maps • Narrative on species new to the Basin • Narrative to say barriers to movement still exist and are being addressed through multiple programs • Potential case study by Peter Unmack focusing on connection of a few example species
Population dynamics		
• What are the population abundance (or relative abundance) trends for key species and case study species? • What are the assessments for the species overall and for key populations?	Basin scale (Northern and Southern Basins), river valley, river reach or locality (e.g. wetland or headwaters for rare	• Narrative (with examples) on population structures, for long- and short-lived species, and risks if structure is skewed or recruitment not occurring. Table of demographic attributes (size/age at maturity, max age,

Potential evaluation question by attribute	Spatial scale	Potential outputs
• What is the current population structure of species in recent years (define the date)? • Has the proportion of recruits/adults changed over time? • Is the proportion of adults/recruits/ subadults likely to reflect a 'healthy population over time'? Is the adult spawning stock sufficient to maintain sustainable sub-populations? • Has recruitment been occurring? • Can we follow cohort survival in populations over time – are there examples of cohorts that have been impacted (e.g. harvest, fish deaths)? (May use a case study approach.) • Has the number of sub-populations of wild stock increased, decreased or remained stable? • Are populations fragmented? Is there a narrative about how important connectivity is to each species?	species) For some species/localities– this will be case studies to illustrate particular points and hopefully indicate how additional sampling can help	fecundity, reproduction type, etc.) • Narrative (with examples) on why distribution, fragmentation and connectivity is important to populations • Tables of population changes and narrative of how crucial to species' survival these changes are • Narrative on influence of stocking and harvesting (relate this to take size limits) on populations and structure. (only for a few target species – calculate percentage impact on populations?). Similarly, translocation data/information for threatened species? • Narrative on the impacts of differences in structure and population demographics (Murray cod structure in SA; silver perch age differences; Murray crayfish harvest rates) • Narrative on detection and adequate sampling of smaller, cryptic and wetland fish – relate to recruits also? Need for specific sampling? • Narrative on use of condition factor (calculated from length and weight) but acknowledging it being a poor predictor of body condition. and that data on this is highly variable across datasets • Narrative of sampling undertaken, species included methods and interpretation of data • Narrative on the potential use of other indicators such as habitat areas, habitat loss or restoration actions (e.g. fishways) • Case study on carp as a prominent invasive species

Introduction and invitation to supply data

In August 2022 a list of key contacts across research institutions in all jurisdictions were sent an introduction to the project, which included an invitation to provide available data (reproduced below).

Introducing the 2022 Native fish status assessment

Background

The MDBA has commenced a status assessment of native fish across the Murray–Darling Basin as part of the Native Fish Recovery Strategy. Of particular interest are trends in important attributes of self-sustaining native fish populations:

- The total number of native fish species present across the Murray–Darling Basin
- The spatial distribution of each species, and whether distributions remain stable, have expanded or contracted (i.e. compared with a defined point of refence/baseline), are connected or fragmented
- The abundance and population structure of each native fish species, including recruitment at varying spatial and temporal scales
- The conservation status for each species, including endemicity (this may be at a range of spatial/management scales).

Potential evaluation questions underpinning the status assessment are summarised Table 19. These will be refined as the data available for the status assessment are confirmed.

Table 19. Potential evaluation questions on the status of native fish

Native fish attribute	Potential evaluation question	Spatial scale
Total number of species	• What is the total number of native fish species (i.e. finfish; crayfish and mussels pending sufficient data)? • Has the total number of species increased, decreased or remained stable? Why has this occurred (e.g. new discoveries or taxonomic changes)? • Has the total number of alien species increased, decreased or remained stable?	Basin scale (Northern and Southern Basins), jurisdiction, river valley, river reach or locality (e.g. wetland or headwaters for rare species).
Spatial distribution of species	• Has the distribution of species increased, decreased or remained stable? • Are species sub-populations connected or fragmented? • Can species move throughout their known range? • Is stocking or translocations occurring?	Basin scale (Northern and Southern Basins), jurisdiction, river valley, river reach or locality (e.g. wetland or headwaters for threatened species).
Species sub-population structure	• Has the number of sub-populations of wild stock increased, decreased or remained stable? • Has the number of individuals in sub-populations of wild stock changed and does this vary spatially? • Is recruitment occurring in sub-populations of wild stock at self-sustaining rates? • Is recruitment sufficient to maintain sustainable sub-populations of stocked species? • Where has stocking occurred and has this influenced population abundance and structure?	Basin scale (Northern and Southern basins), jurisdiction, river valley, river reach or locality (e.g. wetland or headwaters for rare species).
Species conservation status	• What is the current conservation status of each species or genetic management unit? • Has the number of threatened species increased, decreased or remained stable (compared with a refence point)? • Are there yet-to-be-listed species whose decline is of concern?	International, national, Basin scale, jurisdiction.

Approach

The MDBA will use available summary reports/information, expert advice and native fish data to undertake the status assessment. The project team assembled to undertake the assessment includes:

- Assoc Prof Mark Lintermans (species distribution and conservation status)

- Dr John Koehn (species population structure)
- Assoc Prof Alison King (expert review)
- Dr Wayne Robinson (analytical advice)
- Dr Shane Brooks (data management advice)
- Peter Cottingham (project manager).

While the team assembled will do the bulk of the assessment work, the assessment project will be undertaken in a collaborative way, incorporating the work and perspectives of State and Commonwealth based scientists, and other independent experts.

Information request

We are seeking reports and/or data that will help us assess the native fish evaluation framed in the table above.

Many data sets have already been provided to Assoc Prof Mark Lintermans for the new edition of the Fishes of the Murray–Darling Basin book. We are looking for post-2017 gap-filling records, particularly range extensions from the 2007 MDB fish book, records of threatened species since 2017, and records from non-stream environments (wetlands, off-channel habitats).

If you have not already supplied data directly to Mark Lintermans, but would like to do so, please contact him.

Other data sets we have in hand include all the historic SRA data and up-to-date MDB Fish Survey data, along with data to 2017 from NSW Fisheries, the Victorian Biodiversity Atlas, several Queensland, Victorian and South Australian fish sampling programs since 2000, data from several individual fish researchers, and historic Museum datasets.

Data relating to native fish population dynamics (including abundance, recruitment) at various scales would greatly assist the status assessment. The dataset used for the Basin Plan 2020 evaluation will also be available to this project.

Permissions and attribution

We will be seeking approval to utilise data for the current project via direct correspondence with those data holders who have generously shared their information. We ask for your permission to use any new data and reports you can send us for use in the 2022 Native fish status assessment. All contributors will be formally acknowledged. If there are any limitations on data use or specific attribution or data sharing arrangements that you require, please let us know so that we can accommodate them.

Timing

The project is to be conducted within a tight timeframe in order that results may be presented at the Native fish forum. The project team will contact jurisdiction staff, managers and others known to be custodians of native fish data in coming weeks. We will be seeking to confirm relevant summary reports and data that can be made available to the status assessment, as well as discuss how best to address data/information sharing and intellectual property issues. Accessing the required reports and data in a timely fashion will also be an important activity.

Contacts

For further information on the project, please contact:

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Native Fish Recovery Team Paul Anderson, Greg Ringwood, Stu Little, Lauren McLeod

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Data sourced – best available

Data sourced for this assessment is incomplete but represents that best available to the project within the scope and the response to the invitation to supply data/information. Compilation of data was undertaken by the MDBA and also Mark Lintermans (see Appendix 4).

Major data sets accessed/included were:

- Status and trends in large-bodied fish population – NSW MDB (1994–2022)
  – Crook, D., Schilling H.T., Gilligan, D., Asmus M., Boys C., Butler G., Cameron L., Hohnberg D., Michie, L., Miles N., Rayner T.S., Robinson W., Rourke M.L., Stocks J., Thiem, J.R., Townsend A., van der Meulen, D., Wooden, I. and Cheshire K. (2023). Multi-decadal trends in large-bodied fish populations in the New South Wales Murray–Darling Basin, Australia. *Marine and Freshwater Research,* 67(10):1401–1409. doi:10.1071/MF15037
- Sustainable Rivers Audit (2004–2013)
  – Murray–Darling Basin Authority (2019). Sustainable Rivers Audit. Occurrence dataset https://doi.org/10.15468/etifyb, accessed via GBIF.org on 01.01.2023
- Murray–Darling Basin Fish Survey (MDBFS) dataset (2014 to 2022)
  – Murray–Darling Basin Authority. Murray–Darling Basin Fish Monitoring Survey. Occurrence dataset https://data.gov.au/data/dataset/7826d7c9-bcc5-48c0-832a-66aaedfe7b0f accessed on 01.01.2023
- LTIM adult fish data (2014 to 2021)
  – CEWO Flow-MER (2022) Fish Adult Catch. Flow-MER Program. Commonwealth Environmental Water Office, Australian Government Department of Climate Change, Energy, the Environment and Water. Sourced from https://data.gov.au/data/dataset/flow-mer-fish-adult-catch on 01.01. 2023.

Limitations specific to the MDBFS and SRA datasets relative to the native fish status assessment

Sampling frame limitations

The SRA/MDBFS datasets only represent flowing networks with more than 25 M/L per day. Under-represented fish habitats include:

- ephemeral or perennial low-flow (e.g. stream order 1) channels
- wetlands.

There is an over-representation of higher elevation streams in both datasets. That is, the total number of sites sampled in the three coarse strata levels – upland, midland or lowland river systems – are almost identical across both datasets, but there is significantly fewer kilometres of upland streams in the MDB. Consequently:

- expertise with probability sampling is required for any analyses that includes data from different valleys or different strata within the same valley
- analyses within strata that have no sites missing at random are not affected
- integration with other research projects is possible if the sampling frame when those additional sites were selected is known.

Electrofishing only dataset limitations

Analyses for abundance, biomass or size classes using the SRA/MDBFS data should be treated as relative estimates because:

- species not well sampled by electrofishing are under-represented in the dataset (species bias)
- some size classes of fish are disproportionately sampled by electrofishing and are disproportionately represented in the dataset (size bias)
- the SRA/MDBFS protocols do not require counting of fish under 15 mm length, hence this limits the detection of early recruits and small species
- the data are from a spatial sampling design in which the sampling unit is a site; data (e.g. size classes) from any individual site cannot legitimately be 'pooled' with data from any other site(s)
- the efficacy of electrofishing sampling (detectability of individual fish) is variable through space and time (Lyon et al. 2014) and this compounds the above points.

The SRA sampling program was primarily designed to detect presence of species at the valley scale, which significantly moderates issues associated with the detection differences of individual fish:

- The within-site sampling protocol (15 shots per site) used in both datasets expects to detect the presence of a species if it is there. This was validated after SRA implementation and 174 of 180 sites in the first round of the SRA in 2005 had complete species lists (Robinson et al. 2019).

- There were at least seven sites per strata in the SRA dataset, and the analysis showed that there is less than a 5% chance of a species not being detected at least once in seven sites of a strata. Ubiquitous species were never missed at the strata scale (*n* = 24) in 2005.
- There is less than 0.013% (1 in 8 000) chance that a species is present in a valley and not detected in the valley (minimum of 20 sites per valley in the SRA) (Robinson et al. 2019).
- With the change to only two sites per strata (six per valley) in the MDBFS, these rules are slightly compromised. However, as the first round of the SRA in 2005 found that five sites per strata returned species lists within 10% of the final list in most strata, the effect may not be severe at the valley scale.

Given the known relationship between abundance and detection probability at any site (e.g. McCarthy et al. 2013), there is practically no chance that any abundant or ubiquitous riverine species that occurs in any of the 23 valleys and was not detected there by the SRA. Further, the abundance and detection relationship implies that using proportion of river kilometres that a species is detected in through time is a reasonable alternative measure of population relative abundance through time. Nevertheless, all analyses should be treated as relevant only to fish detected by electrofishing. There are no statements made about fish species that were not detected by electrofishing.

Appendix 2 – Native fish species of the Murray–Darling Basin

The native fish species list presented in Table 2 (Chapter 3) has been reorganised into three tables, Table 20 to Table 22, based on common names, the relative sizes of adults and an indication of where they predominantly occur in the MDB. Important crayfish and freshwater mussel species are listed in Table 23 and Table 24.

Each individual First Nations language group (40+ languages) across the Basin has specific names for many of these species. Not all species will have a First Nation language name, as some species may not be a resource or culturally significant, whereas others have roles as totems, spirits, Dreaming figures, part of songs or dances, place/river/aquifer/wetland creation, an indicator for seasons or water quality, a food source, or just noted as being part of the environment and local ecology.

Over time this appendix will be built on in a program led by First Nation peoples to collate traditional language across the Basin. This appendix will evolve into a document that shares traditional language, while maintaining the intellectual property rights of First Nations peoples.

Table 20. Small sized native fish species

Common name	*Scientific name*	Occurrence	Environmental zone
Australian smelt	*Retropinna semoni*	Basin-wide	Slopes Lowlands
Barred galaxias	*Galaxias fuscus*	Southern Basin	Montane
Bald carp gudgeon (formerly Midgley's carp gudgeon)	*Hypseleotris gymnocephala*	Southern Basin	Montane
Boofhead carp gudgeon (formerly Midgley's carp gudgeon)	*Hypseleotris bucephala*	Basin-wide	Lowlands Slopes
Carp gudgeon species complex (including western carp gudgeon, Lake's gudgeon)	*Hypseleotris* spp.	Basin-wide	Slopes Lowlands
Cryptic carp gudgeon (formerly Murray–Darling carp gudgeon)	*Hypseleotris acropinna*	Basin-wide	Lowlands Slopes
Climbing galaxias	*Galaxias brevipinnis*	Southern Basin	Slopes Lowlands
Common galaxias	*Galaxias maculatus*	Southern Basin – diadromous	Estuaries Lowlands
Congolli	*Pseudaphritis urvillii*	Southern Basin –	Estuaries Lowlands

Common name	*Scientific name*	Occurrence	Environmental zone
		diadromous	
Darling hardyhead (MDB population)	*Craterocephalus amniculus*	Northern Basin	Slopes
Desert rainbowfish	*Melanotaenia splendida tatei*	Northern Basin	Lowlands
Dwarf flathead gudgeon	*Philypnodon macrostomus*	Basin-wide	Slopes Lowlands
Flathead galaxias	*Galaxias rostratus*	Southern Basin	Slopes Lowlands
Flathead gudgeon	*Philypnodon grandiceps*	Basin-wide	Slopes Lowlands
Lagoon goby, Scary's Tasman goby	*Tasmanogobius lasti*	Southern Basin – estuarine	Estuaries
Mountain galaxias	*Galaxias olidus*	Basin-wide	Montane Uplands Slopes Lowlands
Murray–Darling rainbowfish	*Melanotaenia fluviatilis*	Basin-wide	Lowlands
Murray hardyhead	*Craterocephalus fluviatilis*	Southern Basin	Lowlands
Obscure galaxias	*Galaxias oliros*	Southern Basin	Montane Uplands Slopes
Olive perchlet (MDB population)	*Ambassis agassizii*	Basin-wide	Lowlands
Ornate galaxias	*Galaxias ornatus*	Southern Basin	Uplands Slopes
Rendahl's tandan	*Porochilus rendahli*	Northern Basin	Headwaters
Riffle galaxias	*Galaxias arcanus*	Southern Basin	Uplands Slopes
Sandy sprat	*Hyperlophus vittat*	Southern Basin –	Estuaries

Common name	*Scientific name*	Occurrence	Environmental zone
		estuarine	
Small-mouthed hardyhead	*Atherinosoma microstoma*	Southern Basin – estuarine	Estuaries
Spotted galaxias	*Galaxias truttaceus*	Southern Basin	Slopes
Southern purple-spotted gudgeon (MDB population)	*Mogurnda adspersa*	Basin-wide	Uplands Slopes Lowlands
Southern pygmy perch (MDB lineage)	*Nannoperca australis*	Southern Basin	Uplands Slopes Lowlands
Stocky galaxias	*Galaxias tantangara*	Southern Basin	Montane
Tamar goby	*Afurcagobius tamarensis*	Southern Basin – estuarine	Estuaries
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	Basin-wide	Slopes Lowlands
Western blue-spot goby	*Pseudogobius olorum*	Southern Basin – estuarine	Estuaries
Western carp gudgeon	*Hypseleotris klunzingeri*	Basin-wide	Slopes Lowlands
Yarra pygmy perch (MDB population)	*Nannoperca obscura*	Southern Basin	Lowlands

Table 20. Medium-sized native species

Common name	Scientific name	Occurrence	Environmental zone
Bony herring Also known as bony bream	*Nematalosa erebi*	Basin-wide	Lowlands
Greenback flounder	*Rhombosolea tapirina*	Southern Basin – estuarine	Estuaries
Hyrtl's tandan	*Neosilurus hyrtlii*	Northern Basin	Headwaters Slopes Lowlands
Pouched lamprey	*Geotria australis*	Southern Basin – diadromous	Estuaries Lowlands
Northern river blackfish	*Gadopsis marmorata*	Basin-wide	Uplands Slopes Lowlands
Few-spined river blackfish	*Gadopsis* sp. *nov 'Wimmera'*	Southern Basin	
Short-headed lamprey	*Mordacia mordax*	Southern Basin – diadromous	Estuaries Lowlands Inshore
Silver tandan	*Porochilu argenteus*	Northern basin	Lowland
Spangled perch	*Leiopotherapon unicolor*	Northern Basin	Slopes Lowlands Headwaters
Two-spined blackfish	*Gadopsis bispinosa*	Southern Basin	Montane Uplands
Yellow-eyed mullet	*Aldrichetta forsteri*	Southern Basin – estuarine	Estuaries

Table 21. Large sized native species

Common name	Scientific name	Occurrence	Environmental zone
Black bream	*Acanthopagrus butcheri*	Southern Basin – estuarine	Estuaries
Estuary perch	*Macquaria colonorum*	Southern Basin – estuarine	Estuaries
Freshwater catfish (MDB population)	*Tandanus tandanus*	Basin-wide	Slopes Lowlands
Golden perch	*Macquaria ambigua*	Basin-wide	Slopes Lowlands
Jewfish, mulloway	*Argyrosomus japonicus*	Southern Basin – estuarine	Estuaries Inshore
Long-finned eel	*Anguilla reinhardtii*	Basin-wide	Lowlands Estuaries
Macquarie perch	*Macquaria australasica*	Southern Basin	Montane Upland Slopes Lowlands
Murray cod	*Maccullochella peelii*	Basin-wide	Uplands Slopes Lowlands
Silver perch	*Bidyanus bidyanus*	Basin-wide	Uplands Slopes Lowlands
Short-finned eel	*Anguilla australis*	Southern Basin	Lowlands Slopes Estuaries
Trout cod	*Maccullochella macquariensis*	Southern Basin	Montane Upland Slopes Lowlands

Table 22. Spiny crayfish

Common name Scientific name	Occurrence	Environmental zone	Conservation status
Alpine spiny crayfish *Euastacus crassus*	Southern Basin	Montane	Vic: Endangered ACT: Protected
Central highland spiny crayfish *Euastacus woiwuru*	Southern Basin	Southern Montane Slopes	
Clayton's crayfish *Euastacus claytoni*	Southern Basin	Montane	
Cudgegong giant spiny crayfish *Euastacus vespar*	Northern Basin	Montane	
Gamilaroi crayfish *Euastacus gamilaroi*	Northern Basin	Montane	
Jagara hairy crayfish *Euastacus jagara*	Northern Basin	Montane	Qld: Critically Endangered
Mountain crayfish *Euastacus sulcatus*	Northern Basin	Montane	Qld: Protected
Murray crayfish *Euastacus armatus*	Southern Basin	Montane Slopes	NSW: Vulnerable Vic: Threatened SA: Protected ACT: Vulnerable
Riek's crayfish *Euastacus rieki*	Southern Basin	Montane	ACT: Protected
Simple crayfish *Euastacus simplex*	Northern Basin	Montane	
Small crayfish *Euastacus spinichelatus*	Northern Basin	Montane	
Sutton's crayfish *Euastacus suttoni*	Northern Basin	Slopes Montane	Qld: Protected
Terrestrial crayfish *Euastacus maccai*	Northern Basin	Montane	

Table 23. Freshwater mussels

Common name Scientific name	Occurrence	Environmental zone	Conservation status
Freshwater mussel *Alathyria condola*	Mostly Southern Basin, but occurs in Macquarie as well as Lachlan and Murrumbidgee	Uplands, Lowlands	
River mussel *Alathyria jacksoni*	Basin-wide	Uplands, Lowlands	Qld: Regulated (possession limit of 30)
Purple nacre mussel *Alathyria pertexta pertexta*	Northern Basin	Uplands, headwaters	Qld: Regulated (possession limit of 30)
Billabong mussel *Velesunio ambiguus*	Basin-wide	Uplands, Lowlands	Qld: Regulated (possession limit of 30)
Wilson's mussel *Velesunio wilsonii*	Northern Basin	Uplands, Lowlands	Qld: Regulated (possession limit of 30)

Appendix 3 – Species records pre- and post-2010

Table 25. Species presence at Basin scale for each time period

Taxon	1980–2010	Post-2010	Taxon	1980–2010	Post-2010
Tamar River goby	✓	✓	Western carp gudgeon	✓	✓
Olive perchlet	✓	✓	unidentified carp gudgeons	✓	✓
Short-finned eel	✓	✓	Spangled perch	✓	✓
Long-finned eel	✓	✓	Trout cod	✓	✓
Small-mouthed hardyhead	✓	✓	Murray cod	✓	✓
Silver perch	✓	✓	Golden perch	✓	✓
Darling River hardyhead	✓	✓	Macquarie perch	✓	✓
Murray hardyhead	✓	✓	Estuary perch	✓	X
Unspecked hardyhead	✓	✓	Murray–Darling rainbowfish	✓	✓
Two-spined blackfish	✓	✓	Desert rainbowfish	✓	✓
River blackfish	✓	✓	Southern purple-spotted gudgeon	✓	✓
Riffle galaxias	✓	✓	Short-headed lamprey	✓	✓
Climbing galaxias	✓	✓	Southern pygmy perch	✓	✓
Barred galaxias	✓	✓	Yarra pygmy perch	✓	✓
Common galaxias	✓	✓	Bony herring	✓	✓
Mountain galaxias	✓	✓	Hyrtl's tandan	✓	✓
Obscure galaxias	✓	✓	Flathead gudgeon	✓	✓
Ornate galaxias	✓	X	Dwarf flathead gudgeon	✓	✓
Flat-headed galaxias	✓	✓	Silver catfish	X	✓
Tantangara galaxias	✓	✓	Rendahl's tandan	✓	✓
Spotted galaxias	✓	✓	Congolli	✓	✓
Pouched lamprey	✓	✓	Blue-spot goby	✓	✓
Cryptic carp gudgeon	✓	✓	Australian smelt	✓	✓
Boofhead carp gudgeon	✓	✓	Freshwater catfish	✓	✓
Bald carp gudgeon	x	✓	Lagoon goby	✓	✓

Table 26. Species presence at the scale of the Northern and Southern Basins for each time period

Northern Basin			Southern Basin		
Taxon	1980–2010	Post-2010	Taxon	1980–2010	Post-2010
Olive perchlet	✓	✓	Tamar River goby	✓	✓
Short-finned eel	X	X	Olive perchlet	✓	✓
Long-finned eel	✓	✓	Short-finned eel	✓	✓
Silver perch	✓	✓	Long-finned eel	X	✓
Darling River hardyhead	✓	✓	Small-mouthed hardyhead	✓	✓
Unspecked hardyhead	✓	✓	Silver perch	✓	✓
River blackfish	✓	✓	Murray hardyhead	✓	✓
Mountain galaxias	✓	✓	Unspecked hardyhead	✓	✓
Flat-headed galaxias	X	X	Two-spined blackfish	✓	✓
Cryptic carp gudgeon	✓	✓	River blackfish	✓	✓
Boofhead carp gudgeon	✓	✓	Riffle galaxias	✓	✓
Western carp gudgeon	✓	✓	Climbing galaxias	✓	✓
unidentified carp gudgeons	✓	✓	Barred galaxias	✓	✓
Spangled perch	✓	✓	Common galaxias	✓	✓
Trout cod	✓	✓	Mountain galaxias	✓	✓
Murray cod	✓	✓	Obscure galaxias	✓	✓
Golden perch	✓	✓	Ornate galaxias	✓	X
Macquarie perch	X	✓	Flat-headed galaxias	✓	✓
Murray–Darling rainbowfish	✓	✓	Tantangara galaxias	✓	✓
Desert rainbowfish	✓	✓	Spotted galaxias	✓	✓
Southern purple-spotted gudgeon	✓	✓	Pouched lamprey	✓	✓
Southern pygmy perch	X	✓	Cryptic carp gudgeon	✓	✓
Bony herring	✓	✓	Boofhead carp gudgeon	✓	✓
Hyrtl's tandan	✓	✓	Bald carp gudgeon	X	✓

Northern Basin			Southern Basin		
Taxon	1980–2010	Post-2010	Taxon	1980–2010	Post-2010
Flathead gudgeon	✓	✓	Western carp gudgeon	✓	✓
Dwarf flathead gudgeon	✓	✓	unidentified carp gudgeons	✓	✓
Rendahl's tandan	✓	✓	Spangled perch	✓	✓
Australian smelt	✓	✓	Trout cod	✓	✓
Freshwater catfish	✓	✓	Murray cod	✓	✓
			Golden perch	✓	✓
			Macquarie perch	✓	✓
			Estuary perch	✓	X
			Murray–Darling rainbowfish	✓	✓
			Southern purple-spotted gudgeon	✓	✓
			Short-headed lamprey	✓	✓
			Southern pygmy perch	✓	✓
			Yarra pygmy perch	✓	✓
			Bony herring	✓	✓
			Flathead gudgeon	✓	✓
			Dwarf flathead gudgeon	✓	✓
			Congolli	✓	✓
			Blue-spot goby	✓	✓
			Australian smelt	✓	✓
			Freshwater catfish	✓	✓
			Lagoon goby	✓	✓

Species distribution/count records by valley pre- and post-2010

The following series of tables presents the species distribution (count of records) of each native species occurring in each valley across time periods from the combined dataset. Red text indicates losses of taxa since 2010; blue text indicates gains. Green shading indicates present in both 1980–2010 and post-2010 time periods; Unshaded indicates only records from pre-2010 exist; Pale yellow shading indicates the species was excluded from the assessment. Loss? indicates that the absence post-2010 may be a loss, but it is such a rare species that it is unknown whether it is a true loss or just a sampling failure to record it.

Northern Basin

Table 27. Border Rivers

Basin	Valley	1980–2010	Post-2010	Net change
Northern Basin	Border Rivers	19	15	−4

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	73	59	2020	
Bidyanus bidyanus	40	34	2019	
Craterocephalus amniculus	122	31	2020	
Craterocephalus stercusmuscarum fulvus	138	255	2022	
Gadopsis marmorata	14	na	2006	Also not recorded since 2010 in SRA/MDBFS
Galaxias olidus	94	na	2008	Also not recorded since 2010 in SRA/MDBFS
Hypseleotris acropinna	1	5	2016	Newly described species; old record counts not an accurate reflection
Hypseleotris bucephala	1	5	2016	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	1	4	2016	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative

Hypseleotris spp.	1 417	805	2022	Deleted from assessment
Leiopotherapon unicolor	157	214	2022	
Maccullochella peelii	326	1 038	2022	
Macquaria ambigua	358	426	2022	
Melanotaenia fluviatilis	340	407	2022	
Mogurnda adspersa	99	23	2020	
Nematalosa erebi	985	841	2022	
Philypnodon grandiceps	1	na	2006	Also not recorded since 2010 in SRA/MDBFS
Philypnodon macrostomus	3	na	2006	Also not recorded since 2010 in SRA/MDBFS
Retropinna semoni	191	176	2022	
Tandanus tandanus	425	277	2022	

na = not applicable

Table 28. Castlereagh

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Castlereagh	7	9	+2

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Gadopsis marmorata	3		2001	Also not recorded since 2010 in SRA/MDBFS
Galaxias olidux	8		2008	Also not recorded since 2010 in SRA/MDBFS
Hypseleotris acropinna	na	1	2014	Newly described species; old record counts not an accurate reflection
Hypseleotris bucephala	na	2	2014	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	103	319	2022	Deleted from assessment
Leiopotherapon unicolor	36	29	2022	
Macquaria ambigua	7	52	2022	
Mogurnda adspersa	na	2	2013	Addition, also not recorded 1980–2010 in SRA/MDBFS
Nematalosa erebi	35	115	2022	
Retropinna semoni	49	58	2022	
Tandanus tandanus	4	4	2022	

na = not applicable

Table 29. Condamine

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Condamine	17	18	0

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	132	17	2022	
Anguilla reinhardtii	5	na	2009	Loss?, rare, never recorded in either time slice by SRA/MDBFS
Bidyanus bidyanus	14	16	2022	
Craterocephalus stercusmuscarum fulvus	21	12	2022	
Gadopsis marmorata	6	39	2013	
Hypseleotris acropinna	na	8	2015	Newly described species; old record counts not an accurate reflection
Hypseleotris bucephala	1	6	2015	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	1	5	2014	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	519	143	2022	Deleted from assessment
Leiopotherapon unicolor	542	217	2022	
Maccullochella peelii	76	43	2021	
Macquaria ambigua	881	338	2022	
Melanotaenia fluviatilis	215	39	2022	
Mogurnda adspersa	19	3	2013	
Nematalosa erebi	789	397	2022	

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Neosilurus hyrtlii	57	73	2022	
Philypnodon macrostomus	89	5	2020	
Porochilus rendahli	11	11	2022	
Retropinna semoni	214	70	2022	
Tandanus tandanus	166	50	2022	

na = not applicable

Table 30. Darling (northern)

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Darling	13	14	+1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	1	7	2021	
Bidyanus bidyanus	26	5	2018	
Craterocephalus stercusmuscarum fulvus	15	na	2007	May be present after 2010; some discrepancies between datasets
Hypseleotris bucephala	na	3	2014	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	104	237	2021	Deleted from assessment
Leiopotherapon unicolor	133	138	2022	
Maccullochella peelii	203	41	2020	
Macquaria ambigua	333	402	2022	

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Melanotaenia fluviatilis	50	124	2022	
Melanotaenia splendida tatei	6	1	2011	Post-2010 records not representative of abundance
Nematalosa erebi	748	1 007	2022	
Neosilurus hyrtlii	6	5	2011	
Philypnodon macrostomus	1	na	2004	Loss, also not recorded since 2010 in SRA/MDBFS
Retropinna semoni	59	25	2021	
Tandanus tandanus	1	na	2002	May be present after 2010; some discrepancies between datasets

na = not applicable

Table 31. Gwydir

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Gwydir	13	16	+3

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	na	2	2017	Addition, also not recorded 1980–2010 in SRA/MDBFS
Bidyanus bidyanus	12	1	2016	
Craterocephalus amniculus	8	5	2019	
Craterocephalus stercusmuscarum fulvus	80	373	2022	
Gadopsis marmorata	171	9	2017	
Galaxias olidus	92	27	2022	
Hypseleotris bucephala	na	8	2016	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	322	1 238	2022	Deleted from assessment
Leiopotherapon unicolor	134	549	2022	
Maccullochella peelii	193	633	2022	
Macquaria ambigua	132	239	2022	
Melanotaenia fluviatilis	166	1 162	2022	
Mogurnda adspersa	8	13	2020	
Nematalosa erebi	242	1 221	2022	
Retropinna semoni	105	423	2022	
Tandanus tandanus	174	170	2022	

na = not applicable

Table 32. Macquarie

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Macquarie	19	21	+2

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	12	19	2020	
Anguilla reinhardtii	na	4	2022	Addition, also not recorded 1980–2010 in SRA/MDBFS
Bidyanus bidyanus	9	12	2018	
Craterocephalus stercusmuscarum fulvus	36	262	2022	
Gadopsis marmorata	25	3	2020	
Galaxias olidus	79	82	2022	
Hypseleotris acropinna	2	1	2014	Newly described species; old record counts not an accurate reflection
Hypseleotris bucephala	2	3	2016	Newly described species; old record counts not an accurate reflection
Hypseleotris klunzingeri	3	1	2014	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	307	692	2022	
Leiopotherapon unicolor	54	144	2022	
Maccullochella macquariensis	4	5	2016	
Maccullochella peelii	86	474	2022	
Macquaria ambigua	133	454	2022	
Macquaria australasica	na	2	2021	Addition, stocked/translocated individuals
Melanotaenia fluviatilis	67	257	2021	

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Mogurnda adspersa	2	na	2005	Also not recorded since 2010 in SRA/MDBFS
Nematalosa erebi	165	439	2022	
Neosilurus hyrtlii	na	4	2017	Addition, also not recorded 1980–2010 in SRA/MDBFS
Philypnodon grandiceps	54	269	2022	
Philypnodon macrostomus	3	3	2017	
Retropinna semoni	156	365	2022	
Tandanus tandanus	103	85	2020	

na = not applicable

Table 33. Namoi

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Namoi	12	14	+2

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Bidyanus bidyanus	24	6	2019	
Craterocephalus amniculus	14	7	2020	
Craterocephalus stercusmuscarum fulvus	59	41	2022	
Gadopsis marmorata	72	32	2019	
Galaxias olidus	32	7	2017	
Hypseleotris bucephala	na	4	2016	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	308	276	2022	Deleted from assessment
Leiopotherapon unicolor	91	111	2022	
Maccullochella peelii	180	296	2022	
Macquaria ambigua	209	126	2022	
Melanotaenia fluviatilis	161	71	2022	
Nematalosa erebi	257	270	2022	
Retropinna semoni	146	57	2022	
Tandanus tandanus	88	75	2022	

na = not applicable

Table 34. Paroo

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Paroo	11	7	−4

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	1	na	2005	Also not recorded since 2010 in SRA/MDBFS
Bidyanus bidyanus	16	8	2017	
Hypseleotris klunzingeri	1	na	1999	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	39	20	2022	Deleted from assessment
Leiopotherapon unicolor	155	130	2022	
Maccullochella peelii	1	na	2003	Loss
Macquaria ambigua	273	175	2022	
Melanotaenia splendida tatei	88	101	2022	
Nematalosa erebi	263	274	2022	
Neosilurus hyrtlii	69	202	2022	
Retropinna semoni	56	2	2017	
Tandanus tandanus	1	na	2001	Loss

na = not applicable

Table 35. Warrego

	Valley	1980–2010	Post-2010	Net change
Northern Basin	Warrego	13	12	−1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	8	na	2005	Loss, also not recorded since 2010 in SRA/MDBFS
Bidyanus bidyanus	26	3	2022	
Hypseleotris bucephala	1	1	2015	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	4	2	2015	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	129	193	2022	Deleted from assessment
Leiopotherapon unicolor	218	210	2022	
Maccullochella peelii	11	11	2020	
Macquaria ambigua	541	441	2022	
Melanotaenia splendida tatei	138	109	2022	
Nematalosa erebi	385	754	2022	
Neosilurus hyrtlii	39	243	2022	
Philypnodon macrostomus	1	na	2004	Rare, also not recorded since 2010 in SRA/MDBFS
Porochilus rendahli	na	1	2018	Addition
Retropinna semoni	115	84	2022	
Tandanus tandanus	77	15	2022	

na = not applicable

Southern Basin

Table 36. Avoca

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Avoca	13	8	−5

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Anguilla australis	1	na	2005	Rare, likely translocation since 2010
Craterocephalus fluviatilis	2	na	2005	Loss
Craterocephalus stercusmuscarum fulvus	1	na	1989	Rare
Gadopsis marmorata	79	9	2017	
Galaxias oliros	33	62	2021	
Galaxias rostratus	3	na	1989	Loss
Maccullochella peelii	2	7	2020	
Macquaria ambigua	30	4	2021	
Melanotaenia fluviatilis	1	na	1989	Rare
Nannoperca australis	8	1	2011	
Philypnodon grandiceps	53	92	2021	
Retropinna semoni	26	20	2020	
Tandanus tandanus	1	2	2014	

na = not applicable

Table 37. Broken

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Broken	20	16	−4

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Bidyanus bidyanus	8	10	2016	
Craterocephalus stercusmuscarum fulvus	5	5	2012	
Gadopsis bispinosus	675	2	2021	
Gadopsis marmorata	4 076	10	2021	
Galaxias arcanus	1		2004	Rare
Galaxias brevipinnis	9	2	2014	
Galaxias olidus	92	4	2015	
Galaxias oliros	14	42	2021	
Galaxias rostratus	6		1990	Loss
Hypseleotris acropinna	na	2	2015	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	202	25	2020	Deleted from assessment
Maccullochella macquariensis	137	na	2005	Not recorded since 2010 in SRA/MDBFS
Maccullochella peelii	219	47	2020	
Macquaria ambigua	1 528	41	2021	
Macquaria australasica	225	1	2017	
Melanotaenia fluviatilis	238	26	2021	
Nannoperca australis	449	1	2011	

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Nematalosa erebi	2	na	1993	Rare, also not recorded since 2010 in SRA/MDBFS
Philypnodon grandiceps	26	1	2011	
Philypnodon macrostomus	2	na	2007	Rare, also not recorded since 2010 in SRA/MDBFS
Retropinna semoni	414	35	2021	
Tandanus tandanus	5	na	1993	Loss, not recorded since 2010 in SRA/MDBFS

na = not applicable

Table 38. Campaspe

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Campaspe	14	11	−3

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Bidyanus bidyanus	4	na	2000	Loss? also not recorded since 2010 in SRA/MDBFS
Gadopsis marmorata	3	na	1981	Loss? also not recorded since 2010 in SRA/MDBFS
Galaxias maculatus	6	1	2012	
Galaxias olidus	33	7	2019	
Galaxias oliros	22	40	2021	
Galaxias rostratus	2	na	1997	Loss
Galaxias truttaceus	11	1	2012	
Hypseleotris bucephala		1	2013	Newly described species; record counts not an accurate reflection
Hypseleotris spp.	27	12	2021	Deleted from assessment
Maccullochella peelii	58	9	2021	
Macquaria ambigua	539	21	2021	
Macquaria australasica	56	na	1999	Loss
Melanotaenia fluviatilis		395	2021	Addition, also not recorded 1980–2010 in SRA/MDBFS
Nannoperca australis	17	16	2019	
Nematalosa erebi	8	na	2000	Loss
Philypnodon grandiceps	1 334	18	2019	
Retropinna semoni	444	23	2021	

na = not applicable

Table 39. Central Murray

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Central Murray	19	24	+5

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Bidyanus bidyanus	868	426	2022	
Craterocephalus fluviatilis	na	2	2014	Addition
Craterocephalus stercusmuscarum fulvus	1 011	1 176	2022	
Gadopsis marmorata	39	35	2020	
Galaxias arcanus	na	1	2011	Addition
Galaxias brevipinnis	6	2	2015	
Galaxias olidus	2	5	2017	
Galaxias oliros	na	1	2011	Addition
Galaxias rostratus	13	4	2012	
Geotria australis	na	2	2021	Addition
Hypseleotris acropinna	na	2	2017	Newly described species; record counts not an accurate reflection
Hypseleotris bucephala	na	2	2014	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	4	1	2017	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	1 799	2 515	2022	Deleted from assessment
Leiopotherapon unicolor	na	9	2011	Addition
Maccullochella macquariensis	1 260	626	2022	
Maccullochella peelii	1 780	1 728	2022	
Macquaria ambigua	1 725	1 671	2022	

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Melanotaenia fluviatilis	441	1 533	2022	
Mordacia mordax	14	na	1996	Loss
Nannoperca australis	59	41	2015	
Nematalosa erebi	791	929	2022	
Philypnodon grandiceps	524	328	2021	
Philypnodon macrostomus	47	31	2019	
Pseudaphritis urvillii	1	na	1991	Rare
Retropinna semoni	2 216	2 271	2022	
Tandanus tandanus	27	25	2019	

na = not applicable

Table 40. Goulburn

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Goulburn	23	22	–1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Anguilla australis	33	na	2004	1980–2010 records escapees from aquaculture
Bidyanus bidyanus	12	57	2021	
Craterocephalus stercusmuscarum fulvus	2	1	2021	
Gadopsis bispinosus	3 925	42	2021	
Gadopsis marmorata	633	7	2019	
Galaxias arcanus	32	17	2021	
Galaxias brevipinnis	2	na	2005	Rare
Galaxias fuscus	363	2	2012	
Galaxias olidus	370	5	2016	
Galaxias oliros	9	90	2021	
Galaxias ornatus	3	na	2002	
Galaxias rostratus	39	4	2016	
Hypseleotris acropinna	na	3	2015	Newly described species; record counts not an accurate reflection
Hypseleotris bucephala	na	2	2013	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	125	383	2021	Deleted from assessment

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Maccullochella macquariensis	239	17	2021	
Maccullochella peelii	141	393	2021	
Macquaria ambigua	594	252	2021	
Macquaria australasica	608	3	2016	
Melanotaenia fluviatilis	70	318	2021	
Nannoperca australis	213	450	2021	
Nematalosa erebi	6	17	2018	
Philypnodon grandiceps	176	10	2021	
Philypnodon macrostomus	3	na	1990	Rare
Retropinna semoni	250	580	2021	
Tandanus tandanus	25	1	2016	

na = not applicable

Table 41. Kiewa

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Kiewa	13	12	−1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Gadopsis bispinosus	513	55	2022	
Gadopsis marmorata	41	44	2022	
Galaxias arcanus	9	23	2022	
Galaxias brevipinnis	10	1	2012	
Galaxias olidus	55	1	2016	
Galaxias oliros	11	21	2022	
Galaxias rostratus	4		2002	Loss
Hypseleotris klunzingeri	na	1	2015	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	12	9	2021	Deleted from assessment
Maccullochella macquariensis	2	6	2020	
Maccullochella peelii	26	11	2021	
Macquaria ambigua	10		2006	Loss?
Nannoperca australis	13	2	2012	
Philypnodon grandiceps	2	4	2015	
Retropinna semoni	15	17	2022	

na = not applicable

Table 42. Lachlan

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Lachlan	16	16	0

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	2	3	2012	Limited off-channel sampling
Bidyanus bidyanus	38	26	2022	
Craterocephalus stercusmuscarum fulvus	20	61	2021	
Gadopsis marmorata	77	2	2013	
Galaxias olidus	122	191	2021	
Hypseleotris bucephala	na	2	2016	Newly described species; record counts not an accurate reflection
Hypseleotris gymnocephala	1	23	2019	Newly described species; record counts not an accurate reflection, all since 2010 records from targeted sampling of two sites
Hypseleotris klunzingeri	na	2	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	407	724	2022	Deleted from assessment
Maccullochella peelii	107	684	2022	
Macquaria ambigua	165	843	2022	
Macquaria australasica	101	36	2017	
Melanotaenia fluviatilis	3		2009	Loss?, also not recorded since

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
				2010 in SRA/MDBFS
Nannoperca australis	81	23	2021	
Nematalosa erebi	138	2 235	2022	
Philypnodon grandiceps	198	161	2021	
Philypnodon macrostomus	2	na	2000	Rare
Retropinna semoni	246	399	2022	
Tandanus tandanus	14	19	2018	

na = not applicable

Table 43. Loddon

	Valley	1980 – 2010	Post-2010	Net change
Southern Basin	Loddon	19	15	−4

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Bidyanus bidyanus	41	5	2021	
Craterocephalus fluviatilis	4	na	2002	Loss
Craterocephalus stercusmuscarum fulvus	23	18	2021	
Gadopsis marmorata	168	23	2021	
Galaxias maculatus	2	na	1980	Rare
Galaxias olidus	19	na	2004	Old records possibly misidentifications of *G. oliros*
Galaxias oliros	83	17	2021	
Galaxias rostratus	1	na	1989	Not recorded since 2010 in SRA/MDBFS
Galaxias truttaceus	2	na	1990	Not recorded since 2010 in SRA/MDBFS
Hypseleotris bucephala	na	1	2013	Newly described species; record counts not an accurate reflection, all since 2010 records from targeted sampling of two sites
Hypseleotris klunzingeri	1	2	2014	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	60	86	2020	Deleted from assessment

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Maccullochella peelii	48	20	2021	
Macquaria ambigua	373	42	2021	
Macquaria australasica	7	1	2015	Rare
Melanotaenia fluviatilis	86	81	2021	
Mogurnda adspersa	na	7	2020	Addition, translocated
Nematalosa erebi	121	2	2014	
Philypnodon grandiceps	149	58	2021	
Philypnodon macrostomus	2	1	2014	
Retropinna semoni	237	36	2021	
Tandanus tandanus	48	na	2007	Loss, also not recorded since 2010 in SRA/MDBFS

na = not applicable

Table 44. Lower Darling

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Lower Darling	12	15	+3

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Ambassis agassizii	na	1	2022	Addition
Bidyanus bidyanus	17	16	2022	
Craterocephalus stercusmuscarum fulvus	26	23	2017	
Hypseleotris bucephala	na	1	2013	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	443	262	2021	Deleted from assessment
Leiopotherapon unicolor	18	49	2022	
Maccullochella peelii	143	77	2022	
Macquaria ambigua	280	287	2022	
Melanotaenia fluviatilis	43	35	2021	
Nannoperca australis	na	1	2011	Addition, rare
Nematalosa erebi	1 178	762	2022	
Neosilurus hyrtlii	2	1	2022	Rare, flood displacement
Philypnodon grandiceps	26	14	2018	
Philypnodon macrostomus	1		2010	Rare
Retropinna semoni	287	139	2022	
Tandanus tandanus	19	10	2012	

na = not applicable

Table 45. Lower Murray

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Lower Murray	32	31	−1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Afurcagobius tamarensis	98	96	2022	
Ambassis agassizii	3	1	2022	Rare, flood displacement
Anguilla australis	5	1	2016	Rare
Atherinosoma microstoma	229	214	2022	
Bidyanus bidyanus	300	83	2021	
Craterocephalus fluviatilis	198	219	2022	
Craterocephalus stercusmuscarum fulvus	1 491	1 555	2022	
Gadopsis marmorata	48	2	2011	
Galaxias brevipinnis	na	2	2018	Addition, rare, Mount Lofty Ranges
Galaxias maculatus	317	1 489	2022	
Galaxias olidus	17	11	2017	
Galaxias oliros	5	1	2017	
Galaxias truttaceus	4	na	2002	Rare, also not recorded since 2010 in SRA/MDBFS
Geotria australis	5	40	2021	
Hypseleotris acropinna	10	3	2017	Newly described species; record counts not an accurate reflection
Hypseleotris bucephala	11	3	2017	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	8	2	2014	Split out of *Hypseleotris* spp. (only genetically

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
				verified records included) so counts not representative
Hypseleotris spp.	1353	1340	2022	Deleted from assessment
Leiopotherapon unicolor	na	26	2013	Addition, flood displacement
Maccullochella peelii	343	218	2022	
Macquaria ambigua	2 290	1 159	2022	
Macquaria colonorum	2	na	2004	Rare
Melanotaenia fluviatilis	956	649	2022	
Mogurnda adspersa	20	na	2003	Database deficiency, new translocation since 2010
Mordacia mordax	10	10	2021	
Nannoperca australis	288	266	2022	
Nannoperca obscura	23	7	2014	
Nematalosa erebi	4 796	4 160	2022	
Philypnodon grandiceps	1 147	1 766	2022	
Philypnodon macrostomus	240	670	2022	
Pseudaphritis urvillii	61	835	2022	
Pseudogobius olorum	210	362	2022	
Retropinna semoni	2 167	1 000	2022	
Tandanus tandanus	107	82	2022	
Tasmanogobius lasti	112	215	2022	

na = not applicable

Table 46. Mitta Mitta

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Mitta Mitta	16	13	−3

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Gadopsis bispinosus	561	72	2022	
Gadopsis marmorata	96	14	2022	
Galaxias arcanus	12	1	2011	
Galaxias brevipinnis	42	1	2011	
Galaxias maculatus	1	4	2019	
Galaxias olidus	79	12	2017	
Galaxias oliros	4	6	2022	
Galaxias rostratus	8	na	2002	
Hypseleotris bucephala	1	na	2009	Newly described species; record counts not an accurate reflection
Hypseleotris spp.	11	2	2016	Deleted from assessment
Maccullochella macquariensis	19	na	2000	Rare
Maccullochella peelii	10	9	2022	
Macquaria ambigua	15	2	2018	
Macquaria australasica	1 153	8	2019	
Nannoperca australis	41	1	2011	Rare since 2010
Philypnodon grandiceps	104	3	2016	
Retropinna semoni	14	13	2022	

na = not applicable

Table 47. Murrumbidgee

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Murrumbidgee	24	19	−5

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Anguilla australis	2		1990	1980–2010 records are translocations
Anguilla reinhardtii	1		2010	1980–2010 records are translocations
Bidyanus bidyanus	30	61	2021	
Craterocephalus fluviatilis	3		1995	Loss
Craterocephalus stercusmuscarum fulvus	52	55	2021	
Gadopsis bispinosus	47	20	2018	
Gadopsis marmorata	152	75	2022	
Galaxias brevipinnis	3	1	2020	All translocated individuals
Galaxias olidus	98	100	2022	
Galaxias rostratus	4		1995	Loss
Galaxias tantangara	1	3	2021	
Hypseleotris acropinna		1	2013	Newly described species; record counts not an accurate reflection
Hypseleotris bucephala		4	2013	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	3	6	2014	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Hypseleotris spp.	209	834	2022	Deleted from assessment
Leiopotherapon unicolor	4	na	1995	Rare, flood displacement
Maccullochella macquariensis	153	51	2021	
Maccullochella peelii	246	961	2022	
Macquaria ambigua	353	482	2022	
Macquaria australasica	88	54	2022	
Melanotaenia fluviatilis	62	723	2021	
Mogurnda adspersa	2	na	2004	Loss
Nematalosa erebi	88	1 138	2022	
Philypnodon grandiceps	23	211	2022	
Philypnodon macrostomus	7	3	2018	
Retropinna semoni	426	1 154	2022	
Tandanus tandanus	6	na	2002	Rare

na = not applicable

Table 48. Ovens

	Valley	1980 – 2010	Post-2010	Net change
Southern Basin	Ovens	16	15	−1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Craterocephalus stercusmuscarum fulvus	4	10	2017	
Gadopsis bispinosus	3 072	163	2022	
Gadopsis marmorata	233	64	2022	
Galaxias arcanus	31	71	2022	
Galaxias brevipinnis	5	na	2007	Rare
Galaxias olidus	100	4	2015	
Galaxias oliros	6	5	2018	
Galaxias rostratus	3	na	1989	Loss
Hypseleotris bucephala	na	1	2013	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	52	19	2022	Deleted from assessment
Maccullochella macquariensis	54	60	2022	
Maccullochella peelii	209	107	2022	
Macquaria ambigua	152	43	2022	
Macquaria australasica	113	333	2022	
Melanotaenia fluviatilis	5	na	1992	Loss
Nannoperca australis	61	13	2021	
Philypnodon grandiceps	8	21	2022	
Retropinna semoni	57	28	2022	

na = not applicable

Table 49. Upper Murray

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Upper Murray	14	13	−1

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Anguilla australis	1	na	1994	Historic record likely a translocation
Gadopsis bispinosus	467	96	2022	
Gadopsis marmorata	99	33	2020	
Galaxias arcanus	14	7	2015	
Galaxias brevipinnis	155	26	2022	
Galaxias olidus	148	60	2020	
Galaxias oliros	4	9	2021	
Galaxias rostratus	15	1	2013	
Hypseleotris bucephala	na	3	2013	Newly described species; record counts not an accurate reflection
Hypseleotris klunzingeri	na	1	2013	Split out of *Hypseleotris* spp. (only genetically verified records included) so counts not representative
Hypseleotris spp.	10	24	2021	Deleted from assessment
Maccullochella macquariensis	17	5	2022	
Maccullochella peelii	31	54	2022	
Macquaria ambigua	4	na	2008	Rare
Macquaria australasica	3	na	2009	Rare
Nannoperca australis	26	25	2020	
Retropinna semoni	55	96	2022	

na = not applicable

Table 50. Wimmera

	Valley	1980–2010	Post-2010	Net change
Southern Basin	Wimmera	10	8	−2

Species	Records 1980–2010	Records post-2010	Year last recorded	Caveats and comments
Anguilla australis	2	na	1998	Rare
Bidyanus bidyanus		10	2019	Addition
Gadopsis marmorata	49	na	2009	Loss?, also not recorded since 2010 in SRA/MDBFS
Galaxias maculatus	27	19	2020	
Galaxias oliros	54	42	2021	
Hypseleotris spp.	19	1	2012	Deleted from assessment
Maccullochella peelii	50	na	1998	Loss?, also not recorded since 2010 in SRA/MDBFS
Macquaria ambigua	98	17	2021	
Nannoperca australis	79	56	2021	
Philypnodon grandiceps	98	39	2021	
Retropinna semoni	46	4	2021	
Tandanus tandanus	41	3	2020	

na = not applicable

Appendix 4 – Status of individual native fish species

Information sources

Information on the distribution (river valleys) for each species has been drawn from SRA, MDBFS, NSW BPEOM, TLM and other information collated for the revised edition of *Fishes of the Murray–Darling Basin* (Lintermans 2023). Information is also drawn from relevant published literature and personal communications (as cited).

Please refer to Table 4 in the main text for explanations of conservation status for each species.

For many species, there were insufficient data available from the SRA/MDBFS datasets to assess trends in abundance and recruitment. This situation is expected to improve greatly with the recommendations in Section 7.3 to undertake a collaborative and detailed quantitative assessment of native fish status, using appropriate long-term datasets and fish population modelling to assess attributes such as species conservation status, species distribution and population dynamics.

Table 51. Data sources for the revised edition of *Fishes of the Murray–Darling Basin* (Lintermans 2023)

Source identifier	Record count	First year	Last year	Description
R2502	2	1770	1770	Records for two short-finned eel. *Fishes of the Murray–Darling Basin* (1st edition)
NFS_Dist Pop2007	116 500	1770	2006	Observations compiled for Native Fish Strategy records
R2405	8 432	1878	2015	Victorian Biodiversity Atlas dataset
R2387	1 556	1903	2015	Natural Museum of Victoria
R2539	246	1904	2021	Observations compiled by Mark Lintermans for *Fishes of the Murray–Darling Basin* (2nd edition)
R2375a	131	1905	2011	Queensland Museum data
R2591	130	1905	2021	Records of five species from Southern and Northern Basin
R2593	5	1907	2022	Records from 5 long-finned eel
NFS_R50 07	6	1971	1993	Observations for *Fishes of the Murray–Darling Basin* (1st edition)
R2376	22 262	1975	2015	Fish presence data extract from the NSW Fisheries Freshwater Fish Research Database
R2375b	9	1976	2002	Queensland Museum data

Source identifier	Record count	First year	Last year	Description
R2585	193	1987	2019	New genetically verified carp gudgeon records (bald carp gudgeon, boofhead carp gudgeon, cryptic carp gudgeon, western carp gudgeon)
R2566	2	1993	1993	Records of oriental weatherloach from Southern Basin
R2599	4	1995	1995	Additional flat-headed galaxias records detected through Native Fish Status Assessment–Data Analysis
R2565b	25	1996	2022	Records for 13 species in Southern Basin
R2587	125	2000	2021	Records for seven species in Southern Basin
2439	10 004	2001	2016	CEWO Long-term Intervention Monitoring data
R2590c	3 190	2001	2006	Records for 17 species from Northern Basin
SRA/MDB	10 081	2004	2019	Data from the Sustainable Rivers Audit and Murray–Darling Basin Fish Survey
2433	1 871	2005	2010	Observations compiled by Mark Lintermans for *Fishes of the Murray–Darling Basin* (2nd edition)
R2556	73	2006	2021	Records for 10 species in Northern Basin
R2559	7	2006	2021	Records for pouched lamprey, short-finned eel and short-headed lamprey, Southern Basin
R2561	503	2006	2021	Records for southern pygmy perch in Southern Basin
R2407	828	2007	2012	The Living Murray–Barmah–Millewa Forest and Koondrook–Perricoota Forest fish monitoring
R2586	2 351	2007	2012	Records for 13 species in Central Murray catchment–wetland fish dataset
R2406	2 098	2008	2014	The Living Murray–Gunbower fish monitoring
R2584	1	2008	2008	Record for long-finned eel in Northern Basin
R2588	13 208	2008	2022	The Living Murray–Coorong, Lower Lakes and Murray Mouth monitoring
R2565a	26	2009	2021	Records for five species in Southern Basin
R2569	42	2010	2013	Record for river blackfish in Northern Basin
R2589	1	2010	2010	Single long-finned eel record from Southern Basin
R2551	5	2011	2020	Records for southern purple-spotted gudgeon in Loddon catchment
R2378	1 209	2012	2015	Small-bodied fish monitoring and research data from the Lower Lakes (SA)
R2560	723	2012	2021	Records for Macquarie perch, Murray–Darling rainbowfish and trout cod in Southern Basin
R2537	1 906	2014	2019	CEWO Long-term Intervention Monitoring data

Source identifier	Record count	First year	Last year	Description
R2555	3	2014	2019	Records for Murray hardyhead and southern purple-spotted gudgeon in Southern Basin
R2598	25 873	2014	2021	NSW Fisheries Basin Plan Environmental Outcomes Monitoring data
R2553	31	2015	2021	Records for 12 species Southern Basin
R2577	29 188	2015	2021	CEWO Flow-MER program
R2572	3	2016	2017	Records for silver perch and Murray cod in Northern Basin
R2578	62	2017	2018	Records for four species in Northern Basin
R2579	353	2017	2018	Records for 13 species in Northern Basin
R2594	1	2017	2017	Additional Hyrtl’s tandan record in Macquarie River
SRA/MD BFS	6 433	2019	2021	Murray–Darling Basin Fish Survey data
R2570	1	2020	2020	Record for Freshwater catfish in Northern Basin
R2573	1	2020	2020	Record for freshwater catfish in Northern Basin
R2543	104	2021	2021	PIT tagging and detection data for the Murray–Darling Basin from the FishNet Central PIT database
MDBFS_2 021_2022	9 022	2021	2022	Data from the Murray–Darling Basin Fish Survey (2022)
R2568	1	2022	2022	Record for Rehndals Tandan in Northern Basin
R2571	54	2022	2022	Records for nine species in Northern Basin
R2595	1	2022	2022	Additional Hyrtl’s tandan record in Menindee Lakes
R2600	1	2023	2023	Record for Hyrtl’s tandan in Macquarie catchment

CEWO = Commonwealth Environmental Water Office; MER = monitoring, evaluation and research; PIT = passive integrated transponder

Individual species descriptions

Species: *Afurcagobius tamarensis*

Common name: Tamar goby, Tamar River goby

Conservation status:

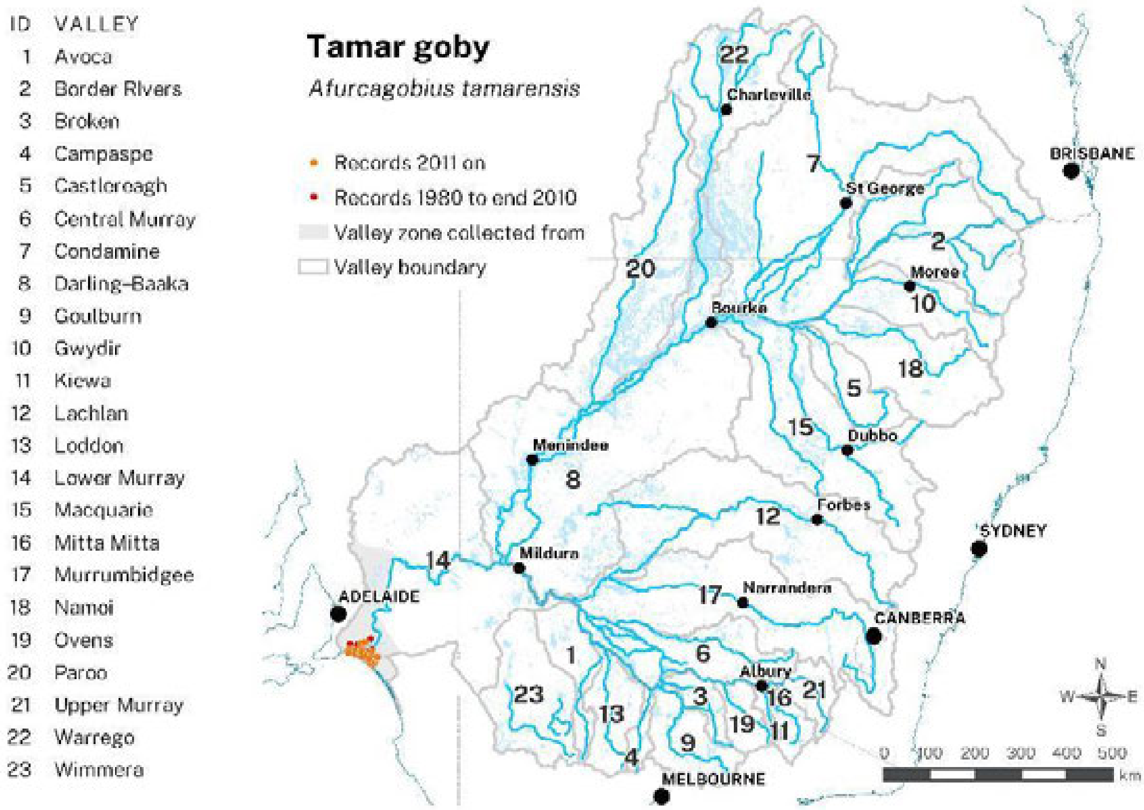
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

A small-bodied estuarine generalist, within the Basin it is only found in the Lower Lakes (Alexandrina and Albert), Coorong, and also in a small proportion of wetlands adjacent to the Lower Lakes (Smith et al. 2009, Wedderburn et al. 2014, Bice et al. 2021, Lintermans 2023).

The species has been recorded in two river valleys in 1980–2010, and since 2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	–	–	–
Southern Basin	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- An estuarine species, it predominantly occurs in the Coorong and estuary but is also present in the Lower Lakes and some associated wetlands. It is usually recorded in still or slow-flowing habitats with mud or silt substrates and abundant cover from rocks, logs or aquatic vegetation (Giatas et al. 2022, Lintermans 2023).
- It is an important prey species for a range of fish and birds in the Coorong and Lower Lakes (Lintermans 2023).
- There are insufficient data to accurately assess population dynamics such as trends in abundance.
- The species breeds in the Coorong, Lower Lakes and Murray Mouth.
- There are insufficient data to accurately assess trends population structure or recruitment.

Overall:

- A locally common species in the Coorong and Lower Lakes.

Native fish status assessment 2023

Species: *Ambassis agassizii*

Common name: Olive perchlet, glass perch, chanda perch, western chanda perch and Agassiz's chanda perch

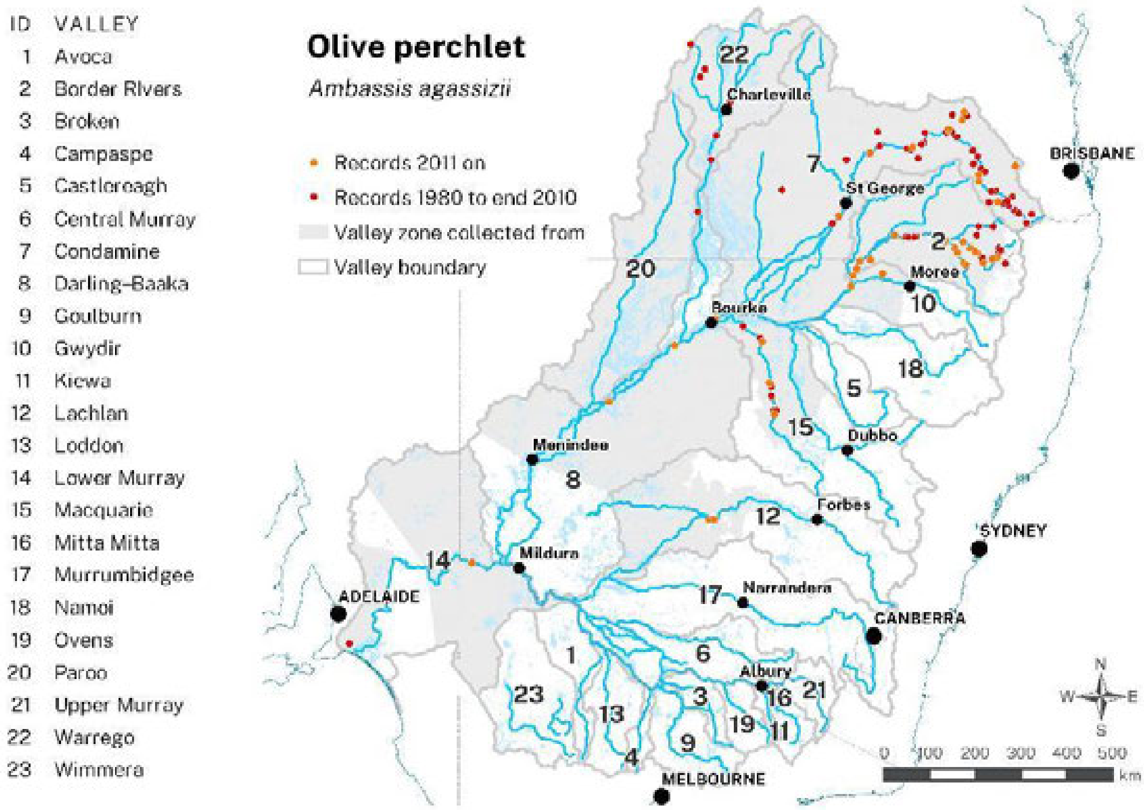
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	PROT	EX	EN	–	–

EN = Endangered; EX = Extinct; LC = Least Concern; PROT = Protected under SA Fisheries Management Act 2007; – = not assessed

Distribution (presence):

Whiterod et al. (2019) describe how the species has experienced widespread historical decline and is now considered extinct in Victoria (last record 1922) and South Australia (last record in 1983). It was considered absent from the NSW section of the southern MDB, before it was rediscovered (after a 47-year absence) in large numbers (almost 5 000 fish) at several sites in the Lachlan River catchment (McNeil et al. 2008). While the species has been lost to the Paroo and Warrego catchments, it has been found in the Gwydir catchment since 2010 (being absent between 1980 and 2010).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	X
	Warrego	✓	X
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	X	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	X	✓
	Lachlan	✓	✓
	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	–	–	–

– = species absent from basin

Population dynamics:

- Inhabits the vegetated edges of lakes, creeks, swamps, wetlands and rivers, and is often associated with aquatic vegetation and woody habitat in areas with little or no flow, particularly backwaters (Lintermans 2023).
- This species is now considered extinct in Victoria (last record 1922) and South Australia (last record in 1983). It was considered absent from the NSW section of the southern MDB, before it was rediscovered (after a 47-year absence) in large numbers in the Lachlan River catchment.
- There are insufficient data to accurately assess population abundance trends.
- There are insufficient data to accurately assess the condition of sub-populations.
- There are insufficient data to accurately assess population structure or recruitment.
- Recent surveys have confirmed that the single known southern MDB sub-population in the Lachlan River catchment has been maintained, although its distribution remains restricted (Whiterod et al. 2019, 2021c). The species remains threatened in numerous jurisdictions.
- Limited data indicate the species is breeding in the Condamine, Border Rivers, Darling, Macquarie and Lachlan river valleys.
- Limited captive breeding to date, but possible with new hatcheries that focus on conservation restocking.

Overall:

- Once occurring more broadly across the MDB, the species has experienced widespread declines and is considered extinct in Victoria and South Australia. It was rediscovered in the NSW section of the southern MDB after a 47-year absence.

- The single known southern MDB sub-population in the Lachlan River catchment has been maintained although its distribution remains restricted.
- Olive perchlet has also declined in Queensland.

Species: *Anguilla australis*

Common name: Short-finned eel, silver eel

Conservation status:

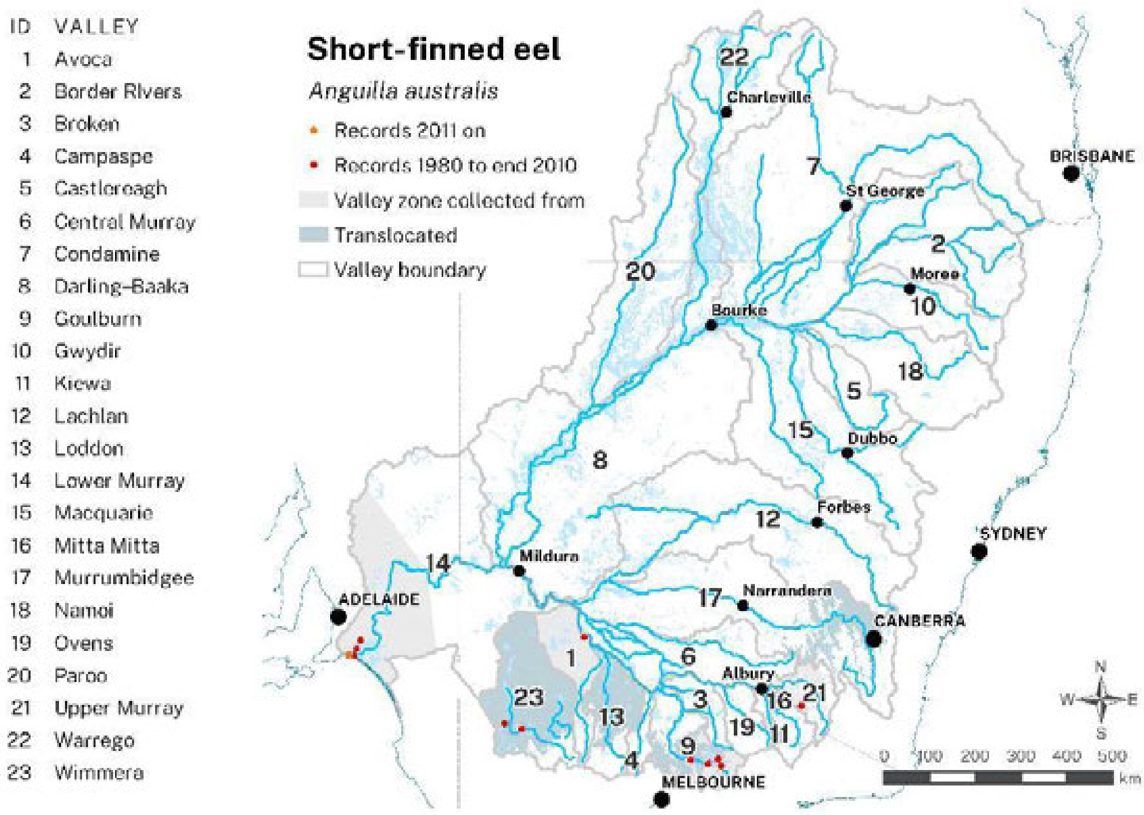
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
NT	–	R	–	–	–	–

NT = Near Threatened; R = Rare; – = not assessed

Distribution (presence):

Eels in south-eastern Australia are generally only recorded from coastal streams outside the Basin, as their life history involves adult migrations from freshwaters to the marine environment and then to the Coral Sea to spawn (Koster et al. 2021). Short-finned eel is one of several catadromous fish species in the MDB and is now found in a variety of locations within the Southern Basin. Most of these recent records are the result of translocation either by anglers, as escapes from aquaculture, or via inter-basin water transfers (Lintermans 2023). Historical records (pre-1980) are known from the lower Murray, Darling, Loddon and Wimmera valleys (Lintermans 2023).

The species has been recorded in five fewer river valleys in 2011–2022 compared with 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	X
	Upper Murray	✓	X
	Lower Murray	✓	✓
	Goulburn	✓	X
	Avoca	✓	X
	Wimmera	✓	X
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- A diadromous species, adults inhabit rivers lakes and wetlands, mainly in coastal catchments.
- Adults migrate to the Coral Sea to spawn, and larvae are transported by ocean currents down eastern Australia.
- A rarely recorded species, there are insufficient data to accurately assess population dynamics such as trends in abundance.

Overall:

- A species that is rarely recorded in conventional sampling programs, and is considered rare in South Australia. No individuals were captured in SRA/MDBFS surveys. While considered to be globally Near Threatened, its conservation status in Australia is not of concern.

Native fish status assessment 2023

Species: *Anguilla reinhardtii*

Common name: Long-finned eel, spotted eel

Conservation status:

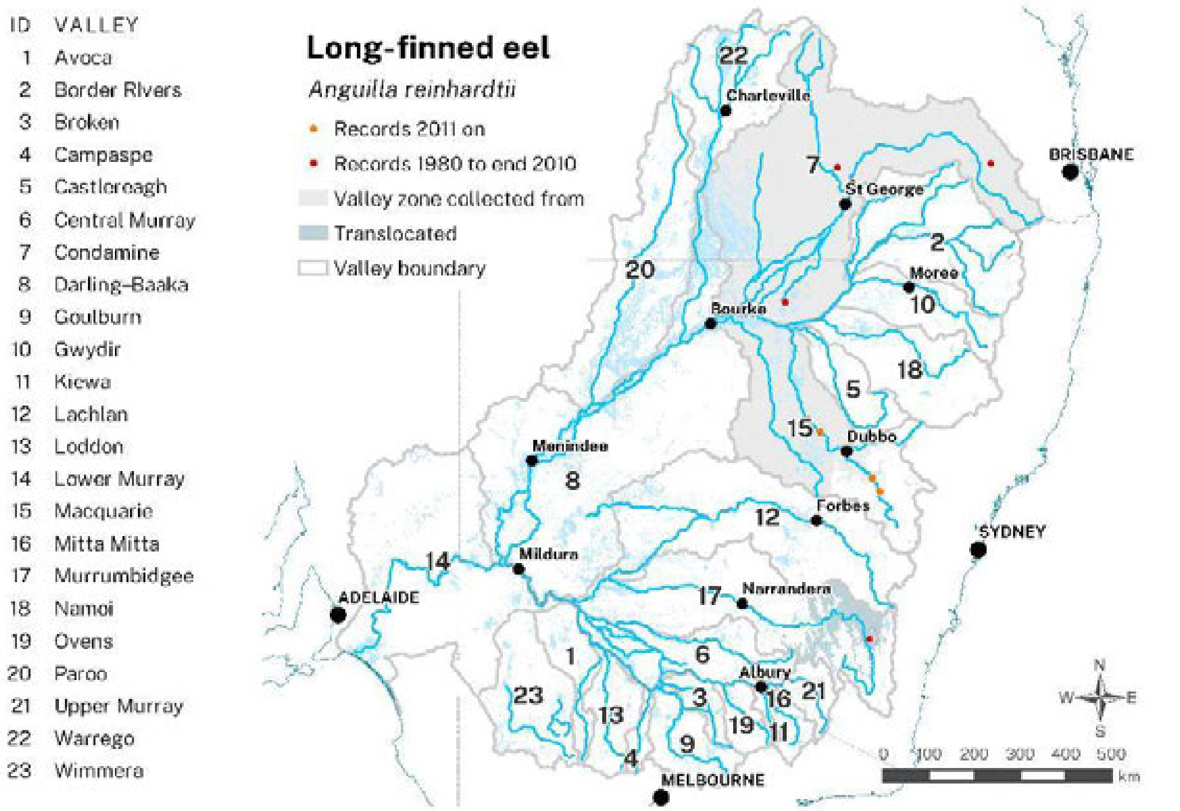
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

Eels in south-eastern Australia are generally only recorded from coastal streams outside the Basin, as their life history involves adult migrations from freshwater to the marine environment and then to the Coral Sea (Koster et al. 2021). The long-finned eel is one of several catadromous fish species in the MDB and is now found in very low abundance (usually single individuals) at a variety of locations, primarily in the Northern Basin. The sole Southern Basin record is almost certainly the result of a translocation by anglers (Murrumbidgee valley at Canberra), whereas some of the records in the Northern Basin are thought to be a result of natural dispersal across low catchment barriers (e.g. into the Condamine Valley from the adjacent coastal Burnett catchment) (Lintermans 2023). There are historic records of this species from the Macquarie River in 1912 near Trangie and Darling-Baaka River at Wilcannia in 1907 (Lintermans 2023). All other known records are post-1980 (Lintermans 2023).

The species has been lost from two river valleys and newly found in one valley in 2011–2022 compared with 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	X
	Macquarie	X	✓
Southern Basin	Murrumbidgee	✓	X
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- A diadromous species, adults inhabit rivers lakes and wetlands, mainly in coastal catchments. Adults migrate to the Coral Sea to breed and larval eels are carried by sea currents down the east coast of Australia.
- A rarely recorded species, there are insufficient data to accurately assess population dynamics such as trends in abundance and recruitment.

Overall:

- A species that is rarely recorded in conventional sampling programs, and is considered rare in South Australia. No individuals were captured in the SRA/MDBFS surveys.
- While considered to be globally Near Threatened, its conservation status in Australia is not of concern.

Native fish status assessment 2023

Species: *Atherinosoma microstoma*

Common name: Small-mouthed hardyhead, smallmouth hardyhead

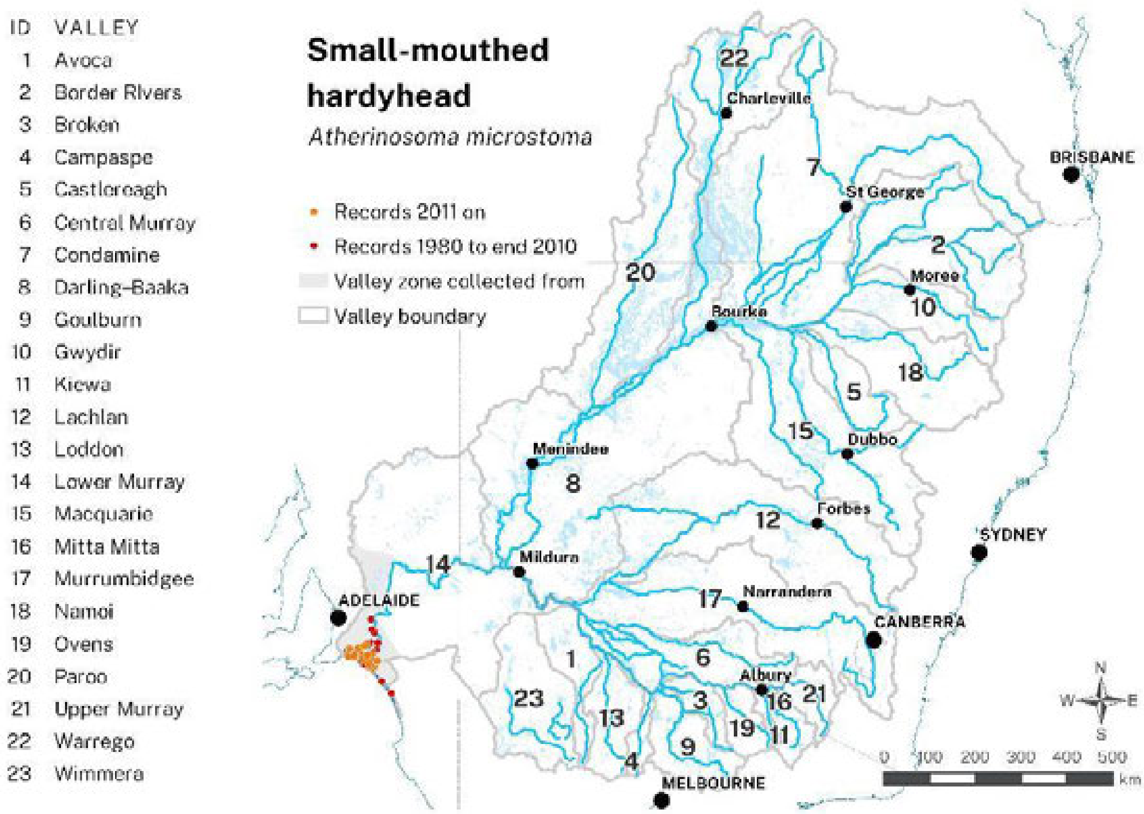
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

A small-bodied species that is abundant in the lowermost reaches of the lower Murray in the Southern Basin including wetlands, the Lower Lakes and Coorong (Smith et al. 2009, Wedderburn et al. 2014, Bice et al. 2021, Lintermans 2023). While normally an estuarine species, it has a very wide salinity tolerance and can live in inland habitats such as lakes at the lower end of freshwater rivers. Accordingly, in the MDB, as well as being abundant in the saline Coorong, it also exists as self-sustaining populations in the freshwater Lower Lakes (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	–	–	–
Southern Basin	–	–	–
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- The species is a common wetland species and occurs as breeding populations in the freshwater Lower Lakes and saline Coorong (Lintermans 2023). The dedicated stream fish monitoring programs in the Basin do not sample wetland habitats, so trends in abundance and distribution of this species in riverine habitats is likely poorly characterised by these programs. The species has not been recorded in the SRA/MDBFS surveys since 2011. It is regularly recorded in the Coorong and Lower Lakes monitoring program (Bice et al. 2021), where it is abundant in the Coorong, and common in the Lower Lakes.
- Variable condition of populations, depending on inflows to the Coorong (Ye et al. 2022).
- The species is an important food item for many estuarine fish and bird species (Giatas et al. 2022).

Overall:

- A common and widespread species in coastal streams of south-east Australia, and a locally common species in the Coorong and Lower Lakes.

Species: *Bidyanus bidyanus*

Common name: Silver perch, black bream, silver bream, bidyan

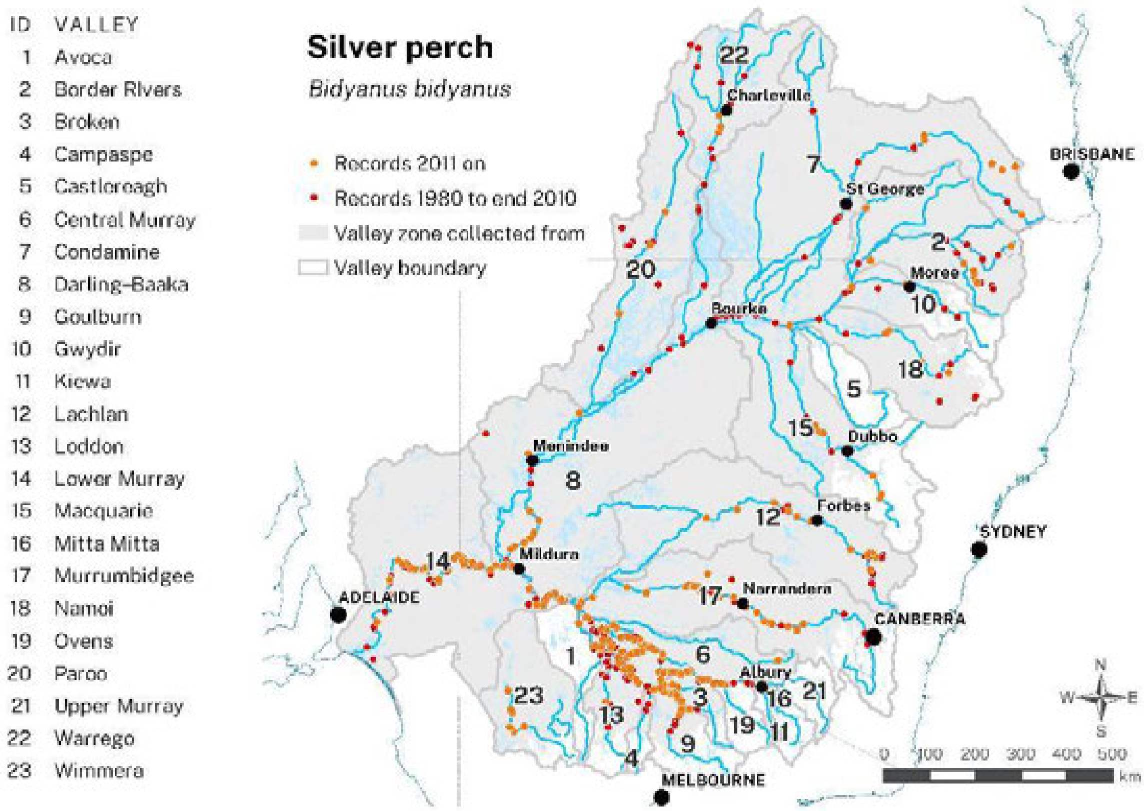
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
NT	CE	EN	EN	VU	EN	REG (no take)

CE = Critically Endangered; EN = Endangered; NT = Near Threatened; REG (no take) = Regulated under Qld Fisheries Act 1994; VU = Vulnerable

Distribution (presence):

Formerly widespread over much of the Murray–Darling Basin excluding the most upper reaches. Historically, the species was also known from more upland environments in NSW (e.g. the upper Murrumbidgee and upper Macquarie rivers) where fish were recorded up to 700 m elevation (Lintermans 2023). Silver perch has declined over most of its range. For example, numbers moving through a fishway at Euston Weir on the Murray River declined by 93% between 1940 and 1990 (Mallen-Cooper and Brand 2007). The species is at very low levels, if not functionally extinct, in the Northern Basin valleys of the Paroo, Warrego, Condamine and Macintyre valleys, and is functionally extinct in the upper Murrumbidgee (Lintermans 2023, Todd et al. 2022).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	X
	Wimmera	X	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Now primarily a fish of lowland rivers, it is not well sampled by the dedicated fish monitoring programs (SRA/MDBFS).
- The mid-reaches of the Murray River support the highest relative abundances of silver perch (Tonkin et al. 2017), even though the population has substantially declined from historical levels.
- Recruitment in the mid-Murray occurred almost each year, including under low within-channel flows and overbank floods year over the 11 years, a period that encompassed extremes in discharge (drought and flood). The strongest year classes of silver perch were associated with low-to-average river discharge and high water temperatures during November and December, and that preceded a year of extended high flows and widespread flooding.
- Todd et al. (2022) used a stochastic metapopulation model to assess silver perch population trajectories in the MDB. Results indicated that the species is likely functionally extinct in the northern MDB and had been subject to a long-term decline in the southern MDB. These

predictions are supported by observed Basin-wide population declines (Clunie and Koehn 2001a, Lintermans 2007, Tonkin et al. 2019, Koehn et al. 2020b), and extremely low numbers in the Northern Basin (Lintermans 2022a).

- The species is a target of some recreational harvest.
- Widely stocked into farm dams and reservoirs for recreational fishing. Some conservation stocking has commenced.

Overall:

- A species that has declined over most of its range, with significant conservation concerns. Its stronghold is the Central Murray and is still patchily abundant in the lower and mid-Murray.

Native fish status assessment 2023

Species: *Craterocephalus amniculus*

Common name: Darling River hardyhead

Conservation status:

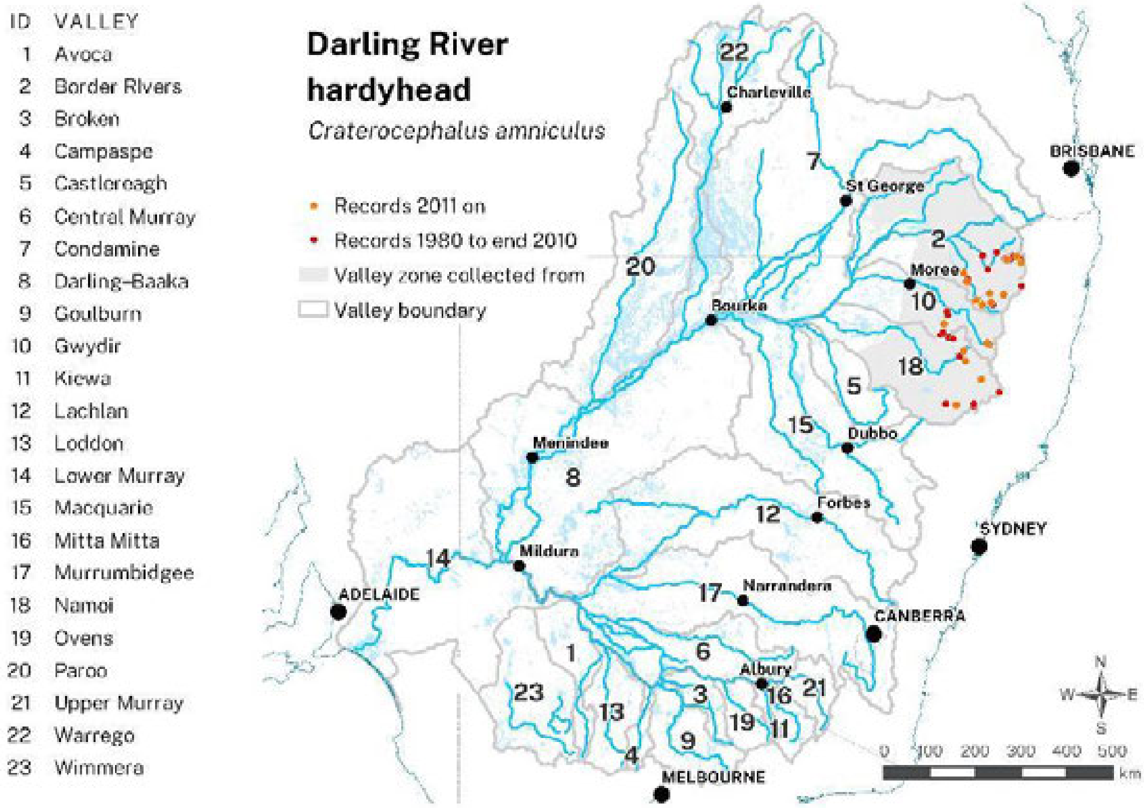
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	VU	–	–	VU	–	–

LC = Least Concern; VU = Vulnerable; – = not assessed

Distribution (presence):

A small-bodied, relatively restricted, threatened species that occurs in the Northern Basin. This species appears to have been hard hit by the 2017–19 drought across NSW that resulted in the drying of many small upland tributaries where this species occurs, and populations declined or were lost. The upper Namoi and Gwydir populations were severely impacted (Moy et al. 2020, Lintermans 2023). In one location in the mid-Gwydir valley, heavy drought-breaking rain in early 2020 on the drought-affected catchment resulted in a wall of sediment impacting a population of this species, and it likely happened in other drought-affected streams (Moy et al. 2020). The population outside of the Basin in the threatened status assessment in NSW was from a listing in 2014 before the MDB population declined in the 2017–19 drought. Similarly, the IUCN Red List assessment was from before the impacts of the drought became apparent (Gilligan and Moy 2019).

The species has been recorded in three river valleys both in 1980–2010 and since 2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
Southern Basin		–	–
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Found in slow-flowing, clear, shallow waters or adjacent to aquatic vegetation at the edge of such waters. It has also been recorded from the edges of faster-flowing habitats, such as runs at the head of pools. (Moy et al. 2018).
- There is insufficient information from which to assess trends in abundance and recruitment.

Overall:

- A relatively restricted species across the Basin, it was impacted by the 2017–19 drought.

Species: *Craterocephalus fluviatilis*

Common name: Murray hardyhead

Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
CR	CE	EN	CE	CE	–	–

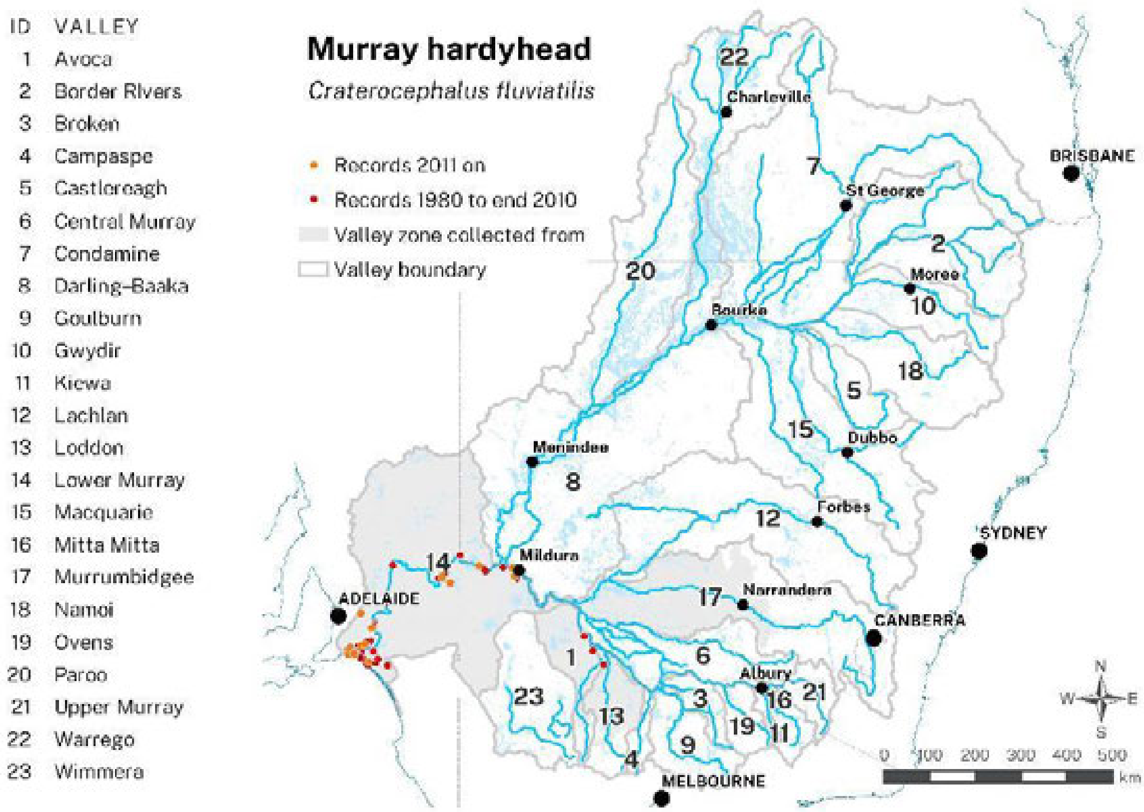
CE = Critically Endangered; CR = Critically Endangered (IUCN); EN = Endangered; – = not assessed

Distribution (presence):

A small-bodied, highly threatened species that inhabits lakes, wetlands, backwaters and billabongs, and is now associated predominantly with floodplains of the mid-to-lower Murray River in the Southern Basin. Formerly widespread and abundant in the Murray and Murrumbidgee river systems in southern New South Wales and northern Victoria, it has suffered a significant reduction in distribution (Ellis et al. 2013, Stoessel et al. 2019, Whiterod et al. 2019, 2021c).

The species has experienced significant declines as a consequence of river regulation and the associated alteration and loss of well-vegetated shallow, saline wetland habitat, exacerbated by critical water shortages during the Millennium drought.

The post-drought conservation of Murray hardyhead has benefited from the establishment of backup populations. Since the end of the drought, there has been some fragmented recovery of wild populations, in part due to active management (environmental watering and reintroductions), and all known sub-populations of the species have persisted since 2019. The species has been recorded in four river valleys in 1980–2010, but only two valleys since 2010. It was present in the Central Murray in pre-1980.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	X
	Central Murray	X	✓
	Lower Murray	✓	✓
	Loddon	✓	X
	Avoca	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Inhabits lakes, wetlands, backwaters and billabongs. Murray hardyhead prefers slow-flowing or still habitats, with sand or silt substrates. Often associated with dense aquatic vegetation (e.g. *Ruppia*, *Myriophyllum* or *Vallesnaria*) (Lintermans 2023). The species can thrive in ephemeral habitats and is tolerant of highly saline conditions, which can reduce or eliminate problem species like carp (Wedderburn et al. 2008, Stoessel et al. 2020, Ellis and Kavanagh 2014, Lintermans 2023).
- As a predominantly wetland or off-channel species, it is inadequately sampled by the dedicated fish monitoring programs (SRA/MDBFS). Only a single individual was recorded from

the SRA (2004–2013) (Lower Murray catchment) with none recorded from the MDBFS (2014–15 to 2021–22).

- The species experienced significant declines as a consequence of river regulation and the associated alteration and loss of well-vegetated shallow, saline wetland habitat, exacerbated by critical water shortages during the Millennium drought (Whiterod et al. 2019, 2021c).
- The post-drought conservation of Murray hardyhead has benefited from the establishment of backup populations. Since the end of the drought, there has been some fragmented recovery of wild populations in part due to active management (environmental watering and reintroductions), and all known sub-populations of the species have persisted since 2019.
- Murray hardyhead persist across a number of locations, often supported by strategic environmental water delivery. The persistence of recently rediscovered and reintroduced populations has improved the outlook for the species.
- There are insufficient data to accurately assess population abundance trends or recruitment.
- Murray hardyhead has been successfully translocated to several managed locations in NSW, Victoria and South Australia to establish new populations (Ellis et al. 2020, 2022, Whiterod et al. 2019, Zukowski et al. 2021).

Overall:

- Murray hardyhead persist across a number of locations, often supported by strategic environmental water delivery.
- The persistence of recently rediscovered and reintroduced populations has improved the outlook for the species, but it remains endangered across all jurisdictions (except the ACT and Queensland, where it does not occur).

Native fish status assessment 2023

Species: *Craterocephalus stercusmuscarum fulvus*

Common name: Unspecked hardyhead, fly-specked hardyhead, non-speckled hardyhead

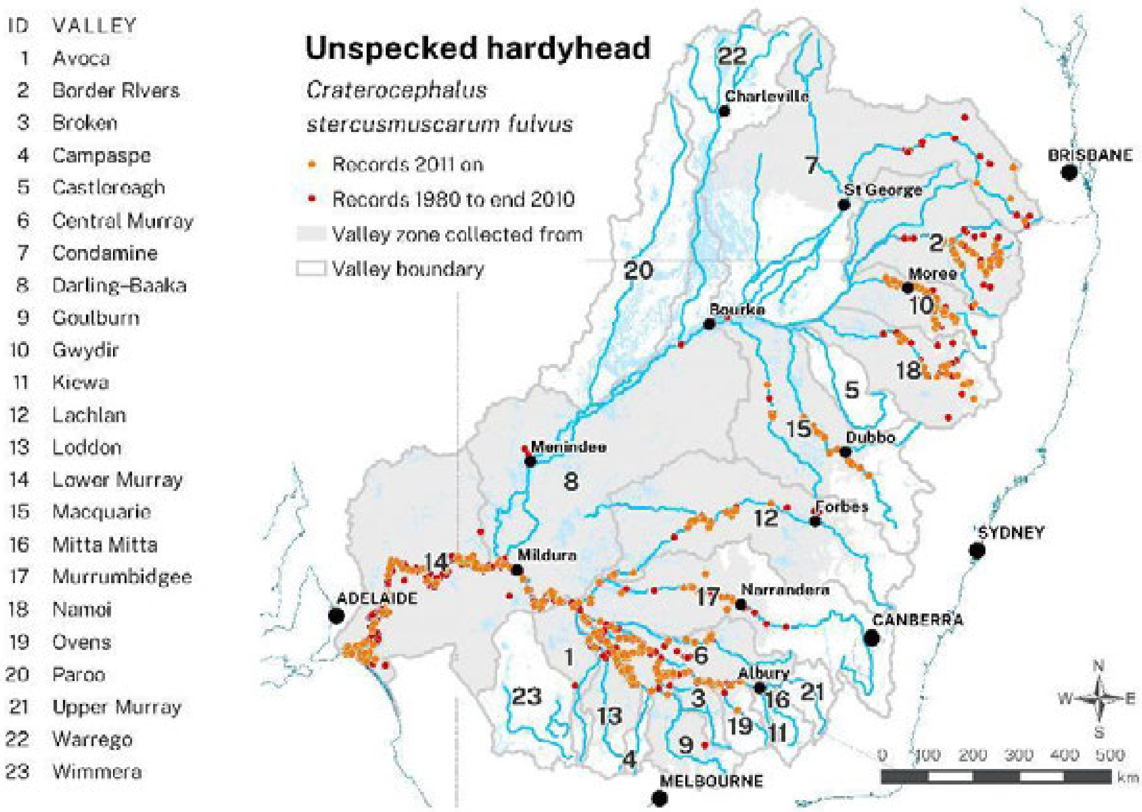
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

A small-bodied species, widespread and abundant in the Northern and Southern Basins (Lintermans 2023). Often collected around the margins of slow-flowing, lowland rivers, and in lakes, backwaters and billabongs, it prefers slow-flowing or still habitats with aquatic vegetation and woody debris, and sand, gravel or mud substrates (Lintermans 2023). It is abundant and widely distributed in wetlands and main channel habitats of the Murray River in South Australia and wetlands in the mid-Murray. The species was the second-most abundant fish captured in wetland monitoring in South Australia from 2004 to 2007 and occurred at 79% of all wetlands sampled (Smith et al. 2009).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	X
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Avoca	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- The species is often collected around the margins of slow-flowing, lowland rivers, and in lakes, backwaters and billabongs. It prefers habitats with aquatic vegetation and woody debris, and sand, gravel or mud substrates (Lintermans 2023).
- As a common wetland species, the dedicated fish monitoring programs in the Basin do not sample wetland habitats, so the abundance and distribution of this species is likely underestimated. The species was recorded in 13 valleys in the SRA (2004–2010) (minus the Avoca and Goulburn valleys recorded in the combined dataset for 1980–2010) and 12 valleys in the SRA/MDBFS since 2011 (minus the Goulburn and Broken valleys recorded in the combined dataset for 2011 onwards).
- SRA/MDBFS data suggest increasing abundance between 2004 and 2019, and declining (although highly variable) abundance since 2019 (Figure 23).

Overall:

- Found throughout lowland river and wetland habitats of the Basin, it is abundant and widely distributed in wetlands and main channel habitats of the Murray River in South Australia and wetlands in the mid-Murray.

- Formerly intermittently abundant, the species appears to have suffered a reduction in distribution in recent years (Lintermans 2023).

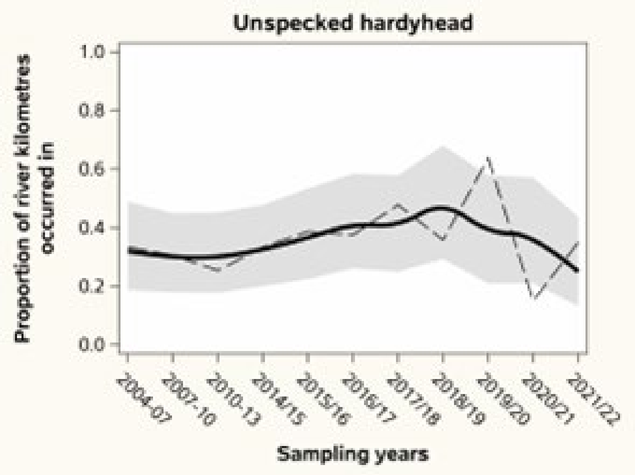


Figure 23. Estimate of proportion of river kilometres inhabited by unspecked hardyhead

Species: *Gadopsis bispinosa*

Common name: Two-spined blackfish

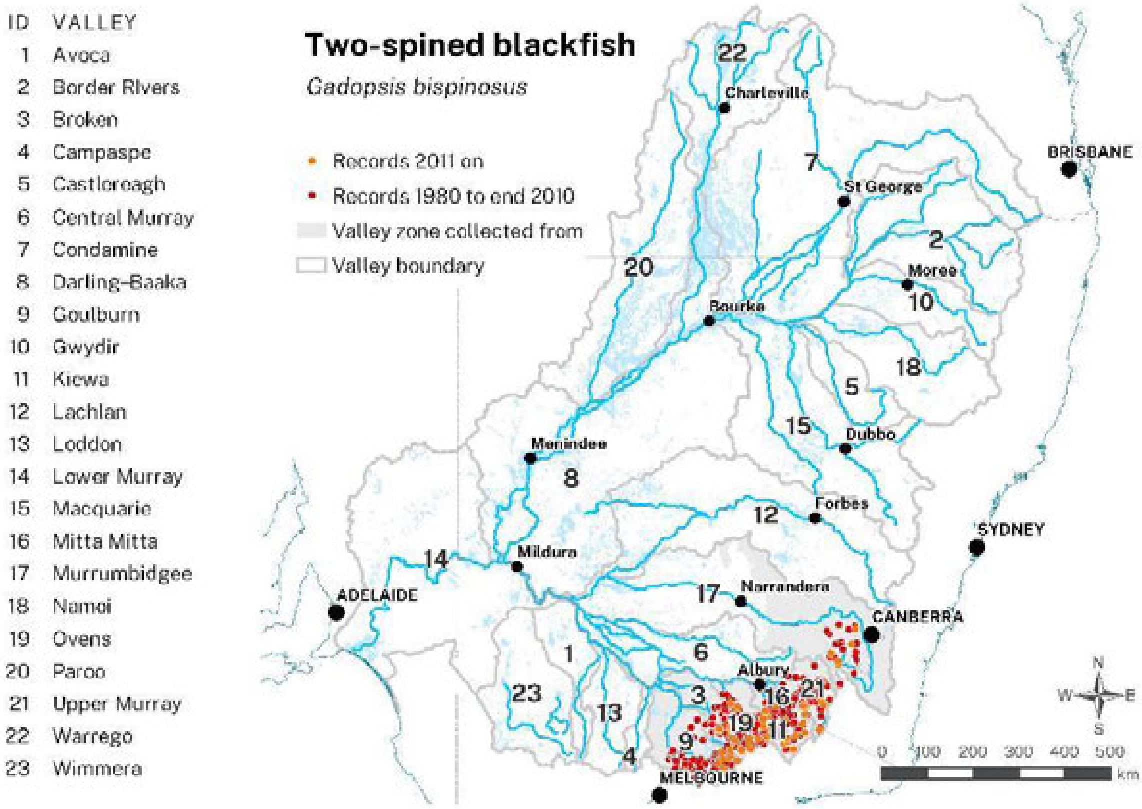
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
NT	–	–	–	–	VU	–

NT = Near Threatened; VU = Vulnerable; – = not assessed

Distribution (presence):

This species is known only from the Murray–Darling Basin, where it has been recorded from rivers in north-east Victoria, the ACT and south-east NSW (Lintermans 2023). It has declined in the ACT, where it has been lost from the Murrumbidgee and Paddys rivers, and possibly the Naas–Gudgenby system (Lintermans 2023). Data for this species and the recently recognised but undescribed Goulburn two-spined blackfish are combined (i.e. they have not been distinguished in the field).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Restricted to cool, clear upland or montane streams (and reservoirs) with abundant instream cover, usually in the form of boulders and cobble (Koehn 1990, Sanger 1990, Lintermans 1998, Broadhurst et al. 2012).
- SRA/MDBFS data suggest abundance and distribution are relatively stable (Figure 24).

Overall:

- A species that appears secure in Victoria but has declined in range and/or abundance in NSW and the ACT, primarily from sedimentation.

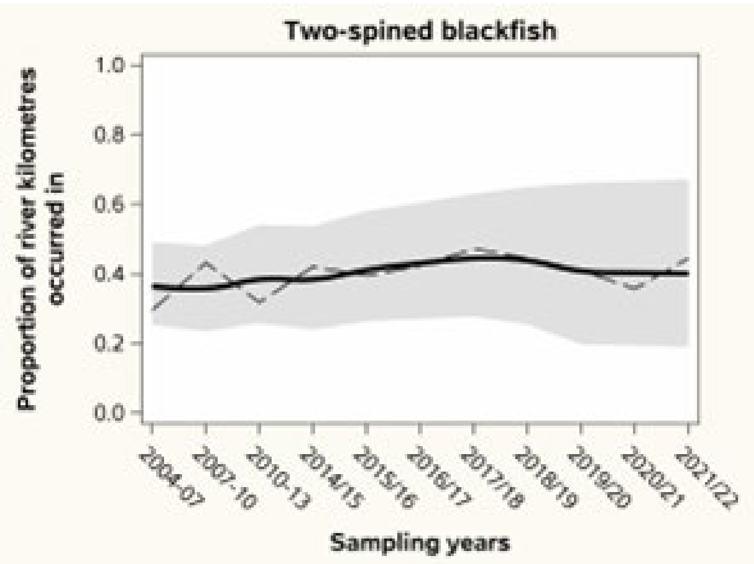


Figure 24. Estimate of proportion of river kilometres inhabited by two-spined blackfish

Native fish status assessment 2023

Species: *Gadopsis marmorata*

Common name: Northern river blackfish, river blackfish, Slippery, Slimy, Muddy, Greasy, Nikki long cod

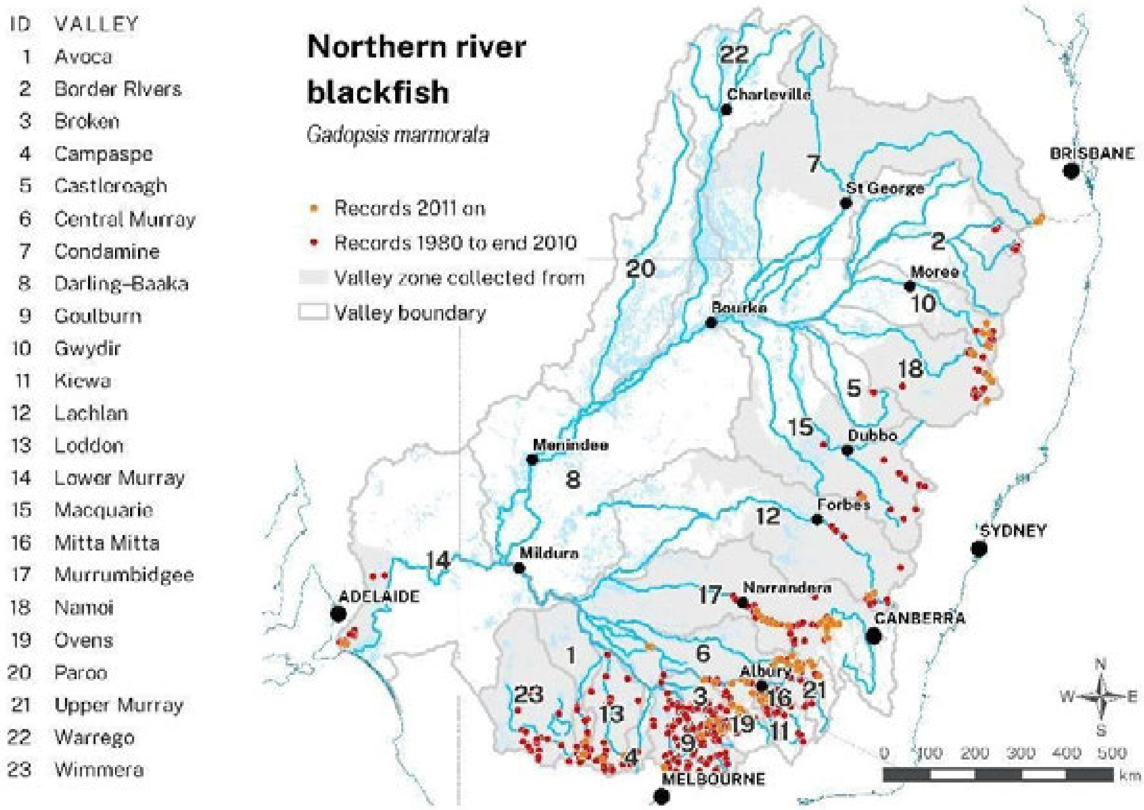
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	EN	–	EN	–	REG (no take)

EN = Endangered; LC = Least Concern; REG (no take) = Regulated under Qld Fisheries Act 1994; – = not assessed

Distribution (presence):

This species is widespread across the Basin, occurring in catchments the Condamine–Balonne in Queensland, catchments in NSW and all the tributaries of the Murray River (Lintermans 2023), although the species has not been recorded in the Campaspe and Wimmera catchments in the 2010–2022 period. Data for this species and the recently recognised but undescribed few-spined river blackfish (from the Wimmera catchment) are combined (i.e. they have not been distinguished in the field).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	X
	Macquarie	✓	✓
Southern Basin	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	X
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Found in a range of upland and lowland river habitats.
- SRA/MDBFS data suggest abundance and distribution are relatively stable (Figure 25).

Overall:

- A widespread species of no conservation concern, despite a reduced range (no records in two catchments in the 2011–2022 period).

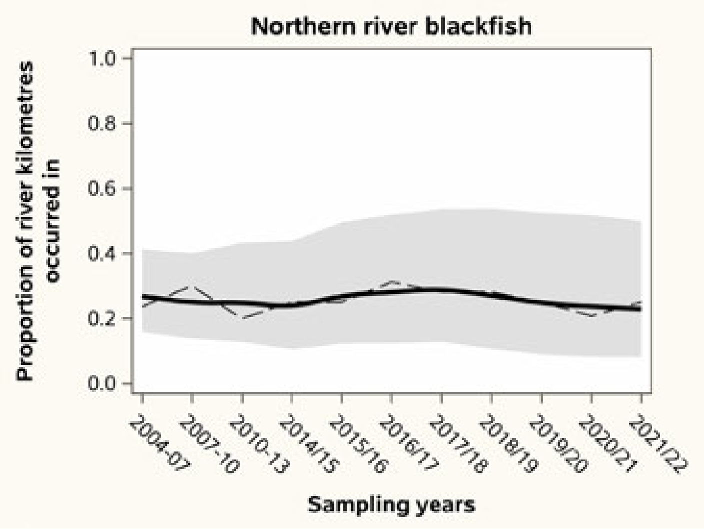


Figure 25. Estimate of proportion of river kilometres inhabited by Northern river blackfish

Species: *Gadopsis* sp. *nov.*

Common name: Few-spined river blackfish

Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

A newly recognised, undescribed cryptic species that is only known from the Wimmera valley in Victoria (Hammer et al. 2014). As an undescribed, cryptic species previously included within river blackfish, there is no information on its distribution from regular survey or monitoring programs.

	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Wimmera	–	–
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Its habitat preferences are assumed to be the same as the closely related river blackfish (Lintermans 2023).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A restricted but probably locally common species.

Species: *Gadopsis* sp. nov. 'Goulburn'

Common name: Goulburn two-spined blackfish

Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

A newly recognised, undescribed cryptic species that is only known from the Goulburn valley in Victoria (Hammer et al. 2014). As an undescribed, cryptic species previously included within two-spined blackfish, there is no information on its distribution from regular survey or monitoring programs.

	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Goulburn	–	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Its habitat preferences are assumed to be the same as the closely related two-spined blackfish (i.e. cobble-bottomed streams) (Lintermans 2023).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A restricted but probably locally common species of no conservation concern.

Native fish status assessment 2023

Species: *Galaxias arcanus*

Common name: Riffle galaxias

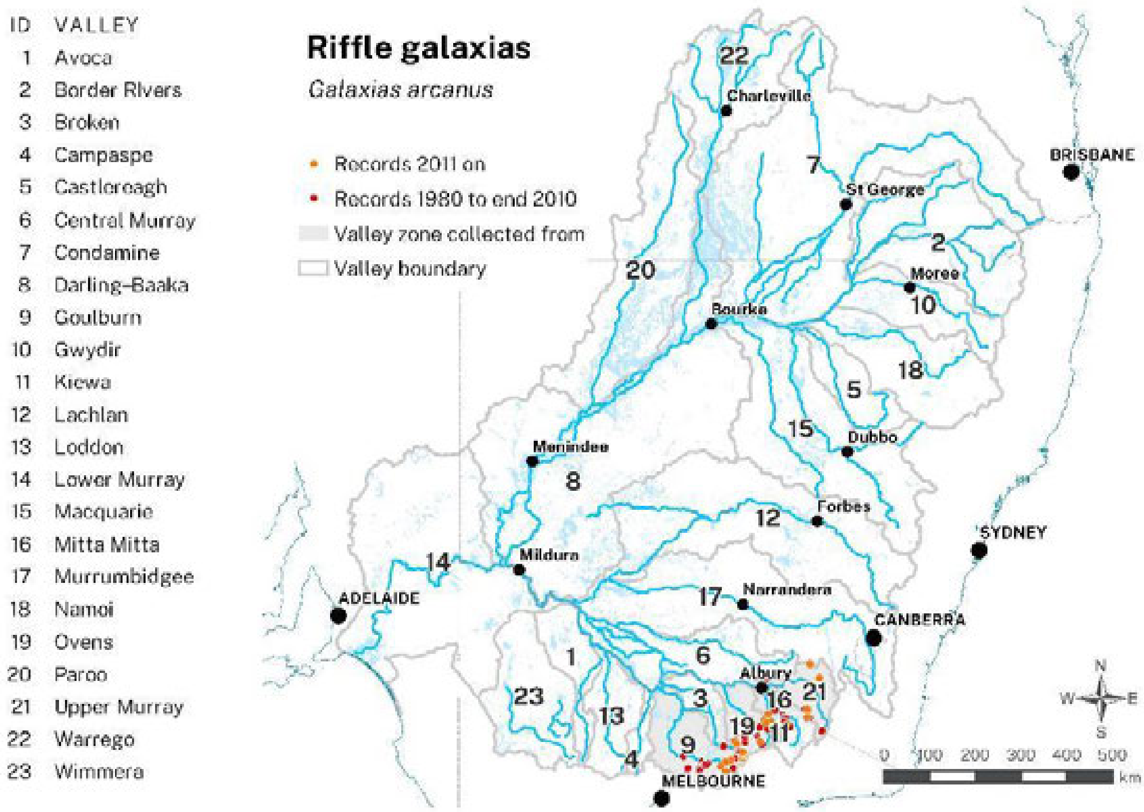
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

The riffle galaxias is a small-bodied, relatively restricted species found in the Southern Basin, primarily in Victoria. It is restricted to a thin band on the north of the Great Dividing Range in north-eastern Victoria, including the upper Murray River from near its headwaters and extending westward to the Goulburn River system. It is currently not recorded from the Murray River downstream from Albury, but there are occasional records from the NSW tributaries of the upper Murray (Raadik 2014, Lintermans 2023) As its name suggests, it has usually been recorded in shallow, fast-flowing riffles and runs from cold to relatively cool, clear water in flowing creeks to large rivers (Raadik 2014, Lintermans 2023). Previously part of the mountain galaxias complex, a recent taxonomic review resulted in its description as a new species (Raadik 2014).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Upper Murray	✓	✓
	Central Murray	X	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- As its name suggests, it has been usually recorded in shallow, fast-flowing and riffles and runs from cold to relatively cool, clear water in flowing creeks to large rivers (Raadik 2014, Lintermans 2023).
- A relatively restricted species across the south-eastern tributaries of the Murray River, the dedicated fish monitoring programs recorded individuals in from only six valleys in the SRA/MDBFS surveys from 2005 to 2010. The SRA/MDBFS surveys recorded the species in five valleys, missing the Central Murray and Broken valleys from the combined dataset.
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A relatively common species of no conservation concern.

Species: *Galaxias brevipinnis*

Common name: Climbing galaxias, broad-finned galaxias

Conservation status:

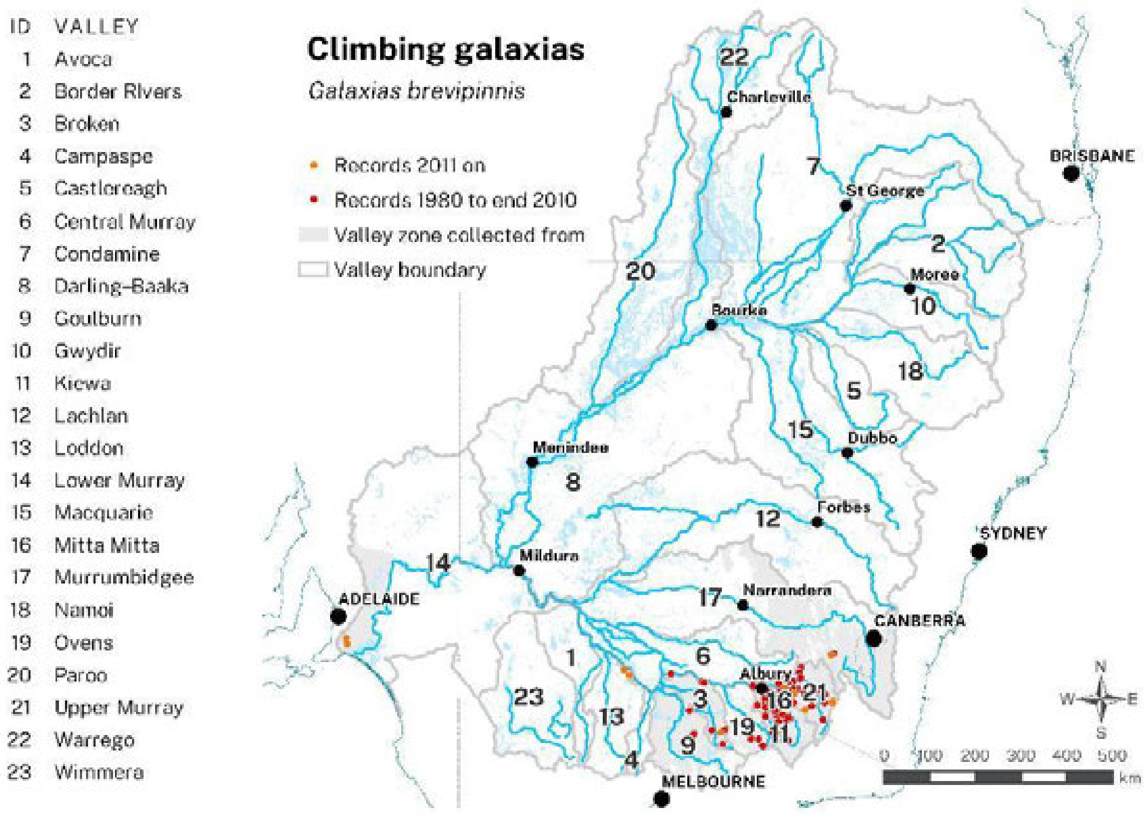
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

Climbing galaxias is a naturally semi-catadromous species whose larvae are swept downstream into the marine environment where they develop for 4–6 months before migrating back into freshwaters as whitebait (Lintermans 2023). It is only native in the lower Murray valley, where it has been rarely recorded from the Mount Lofty Ranges. The species exists as translocated landlocked populations in the Southern Basin, primarily in tributaries of the upper Murray where it was initially introduced via the Snowy Mountains Scheme (Waters et al. 2002). Its translocated range is slowly expanding where large impoundments serve as a marine substitute (Lintermans 2023).

The species has been recorded in two fewer river valleys, both in the Southern Basin, in 2011–2022 compared to 1980–2010. In both these valleys abundance was low in 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	X	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	X
	Ovens	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- An uncommon species only native to the lower Murray, but translocated populations in several valleys in the Southern Basin.

Native fish status assessment 2023

Species: *Galaxias fuscus*

Common name: Barred galaxias

Conservation status:

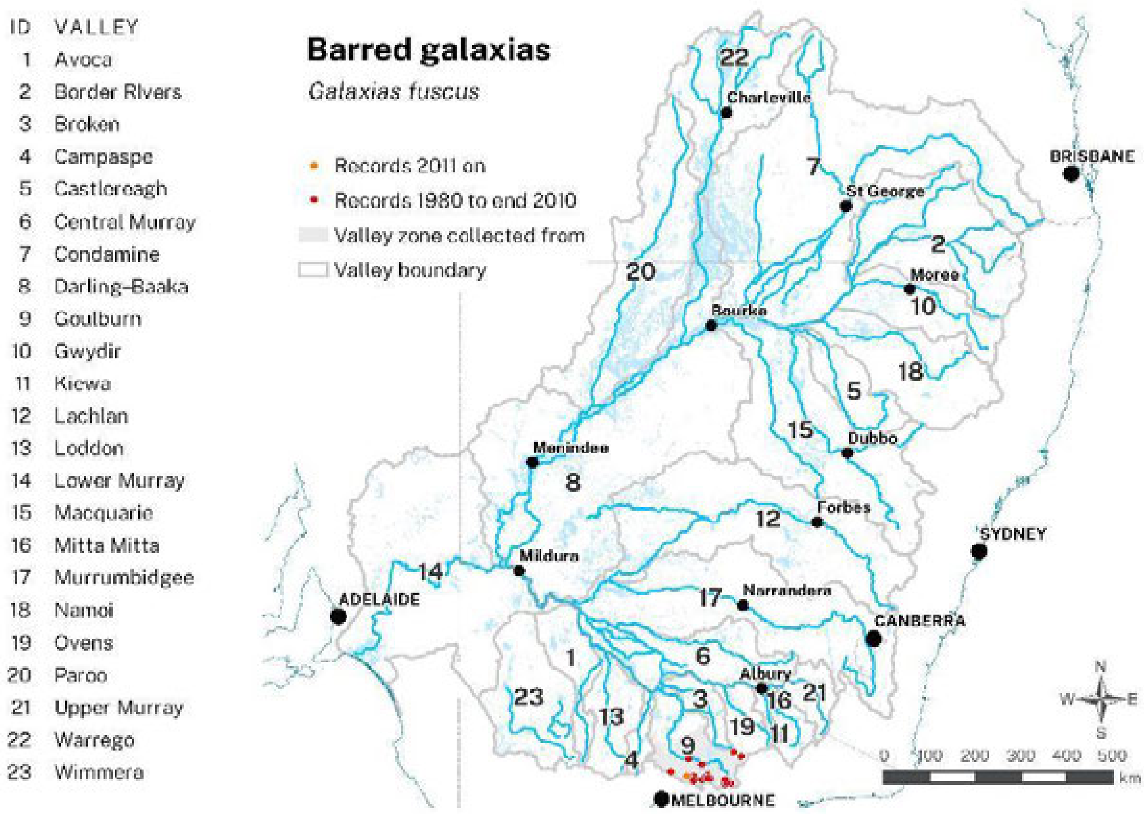
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
EN	EN	–	CE	–	–	–

CE = Critically Endangered; EN = Endangered; – = not assessed

Distribution (presence):

The highly threatened barred galaxias has suffered a catastrophic decline of >95% of its likely historical distribution and abundance. It is now only found in the headwaters (above 400 m altitude) of the Goulburn River catchment in the Southern Basin (Raadik 2014, 2019, Lintermans 2023).

The species has only been recorded in a single valley both pre- and post-2011.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Goulburn	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Occurs in small- to medium-sized, shallow, cool, clear, upland streams with moderate to fast flows and stony or sandy substrates (Raadik 2014, Lintermans 2023).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A restricted, highly threatened species that only occurs in a single valley in the Southern Basin. Active management to prevent and respond to trout invasion is essential for this species.

Species: *Galaxias maculatus*

Common name: Common galaxias, common jollytail

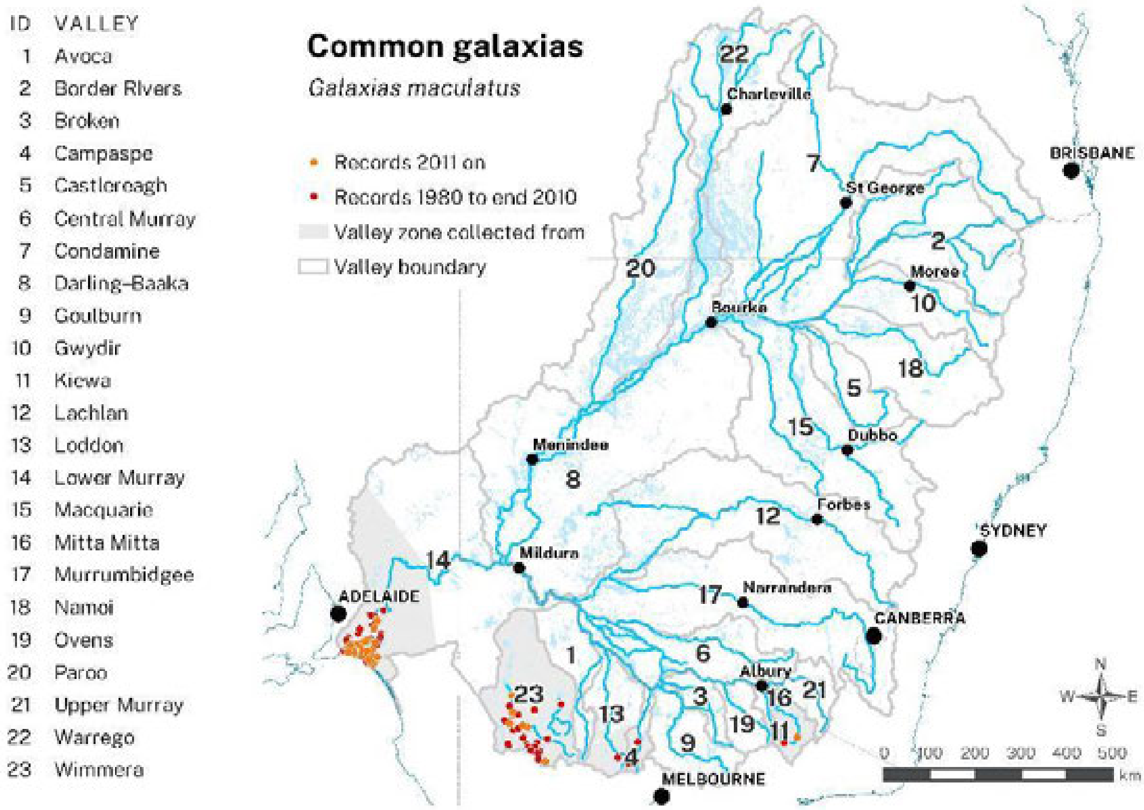
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

The common galaxias is a small-bodied, relatively restricted species primarily found in the western lowland tributaries and mainstem of the Murray River. It naturally occurs in the Lower Lakes (Alexandrina and Albert) (Bice 2010, Bice et al. 2021), extending up to approximately Mannum on the lower Murray and streams of the Mount Lofty Ranges in South Australia. Naturally occurring populations in coastal streams are catadromous, with larvae hatching from estuarine spawning sites utilising high tides to enter the marine environments where they remain for 90–125 days before returning to streams as whitebait the following spring (Pollard 1971, Barbee et al. 2011, Lintermans 2023). Populations in several lowland tributaries and the Mitta Mitta valley are considered translocations, probably introduced through water diversions from coastal streams or in bait buckets. Such landlocked populations in lakes spawn in inflowing tributaries. (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- This is a relatively restricted species across the southern tributaries of the Murray River. There is no conservation concern for this species in Australia, and it is regarded as a threat to other *Galaxias* species when translocated (Lintermans 2023).

Species: *Galaxias olidus*

Common name: Mountain galaxias

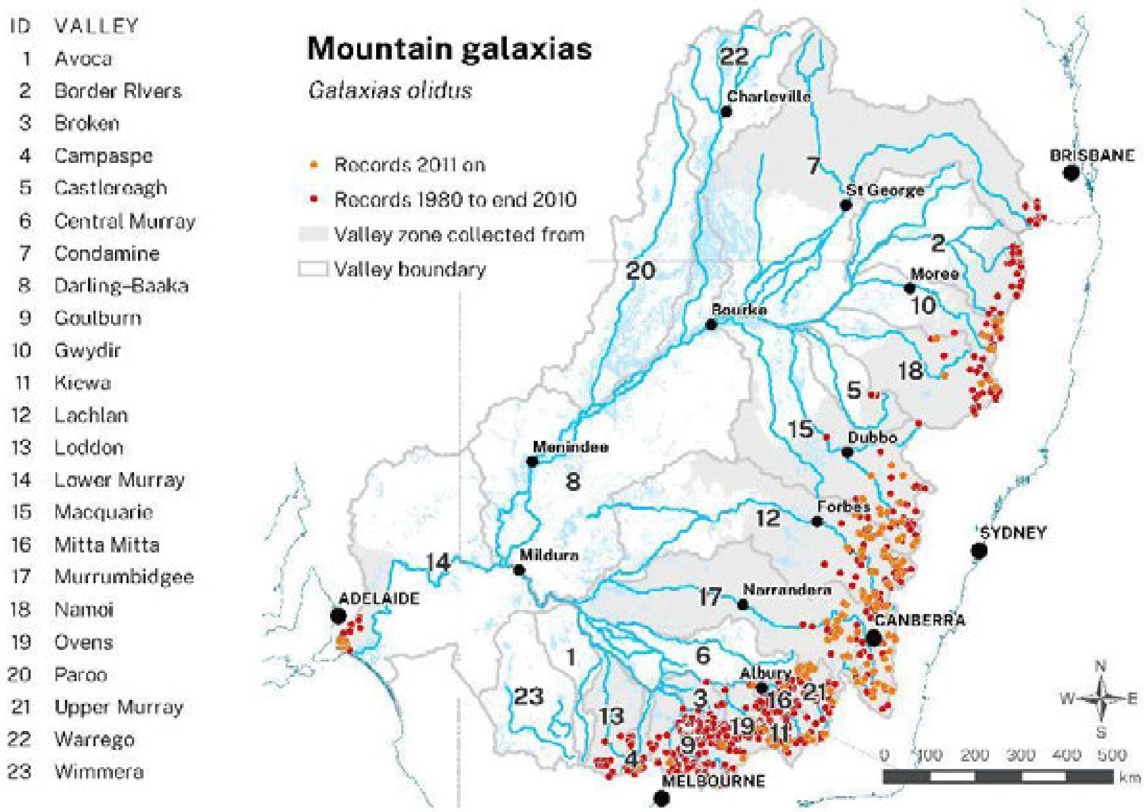
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	R	–	–	–	–

LC = Least Concern; R = Rare; – = not assessed

Distribution (presence):

The mountain galaxias is a small-bodied, widespread species occurring in both the Northern and Southern Basins. Recent taxonomic review has resulted in the description or redescription of 14 additional species from the mountain galaxias complex (Raadik 2014). It is commonly found across a range of elevations (despite its name) but is generally found in the southern and eastern portion of the Basin. It is found in a range of stream sizes from small creeks to larger rivers but is generally more abundant in upland habitats and it does not coexist well with trout (Raadik 2014, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	X
	Border Rivers	✓	X
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	X
	Macquarie	✓	✓
Southern Basin	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Mountain galaxias are found in a variety of habitats from small creeks to large rivers. The species can occur with other members of the mountain galaxias complex such as stocky, obscure and barred galaxias but often it is the only fish species present in small upland streams.
- It is often observed in schools in slower flowing or pool habitats where trout are absent. In situations where trout are abundant, galaxias may be restricted to very shallow edge habitats, among dense aquatic vegetation, rocks or timber debris and riffles.
- SRA/MDBFS data indicate that there has been a declining trend in abundance and distribution across the Basin (Figure 26).

Overall:

- A widespread species across the upper parts of river valleys, individuals in the dedicated fish monitoring programs were recorded from only 14 valleys from 1980 to 2010 in the SRA, and from 13 valleys by the SRA/MDBFS from 2011 onwards. This is a deficit of three and four valleys respectively to that for the combined fish dataset (17 valleys from 1980 to 2010).

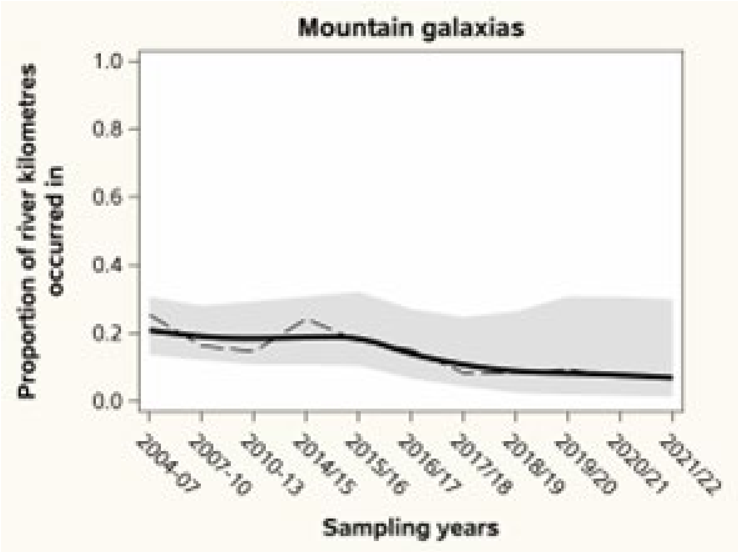


Figure 26. Estimate of proportion of river kilometres inhabited by mountain galaxias

Species: *Galaxias oliros*

Common name: Obscure galaxias

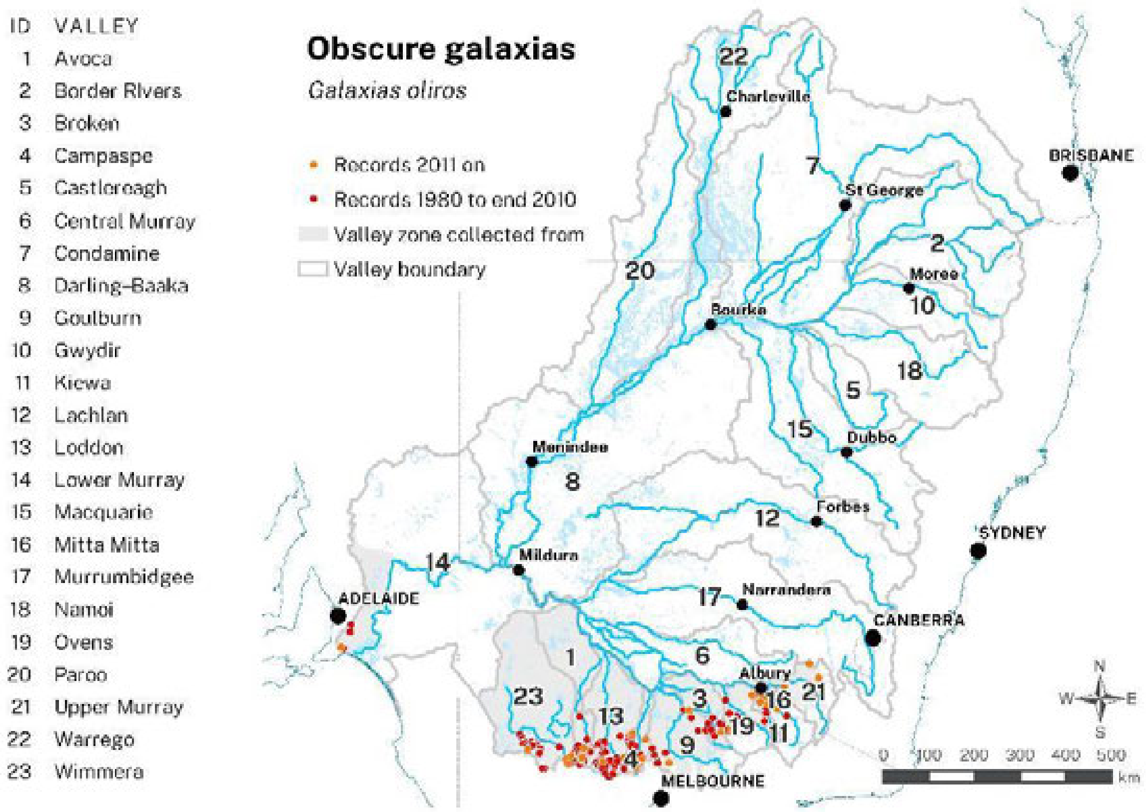
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

The obscure galaxias is a small-bodied, relatively widespread species found in the Southern Basin, largely south of the Murray River. It occurs north of the Murray in tributaries of the upper Murray and is also found in tributaries of the lower Murray draining the eastern Mount Lofty Ranges in South Australia. Previously part of the mountain galaxias complex, a recent taxonomic review resulted in its description as a new species (Raadik 2014). It is recorded from 0–600 m elevation, is widespread and common throughout its range and can be very abundant in swamps, billabongs and isolated pools (Raadik 2014, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Previously confused with mountain galaxias (*Galaxias olidus*), the obscure galaxias was described as a separate species in 2014, and many aspects of its ecology are unknown. However, some aspects are likely to be similar to other members of the mountain galaxias complex.
- Obscure galaxias occur in a range of stream sizes and types ranging from moderately fast-flowing small creeks to slow-flowing medium-to-large lowland rivers. It also occurs in billabongs, anabranches and some wetlands and is usually found among dense aquatic vegetation and timber debris (Lintermans 2023).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A widespread species across the southern tributaries of the Murray River, the dedicated fish monitoring programs recorded individuals from 11 valleys (SRA, 1980–2010) and 10 valleys (SRA/MDBFS, 2011 onwards). The missing valleys from the 2011 onwards fish monitoring program were Loddon and lower Murray with the additional valley being the Central Murray.

Native fish status assessment 2023

Species: *Galaxias ornatus*

Common name: Ornate galaxias

Conservation status:

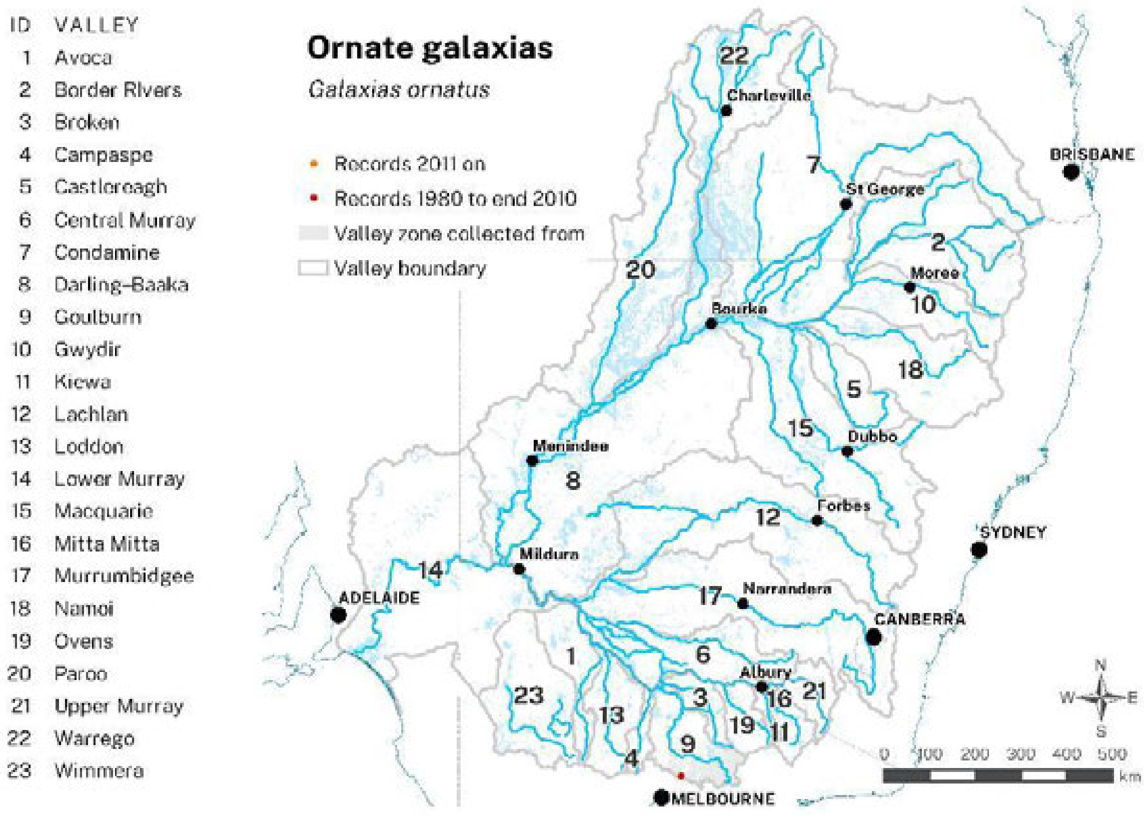
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

The ornate galaxias is a highly restricted small-bodied species found only in a single stream in the Yea River drainage, upstream of a waterfall in Goulburn valley in the Southern Basin (Raadik 2014, Lintermans 2023). Usually a species of southern coastal catchments in Victoria, it is unknown whether this population is a natural remnant in the MDB; a natural dispersal event across the dividing range; or is the result of a translocation (possibly as bait fish) (Raadik 2014, Lintermans 2023). Previously considered part of the mountain galaxias complex, a recent taxonomic review resulted in its reinstatement as a distinct species (Raadik 2014).

The species was recorded in a single valley in 1980–2010 and has not been recorded from 2011 onwards in the composite dataset.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Goulburn	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Like many other species in the mountain galaxias complex, it is impacted by trout in permanent streams, but can survive with trout in ephemeral streams where high temperatures disadvantage trout (Lintermans 2023).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A very restricted species only found in the upper Goulburn valley, no individuals were recorded in the dedicated fish monitoring programs by the SRA (2005–2010), or by the SRA/MDBFS from 2011 onwards.

Species: *Galaxias rostratus*

Common name: Flathead galaxias, Murray jollytail, flat-headed galaxias, flat-headed galaxias

Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
CR	CE	EX	VU	CE	–	–

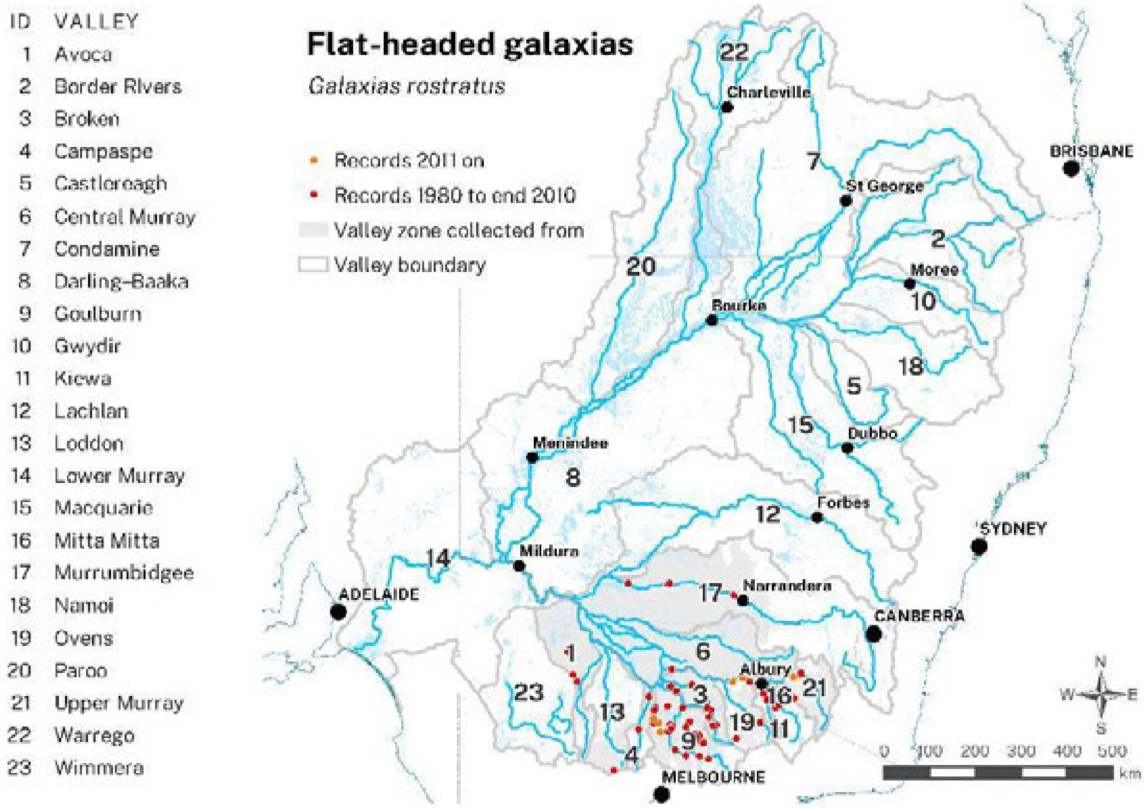
CE = Critically Endangered; CR = Critically Endangered (IUCN); EX = Extinct; VU = Vulnerable; – = not assessed

Distribution (presence):

The flathead galaxias is a rare, highly threatened small-bodied species found in NSW and Victoria in the Southern Basin, usually below 150 m elevation (TSSC 2016, Gilligan et al. 2019a, Lintermans 2023). It has suffered dramatic declines in recent decades (TSSC 2016, Gilligan et al. 2019a). Prior to 1980 it was relatively common in NSW in the Murrumbidgee into the early 1970s, with four isolated records of larval/juvenile individuals in 1995, but not recorded since (TSSC 2016, Lintermans 2023). Historic single records are known from the Lachlan (1972) and Macquarie valleys (1881) (Lintermans 2023). The last population known in NSW (near Albury) has not been recorded since 2003.

While there is no quantitative information on population trends in the species, it is considered to have experienced substantial declines in distribution and abundance, much of which occurred prior to the Millennium drought. The species is now assumed extinct across much of its former range and only irregularly recorded in extremely low numbers in other areas.

The species was recorded in 10 valleys (1980–2010), falling to just three valleys (2011 onwards).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	X
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Mitta Mitta	✓	X
	Kiewa	✓	X
	Broken	✓	X
	Goulburn	✓	✓
	Campaspe	✓	X
	Loddon	✓	X
	Avoca	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Occurs in a variety of habitats including billabongs, lakes, swamps and rivers, with a preference for still or slow-flowing waters (TSSC 2016, Lintermans 2023).
- Off-channel habitats where this species often occurs are poorly sampled in the dedicated fish monitoring programs (SRA/MDBFS). In these programs individuals were recorded from only a single valley (Goulburn) from 2011 onwards, (SRA/MDBFS) with no individuals recorded by the SRA from 2005 to 2010).
- While there is no quantitative information on population trends in the species, it is considered to have experienced substantial declines in distribution and abundance, much of which occurred prior to the Millennium drought (Whiterod et al. 2019, 2021c).
- The species is now assumed extinct across much of its former range and only irregularly recorded in extremely low numbers in other areas.
- There is no data from which to accurately assess population structure or recruitment.
- While there has not been any greater insight provided on the status of flathead galaxias since the Millennium drought, the decline of the species is presumed to continue.

Overall:

- A rare species now restricted to the southern tributaries of the Murray River and the upper Murray, this species has continued to decline, resulting in it being nationally listed in 2016 (TSSC 2016, Whiterod et al. 2019, Zukowski et al. 2021).
- Improved knowledge on distribution may accrue from the recently developed eDNA probe.

Native fish status assessment 2023

Species: *Galaxias tantangara*

Common name: Stocky galaxias, Tantangara galaxias

Conservation status:

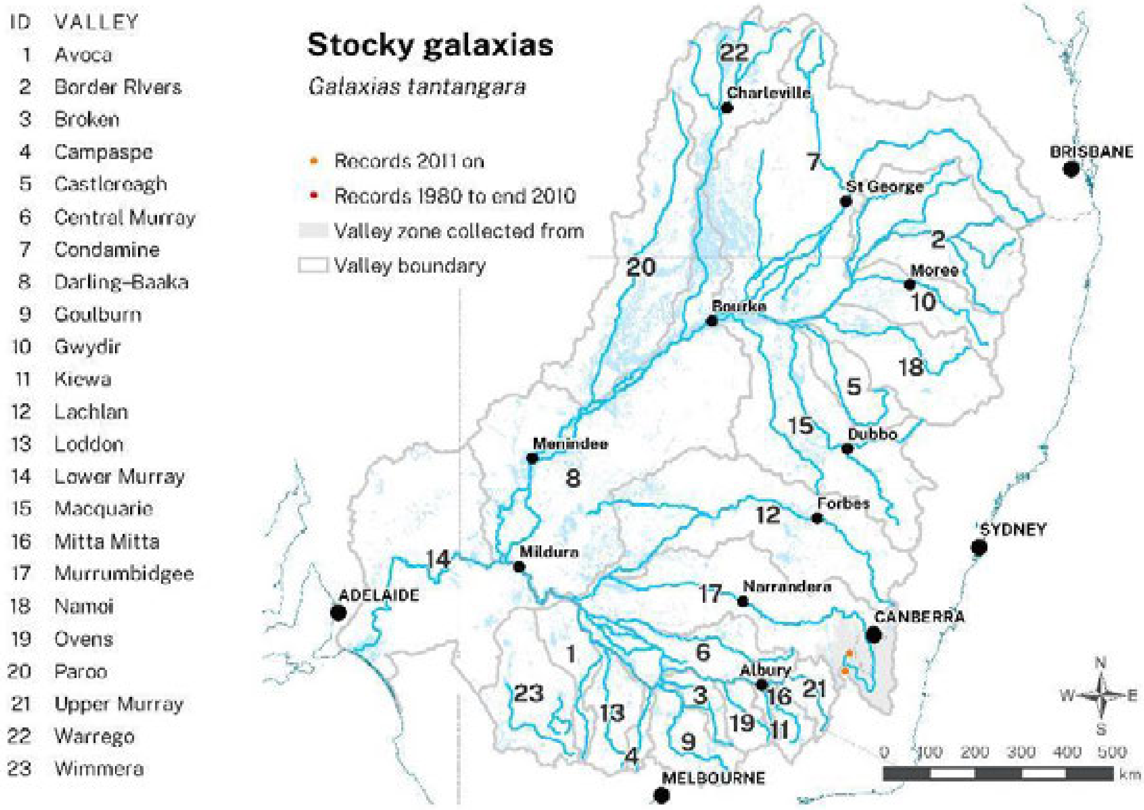
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
CR	CE	–	–	CE	–	–

CE = Critically Endangered; CR = Critically Endangered (IUCN); – = not assessed

Distribution (presence):

The stocky galaxias is a critically endangered, range-restricted, small-bodied species found only in the Murrumbidgee catchment of the Southern Basin (Raadik 2014, Lintermans and Allan 2019, Lintermans et al. 2020, TSSC 2021, Lintermans 2023). Initially only known from a single small stream upstream of Tantangara Reservoir, a second small population was recently discovered in another small tributary in the headwaters of the Goodradigbee River (Lintermans et al. 2021). The species has suffered a dramatic decline (>95%) as a result of predatory trout, and now only occurs upstream of trout barriers in the form of large waterfalls (Raadik 2014, Lintermans et al. 2021, Lintermans 2023). Previously part of the mountain galaxias complex, a recent taxonomic review resulted in its description as a new species (Raadik 2014).

The species was recorded in a single valley both in 1980–2010 and from 2011 onwards.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Murrumbidgee	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Now an inhabitant of very small (<1 m wide, 20 cm deep) subalpine streams in Kosciusko National Park, this species was likely much more widespread in this valley prior to the introduction of trout. No individuals were recorded in the dedicated fish monitoring programs by the SRA (2005–2010), or by the SRA/MDBFS from 2011 onwards.
- There are insufficient data to accurately assess trends in abundance and recruitment.
- Bred for the first time in captivity in 2022.

Overall:

- A very restricted, severely threatened species only found in the upper Murrumbidgee valley.
- A predicted increased frequency of extreme events such as severe drought and bushfire under climate change will seriously threaten this species.

Species: *Galaxias truttaceus*

Common name: Spotted galaxias, spotted mountain galaxias, spotted mountain trout, trout minnow

Conservation status:

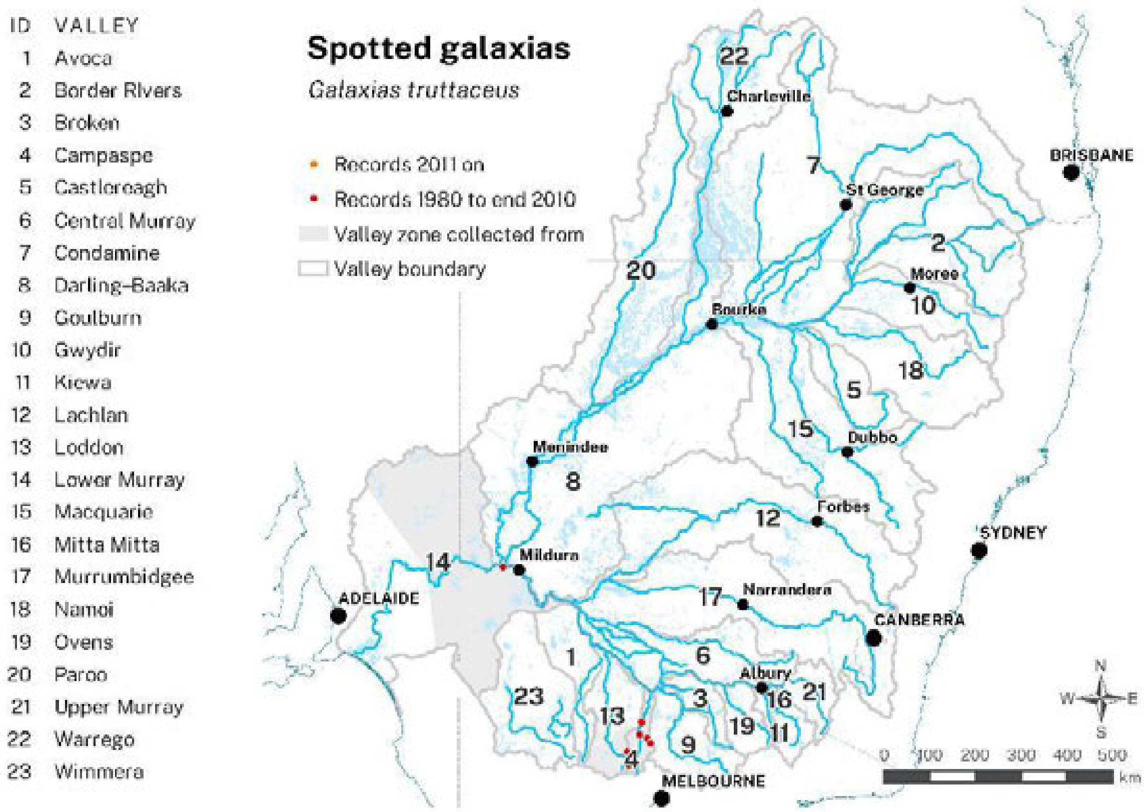
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	EN*	EN	–	–	–	–

EN = Endangered; LC = Least Concern; – = not assessed
* Only the Western Australia population

Distribution (presence):

The spotted galaxias is a rare, small-bodied species normally found in coastal streams and is one of the larger galaxiid species (along with *Galaxias brevipinnis*) found in the Basin. It can reach lengths of 200 mm but is generally <140 mm (Lintermans 2023). It is present in the MDB almost exclusively in area of central Victoria in the Southern Basin (Lintermans 2023). Within this area it is considered likely to be a translocated species, probably introduced as live bait by anglers. It is also possible that it represents a small remnant natural population. A single specimen was also collected as a larvae in 2002 in the lower Murray (Lintermans 2023).

The species was recorded in three valleys (1980–2010), falling to just a single valley from 2011 onwards.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	X
	Campaspe	✓	✓
	Loddon	✓	X
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- It is not well sampled by the dedicated fish monitoring programs, with individuals recorded in very low abundance (two individuals) from only a single valley (Campaspe) by the SRA from 2004 to 2010, and by the SRA/MDBFS from 2011 onwards (five individuals).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- Normally a fish of coastal streams, in the MDB it is an uncommon, and likely translocated species restricted to the Loddon and Campaspe valleys, plus the single larval specimen from 2002 in the lower Murray (Lintermans 2023). While listed as threatened in Western Australia and South Australia (at the edge of its range), it is not of conservation concern in NSW, Victoria or Tasmania.

Species: *Geotria australis*

Common name: Pouched lamprey, pouch lamprey

Conservation status:

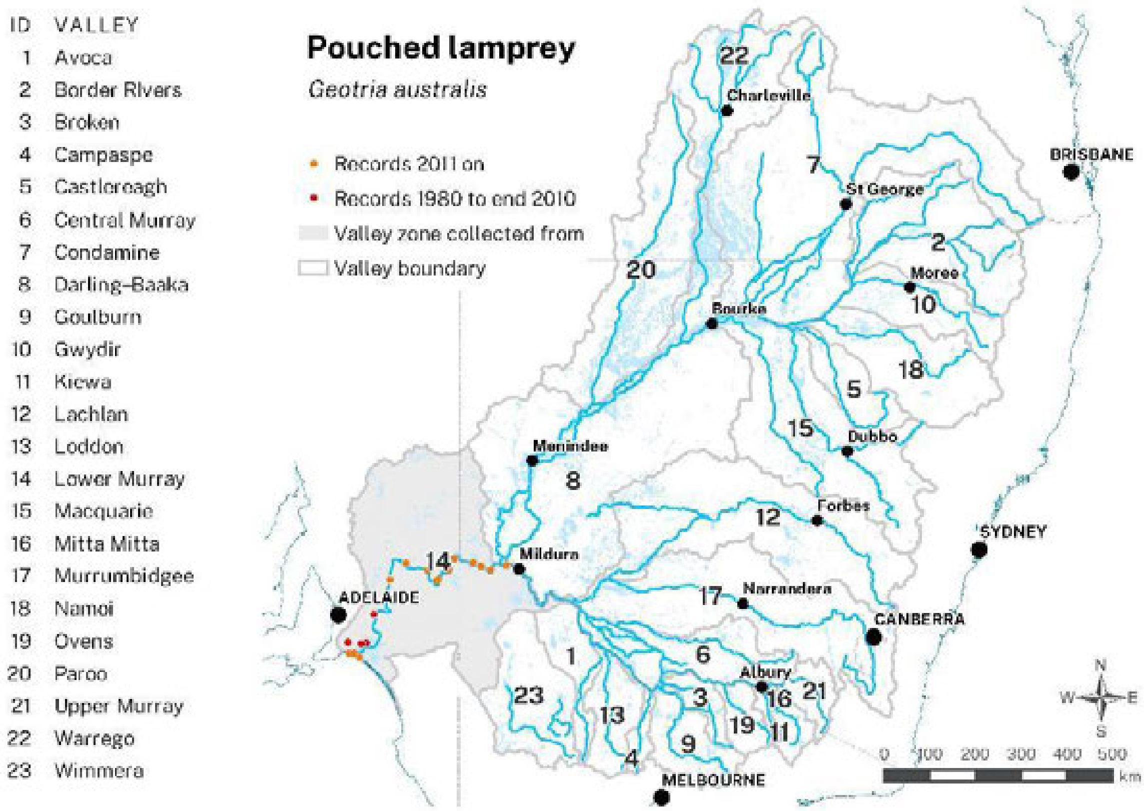
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
DD	–	R	–	–	–	–

DD = Data Deficient; R = Rare; – = not assessed

Distribution (presence):

Pouched lamprey is one of only two anadromous fish species in the MDB and is generally found in South Australia and in NSW in the lower and mid-Murray (Bice et al. 2020, Lintermans 2023). This species has the widest distribution of all lampreys, with a wide southern temperate distribution including Australia, New Zealand and Chile. It is known to have declined in Australia and New Zealand (Bice et al. 2019). Recent improvements to fish passage including fishways on the barrages and the completion of the Sea to Hume fish passage program means the species is likely to be recorded in more upstream locations in coming years. Monitoring of movement of several passive integrated transponder (PIT)-tagged individuals in 2019–21 recorded it migrating 274–878 km (locks 1–11) upstream of the barrages (Bice et al. 2020, 2021). The 2020–21 catch of this species in the Coorong – Lower Lakes monitoring program was the highest since the program's first year in 2006–07 (Bice et al. 2021).

The species has been recorded in one additional river valley in 2011–2022 compared with 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Central Murray	X	✓
	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Most of the adult life is spent at sea. Adults migrate upstream from the sea to breed. The spawning run can involve distances of hundreds of kilometres (Bice et al. 2019, 2020, 2021, Lintermans 2023).
- The species is a primary target of the CLLMM fish monitoring program but no individuals were captured in the SRA (2004–2013) or the MDBFS (2014–22).
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A species that is rarely recorded in conventional MDB sampling programs and considered rare in South Australia. Recent improvements to fish passage including fishways on the barrages and the completion of the Sea to Hume fish passage program means the species is likely to be recorded in more upstream locations in coming years.

Species: *Hypseleotris acropinna*

Common name: Cryptic carp gudgeon

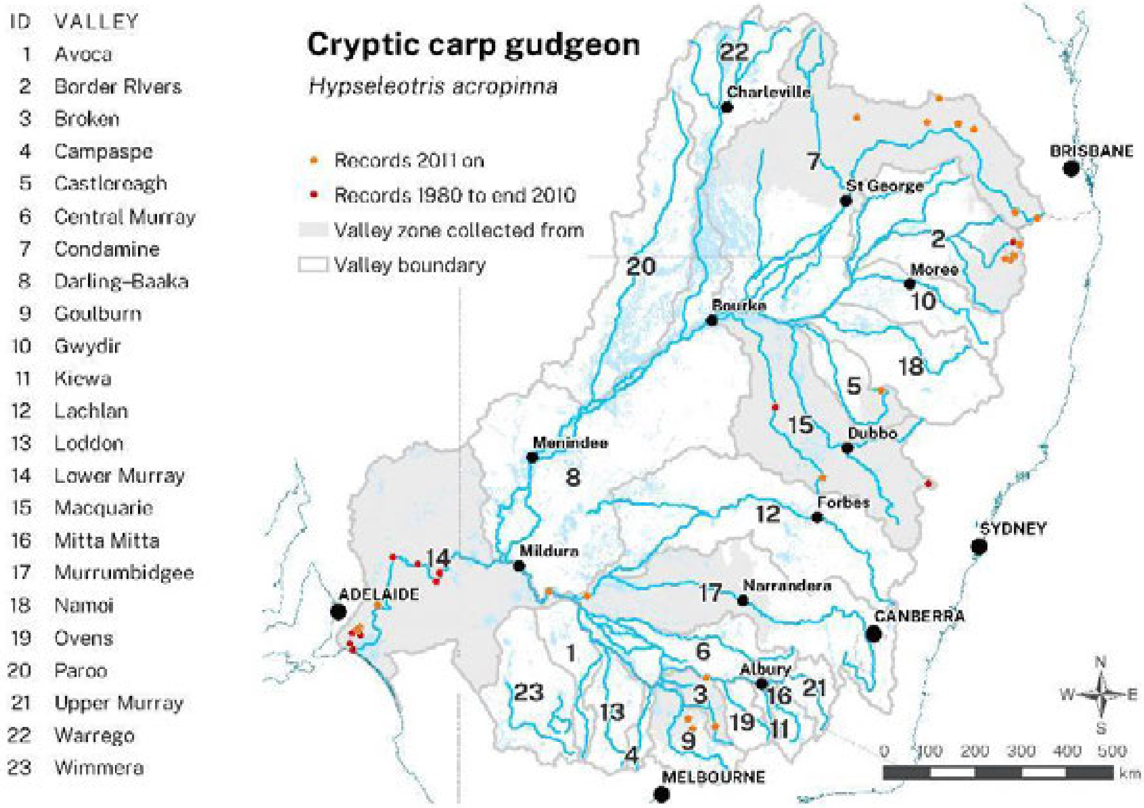
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

There is considerable confusion over the identification of ‘carp gudgeons’ in south-eastern Australia. Genetic studies in the late 1990s identified that there were several sexual species, as well as a range of hemiclonal unisexual hybrids (Bertozzi et al. 2000). Many of the carp gudgeon groups formerly considered as ‘species’ were not formally described (e.g. Lake’s, Murray–Darling and Midgley’s carp gudgeons). Because many of the hemiclonal and sexual lineages look very similar, for about 20 years carp gudgeons in the MDB have been combined into a generic group and referred to as ‘*Hypseleotris* spp.’(i.e. *Hypseleotris* of undefined species). In late 2022, five species were formally described or redescribed and a range of hemiclonal hybrids were identified (Thacker et al. 2022). In the MDB, cryptic carp gudgeon is one of four sexual species now recognised as present (western, bald, boofhead and cryptic carp gudgeons), plus multiple hemiclonal unisexual lineages of hybrid origin between the latter three species. The distribution table below only shows valleys where genetically verified specimens have been recorded (and so absences in each time period are spurious): the distribution of cryptic carp gudgeon is likely much wider (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	X	✓
	Border Rivers	✓	✓
	Castlereagh	X	✓
	Macquarie	✓	✓
Southern Basin	Murrumbidgee	X	✓
	Central Murray	X	✓
	Lower Murray	✓	✓
	Broken	X	✓
	Goulburn	X	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- This group of species is found in slow-flowing or still waters, normally associated with macrophytes or other aquatic vegetation (which provide food, spawning sites and cover). Two to three sexual species of carp gudgeon plus three hemiclonal hybrids often occur sympatrically (Lintermans 2023).
- As noted above, most of the carp gudgeon records are for combined taxa; carp gudgeon are adequately represented in riverine habitats by the conventional MDB fish monitoring programs, but their abundance in wetland or off-channel habitats is not adequately represented.
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- Carp gudgeons are a widespread and abundant group, and cryptic carp gudgeon is also likely to be widespread. The species is not of conservation concern.

Native fish status assessment 2023

Species: *Hypseleotris bucephala*

Common name: Boofhead carp gudgeon

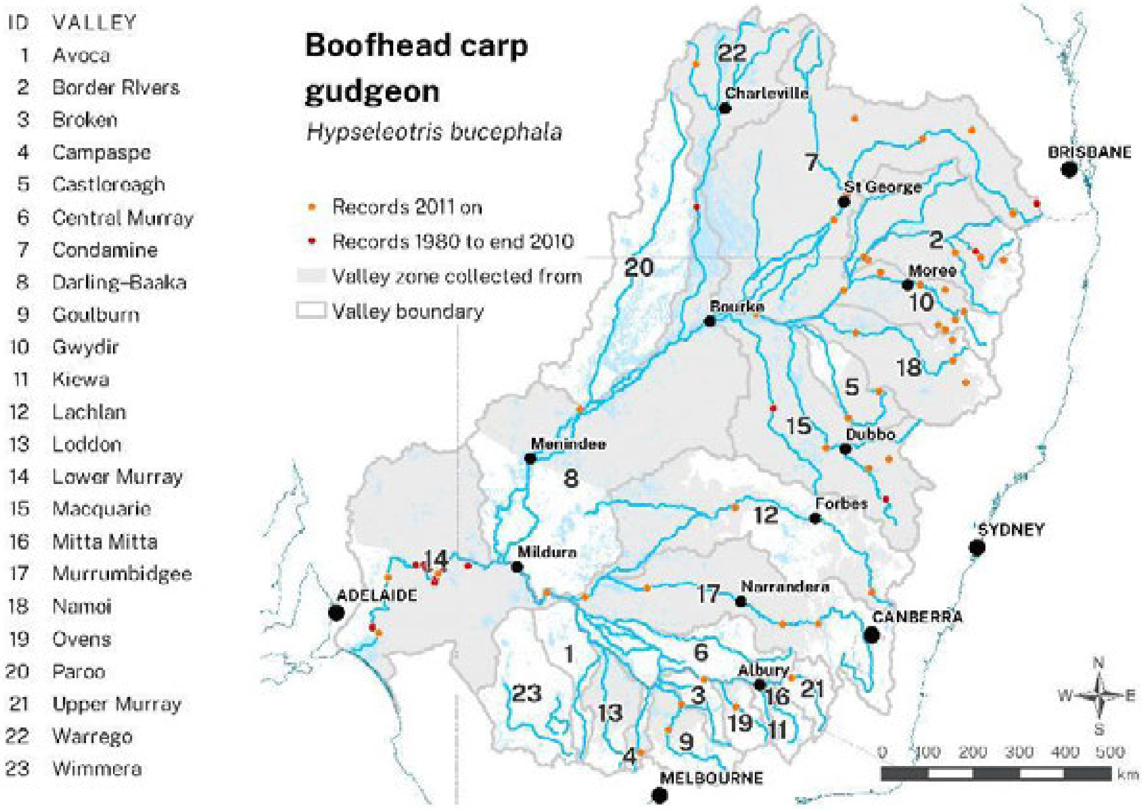
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

There is considerable confusion over the identification of 'carp gudgeons' in south-eastern Australia, which is only now being resolved (see cryptic carp gudgeon, above). In the MDB, boofhead carp gudgeon is one of four sexual species now recognised as present, plus multiple hemiclonal unisexual lineages of hybrid origin. The distribution table below only shows valleys where genetically verified specimens have been recorded (and so absences in each time slice are spurious): the distribution of boofhead carp gudgeon is likely much wider (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	X	✓
	Castlereagh	X	✓
	Macquarie	✓	✓
	Barwon–Darling	X	✓
Southern Basin	Lower Darling	X	✓
	Lachlan	X	✓
	Murrumbidgee	X	✓
	Upper Murray	X	✓
	Central Murray	X	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Ovens	X	✓
	Goulburn	X	✓
	Campaspe	X	✓
	Loddon	X	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- This group of species is found in slow-flowing or still waters, normally associated with macrophytes or other aquatic vegetation (which provide food, spawning sites and cover). Two to three sexual species of carp gudgeon plus three hemiclonal hybrids often occur sympatrically (Lintermans 2023).
- Most carp gudgeon records are for combined taxa; carp gudgeon are adequately represented in riverine habitats by the conventional MDB fish monitoring programs, but their abundance in wetland or off-channel habitats is not adequately represented.
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- Carp gudgeons are a widespread and abundant group, and boofhead carp gudgeon is likely also widespread. It is not of conservation concern.

Native fish status assessment 2023

Species: *Hypseleotris gymnocephala*

Common name: Bald carp gudgeon

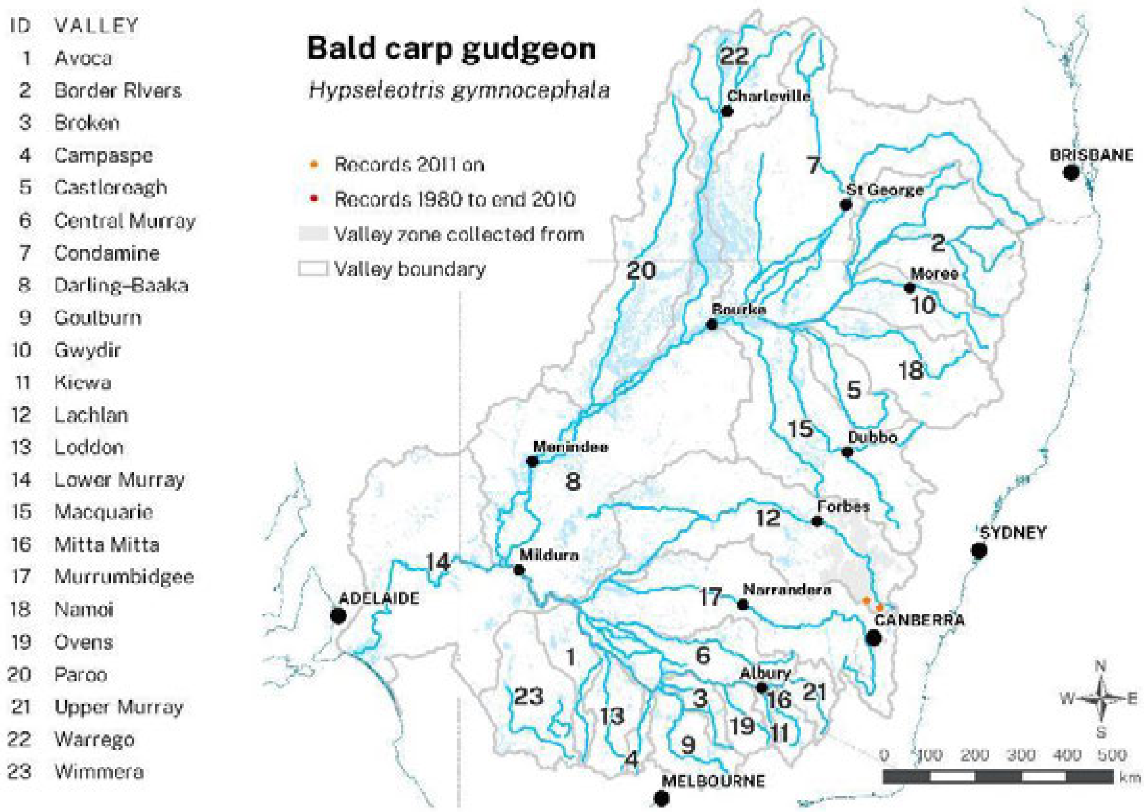
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
CR	CE	–	–	–	–	–

CE = Critically Endangered; CR = Critically Endangered (IUCN); – = not assessed

Distribution (presence):

There is considerable confusion over the identification of 'carp gudgeons' in south-eastern Australia, which is only now being resolved (see cryptic carp gudgeon, above). In the MDB, bald carp gudgeon is one of four sexual species now recognised as present, plus multiple hemiclonal unisexual lineages of hybrid origin. Bald carp gudgeon is the long-missing sexual species that generates the hemiclonal hybrid lineage previously known as Lake's carp gudgeon (Thacker et al. 2022). Bald carp gudgeon is a highly threatened and extremely range-restricted species only known from two small tributary streams in the upper Lachlan catchment (Unmack and Pearce 2019, Lintermans 2023). Despite extensive genetic screening of carp gudgeons, these remain the only two known locations for this species (Unmack et al. 2019, Thacker et al. 2022, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lachlan	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- This species is found in slow-flowing or still waters, normally associated with macrophytes or other aquatic vegetation (which provide food, spawning sites and cover). It occurs with western carp gudgeon (which does not produce hemiclonal hybrids) in one location, and without other carp gudgeons in the other location (Lintermans 2023).
- As noted above, most of the carp gudgeon records are for combined taxa; carp gudgeon are adequately represented in riverine habitats by the conventional MDB fish monitoring programs, but their abundance in wetland, off-channel or small tributary habitats is not adequately represented.
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A highly threatened species with an extremely restricted distribution. Contamination with other carp gudgeon taxa from fish stockings at nearby sites could rapidly result in the loss of this species.

Native fish status assessment 2023

Species: *Hypseleotris klunzingeri*

Common name: Western carp gudgeon

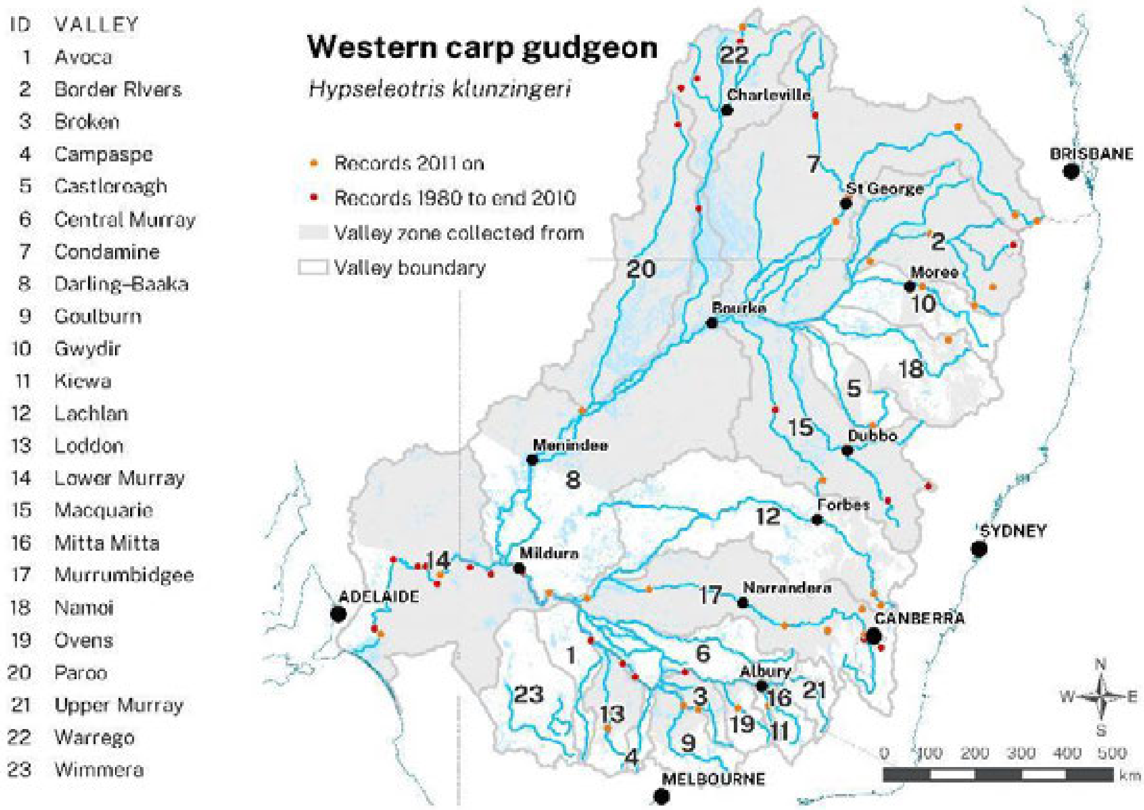
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

There is considerable confusion over the identification of 'carp gudgeons' in south-eastern Australia, which is only now being resolved (see cryptic carp gudgeon, above). In the MDB, western carp gudgeon is one of four sexual species now recognised as present, plus multiple hemiclonal unisexual lineages of hybrid origin. Western carp gudgeon is not of conservation concern (Unmack 2019) and do not hybridise with other carp gudgeons. Western carp gudgeon is the only carp gudgeon that occurs in the upper Murrumbidgee catchment (Lintermans 2023). The distribution table below only shows valleys where genetically verified specimens have been recorded (and so absences in each time slice are spurious): the distribution of western carp gudgeon is likely wider (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	X	✓
	Macquarie	✓	✓
	Barwon–Darling	X	✓
Southern Basin	Lower Darling	X	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Loddon	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	?	?

– = species absent from basin; ? = presence uncertain

Population dynamics:

- Carp gudgeons are found in slow-flowing or still waters, normally associated with macrophytes or other aquatic vegetation (which provide food, spawning sites and cover).
- As noted above, most of the carp gudgeon records are for combined taxa; carp gudgeon are adequately represented in riverine habitats by the conventional MDB fish monitoring programs, but their abundance in wetland, off-channel or small tributary habitats is not adequately represented.
- There are insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- Western carp gudgeon is a widespread and abundant species and is not of conservation concern (Unmack 2019).

Species: *Leiopotherapon unicolor*

Common name: Spangled perch, spangled grunter, jewel perch

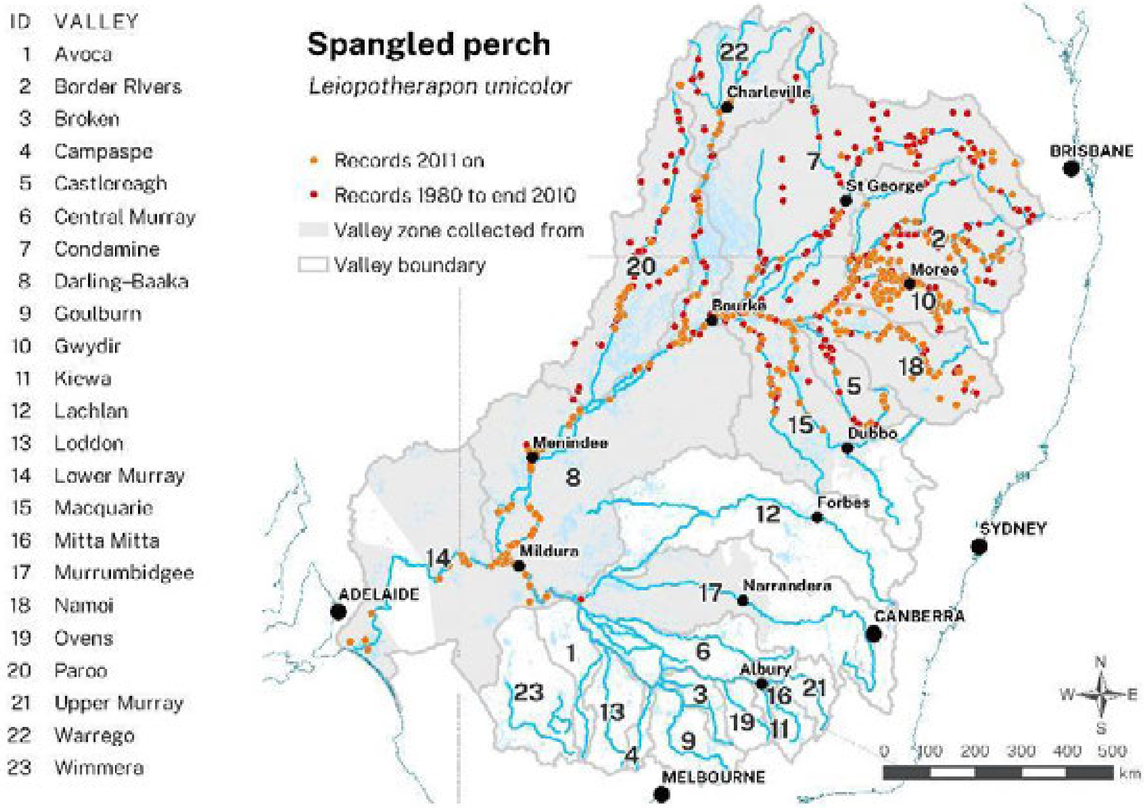
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

A small- to medium-sized hardy species that it can survive temperatures up to 40 °C, but is relatively intolerant of colder water, and so while it can occur in the Southern Basin after displacement by floods, it does not persist (Ellis et al. 2015, Lintermans 2023). Significant numbers were recorded in the Southern Basin following the breaking of the Millennium drought, but they had largely disappeared by 2015 (Ellis et al. 2015).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- This species is well adapted to colonising and surviving in diverse environments including rivers, billabongs, lakes, isolated dams, bore-drains, wells and waterholes in intermittent streams (Lintermans 2023).
- SRA/MDFS data suggest that the abundance and distribution of spangled perch in the Northern Basin has increased in recent years (Figure 27), perhaps as a result of widespread flooding.
- There are insufficient data to accurately assess population structure or recruitment.

Overall:

- A widespread and abundant species of northern Australia and the Northern Basin, which occasionally is displaced to the Southern Basin. Not of conservation concern.

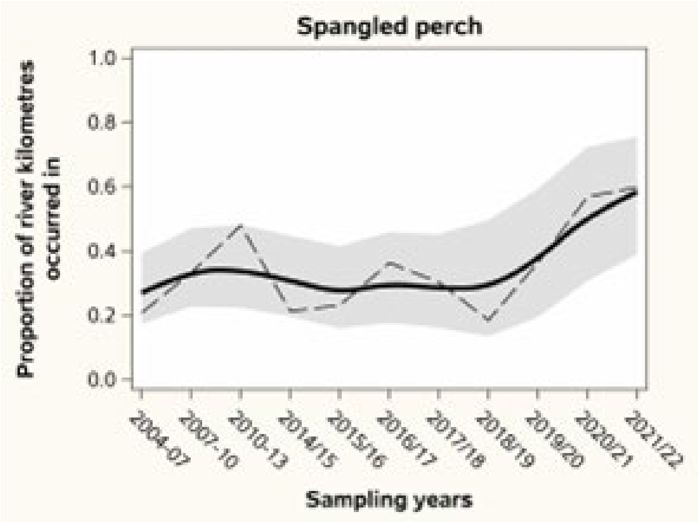


Figure 27. Estimate of proportion of river kilometres inhabited by spangled perch

Native fish status assessment 2023

Species: *Maccullochella macquariensis*

Common name: Trout cod, bluenose

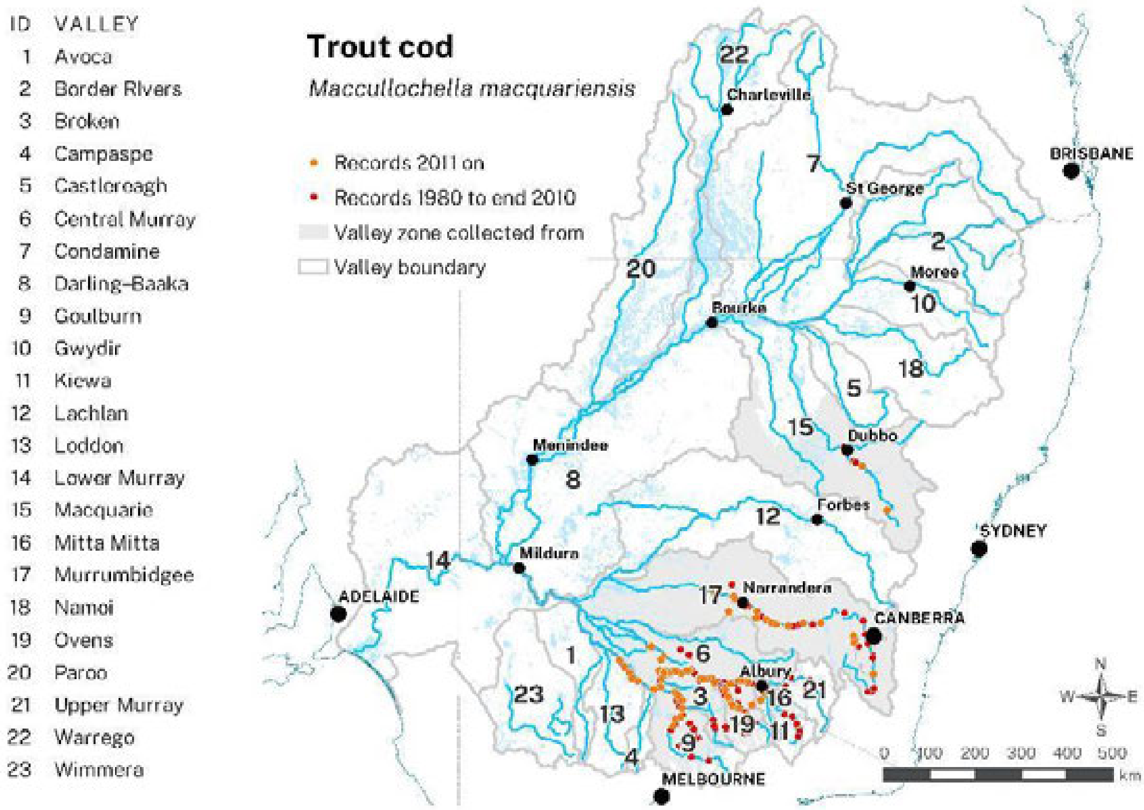
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
VU	EN	EX	EN	EN	EN	–

EN = Endangered; EX = Extinct; VU = Vulnerable; – = not assessed

Distribution (presence):

A large, deep-bodied, endangered fish only formally described in 1972 following major declines in the species. Early confusion regarding the identification of trout cod makes some of its historic distribution unclear. Trout cod was originally described from the Macquarie River, where it has not been recorded since the 1820s, and a single angler record from the Lachlan catchment is the only record from that valley. Declines in the Southern Basin were profound (Cadwallader 1977, Douglas et al. 1994), and by the mid-1980s it was only present in two locations, one of which was a historic translocation (Koehn et al. 2013). It is one of the few large-bodied species that has shown signs of recovery after 30+ years of concerted conservation management (Koehn et al. 2013, 2019b).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Macquarie	✓	✓
Southern Basin	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Mitta Mitta	✓	X
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	X
	Goulburn	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- The species is usually associated with deeper water (pools) and instream cover such as logs and boulders, and where it co-occurs with Murray cod in the Murray River, it occupies slightly faster-flowing locations towards the middle of the river in faster-flowing waters (Koehn and Nicol 2014, Koehn et al. 2020b, Lintermans 2023).
- First listed as threatened in the 1980s and reduced to one truly natural population in the mid-Murray River, progress over three successive national recovery plans (spanning 18+ years) have increased the number of populations and their extent.
- Specifically, the establishment of new populations using hatchery stocking has been successful; this has used the stocking strategy and adaptive management approach outlined by Bearlin et al. (2002) and Todd et al. (2004).
- New, regularly self-recruiting trout cod sub-populations have been successfully established in the Ovens, Goulburn and Murrumbidgee rivers (Ebner et al. 2007, 2009, Lyon et al. 2012, Koehn et al. 2013).

Overall:

- A species that is slowly recovering in the Southern Basin following decades of conservation management but Northern Basin populations show little sign of recovery.

Species: *Maccullochella peelii*

Common name: Murray cod, goodoo

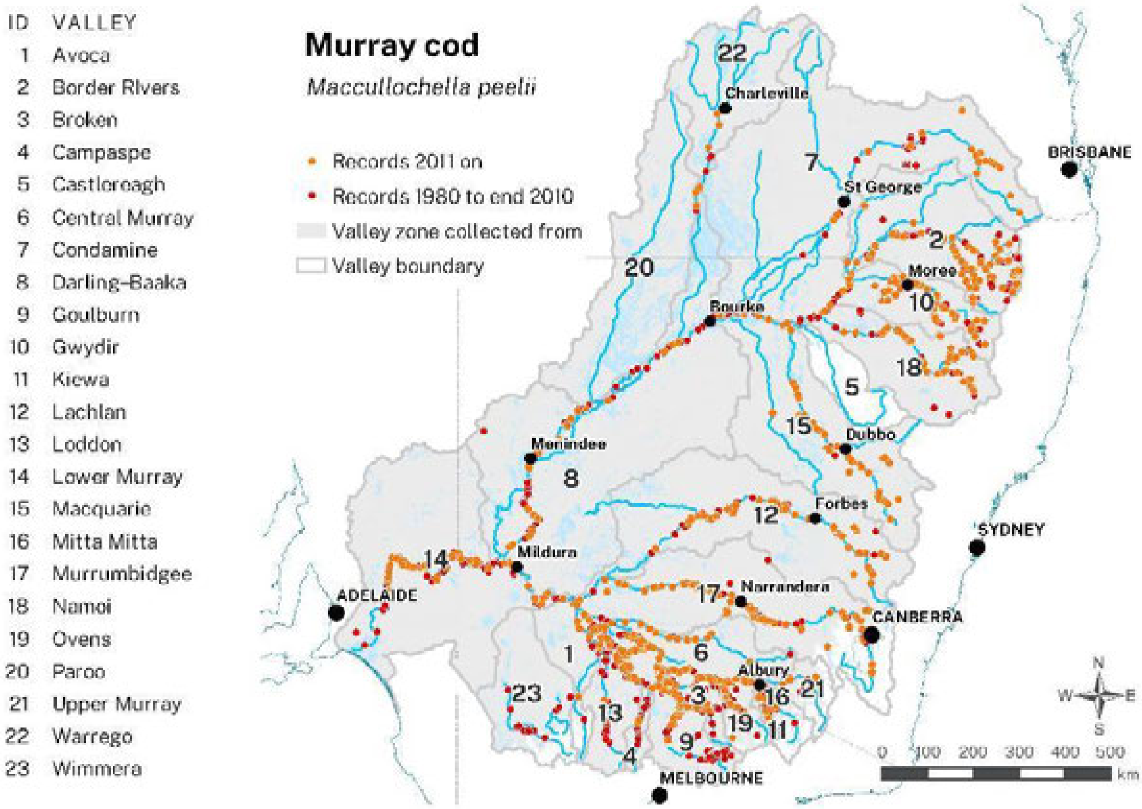
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	VU	EN	EN	–	–	REG

EN = Endangered; LC = Least Concern; REG = Regulated; VU = Vulnerable; – = not assessed

Distribution (presence):

This iconic species is widespread across the MDB, occurring in all river valleys and the Lower Lakes. Nationally listed as a Vulnerable species in 2003, recreational fishery management (stocking, size and bag limits, closed season) and broader conservation actions (fishways, habitat rehabilitation, flow management) have seen this species now stabilised and expanding in range and abundance in many rivers (Gilligan et al. 2019b, Rowland 2020, NSW DPI unpublished data, Woinarski et al. 2023). Along with other large-bodied species, it has disappeared from the Paroo.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	X
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	X
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- Murray cod is a riverine species that is readily captured with standard electrofishing methods, although detection and capture may vary with conditions and fish size (i.e. smaller fish will be under-sampled) (Lyon et al. 2014).
- Basin-scale reporting indicates that overall abundance has increased since 2005 (Figure 28).
- There are some concerns about reductions in / extirpation from other areas such as the Paroo River (Sarac et al. 2011).
- Heavily impacted by fish deaths (Thiem et al. 2017, 2019).
- Widely sought and harvested by recreational fishers, although catch and release is now very common in some reaches, especially for larger fish.

- Widely produced in hatcheries and stocked by government agencies and recreational fishers.

Overall:

- Overall, populations of this species are relatively stable, with an increasing trend in abundance and distribution in recent years.
- The species is heavily managed by state agencies, especially to manage harvest and stocking. In light of this, some jurisdictions may review the conservation status of the species.
- The status of the species on the IUCN Red List was downlisted to Least Concern in 2019 (Gilligan et al. 2019b) and it is no longer considered to meet the criteria for EPBC listing (Woinarski et al. 2023).

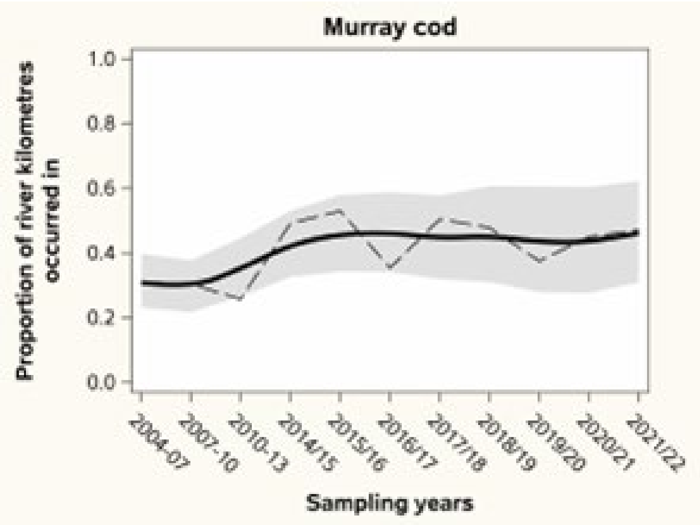


Figure 28. Estimate of proportion of river kilometres inhabited by Murray cod

Native fish status assessment 2023

Species: *Macquaria ambigua*

Common name: Golden perch, yellow belly, callop

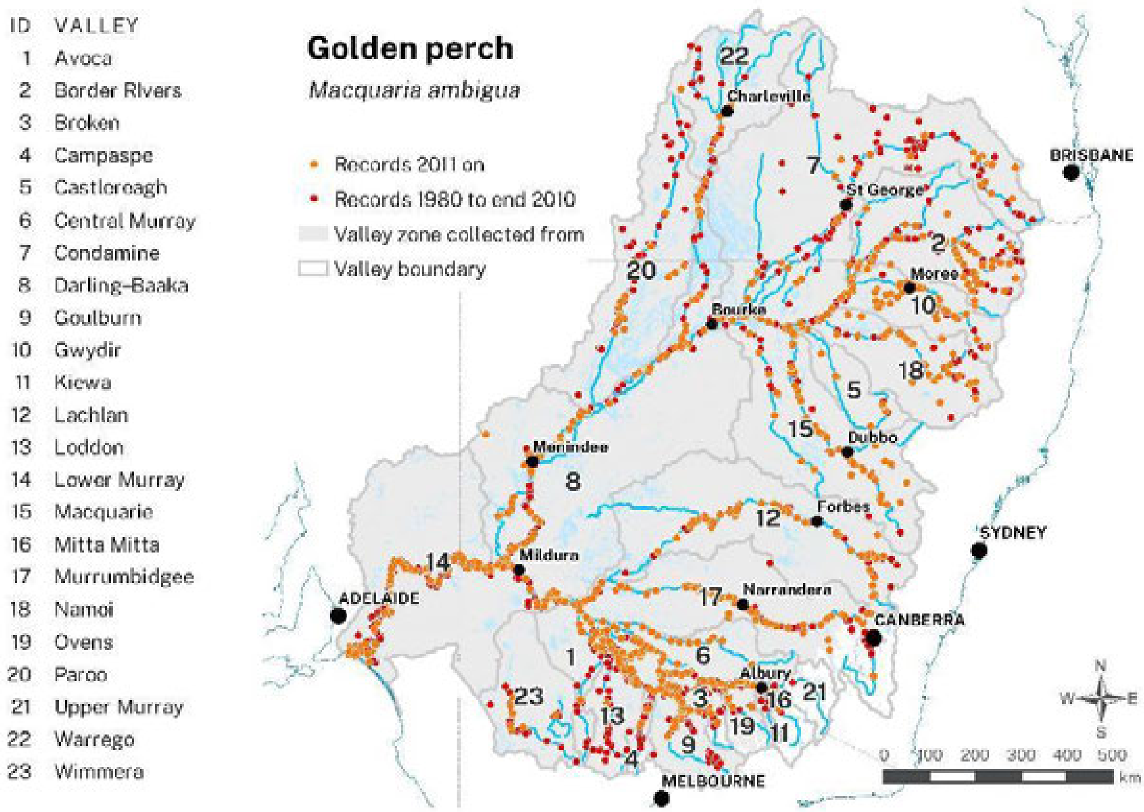
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

A medium-to-large fish generally found in in lowland, warmer, turbid rivers and impoundments across both the Northern and Southern Basins (Lintermans 2023). Golden perch is widespread throughout the lower and mid-reaches of rivers in the MDB, but has declined in some upland areas (Lintermans 2023). It is widely stocked for recreational purposes, with millions of stocked fish released across the Basin in most years (Gillanders et al. 2006, Lintermans 2013a). It is a highly mobile species that can move between the Northern and Southern Basins when conditions are suitable (Thiem et al. 2022, Zampatti et al. 2021a, 2021b).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	X
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	X
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- Found in lowland, warmer, turbid rivers, with juveniles in the lower Murray and the northern MDB also recorded from inundated ephemeral floodplain billabongs and anabranches during summer flooding (Lintermans 2023). It is well represented in the dedicated MDB fish monitoring programs.
- Overall, populations of this species are relatively stable, with an increasing trend in abundance and distribution in recent years (Figure 29).
- Widely produced in hatcheries and stocked by government agencies and recreational fishers.

- Subject to angler harvest.

Overall:

- A widespread and abundant species that is heavily targeted in recreational, hatchery stocking and flow management programs.

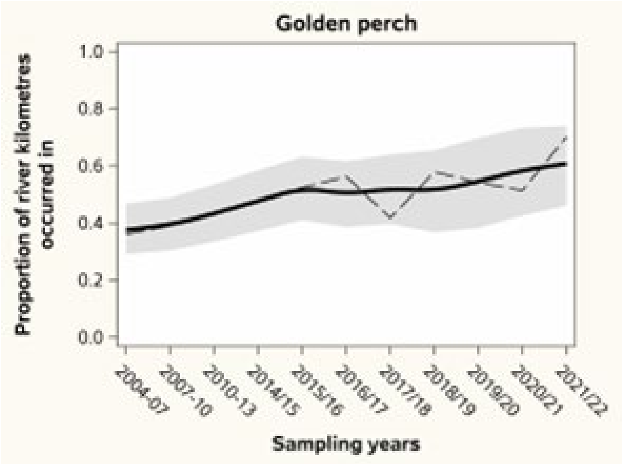


Figure 29. Estimate of proportion of river kilometres inhabited by golden perch

Species: *Macquaria australasica*

Common name: Macquarie perch, white eye, mountain perch, black bream

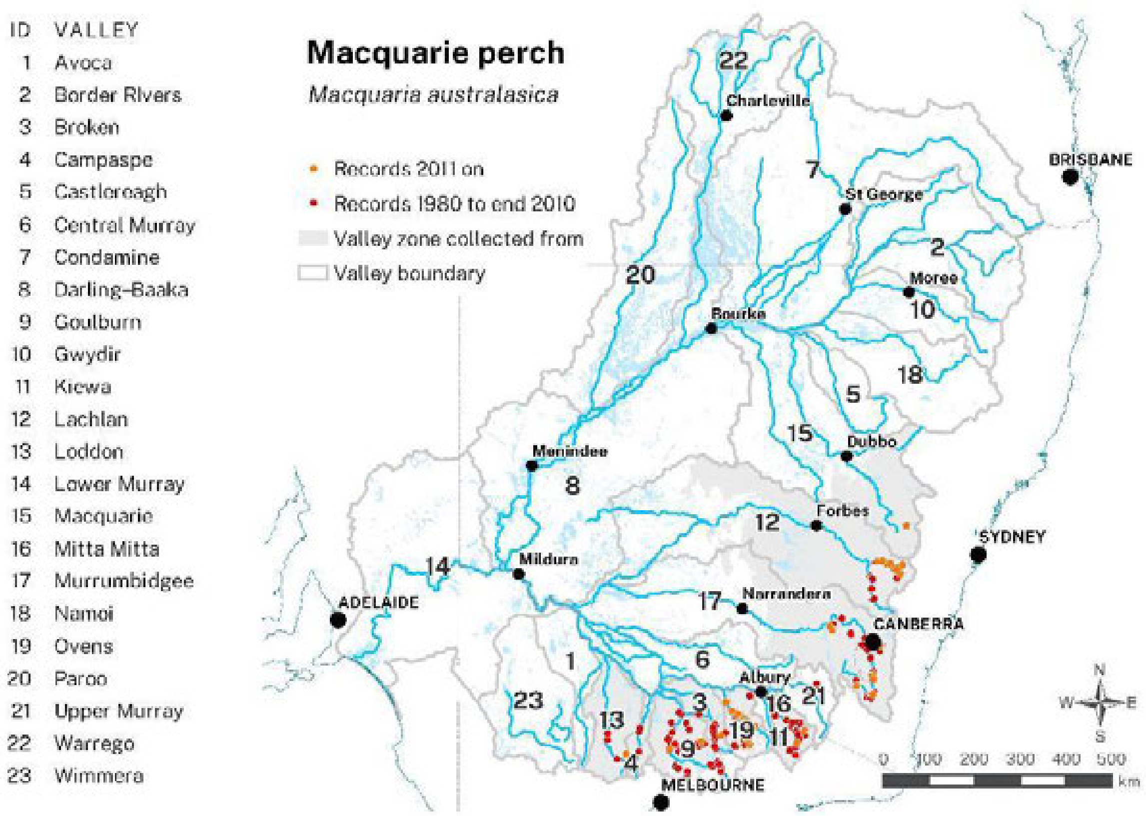
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
EN	EN	EX	EN	EN	EN	–

EN = Endangered; EX = Extinct; – = not assessed

Distribution (presence):

A medium-sized, threatened species currently containing three cryptic species, one of which occurs in the Murray–Darling Basin (Faulks et al. 2010, Pavlova et al. 2017, DEE 2018, Lintermans 2023). The species is currently typically found in the cool, forested upper reaches of streams in Victoria, NSW and the ACT. Such streams with healthy riparian and catchment vegetation and abundant riffles provide the low sedimentation breeding habitats required by this species (Lintermans et al. 2019). Historically it was present in more lowland habitats such as the Murray River between Euston and Tocumwal and the Edwards River and Barmah Lakes near Deniliquin. It is now extinct in these locations and in South Australia (Lintermans 2023). Although originally described from the Macquarie River near Bathurst in the Northern Basin in 1830, it had been extinct in that catchment for more than a century until stocked there in 2021.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Macquarie	X	✓
Southern Basin	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	X
	Central Murray	✓	✓
	Mitta Mitta	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	X
	Loddon	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Typically found in the cool, forested, upper reaches of the Southern Basin with abundant rocky substrate and low sedimentation. The dedicated MDB fish monitoring programs reliably collect adult and subadult individuals, but do not reliably detect recruitment or young-of-the-year fishes (Lintermans 2016).
- There are limited data available from which to assess trends in abundance and distribution. Crook et al. (2023) found there was no clear trend in the relative abundance and biomass of Macquarie perch in NSW. Population structure varied substantially among years with some years dominated by adults and other years dominated by small fish <20 cm total length.

Overall:

- A threatened species whose populations remain at risk from large-scale disturbance such as drought and bushfires.

Species: *Melanotaenia fluviatilis*

Common name: Murray–Darling rainbowfish, Murray River rainbowfish, Murray rainbowfish

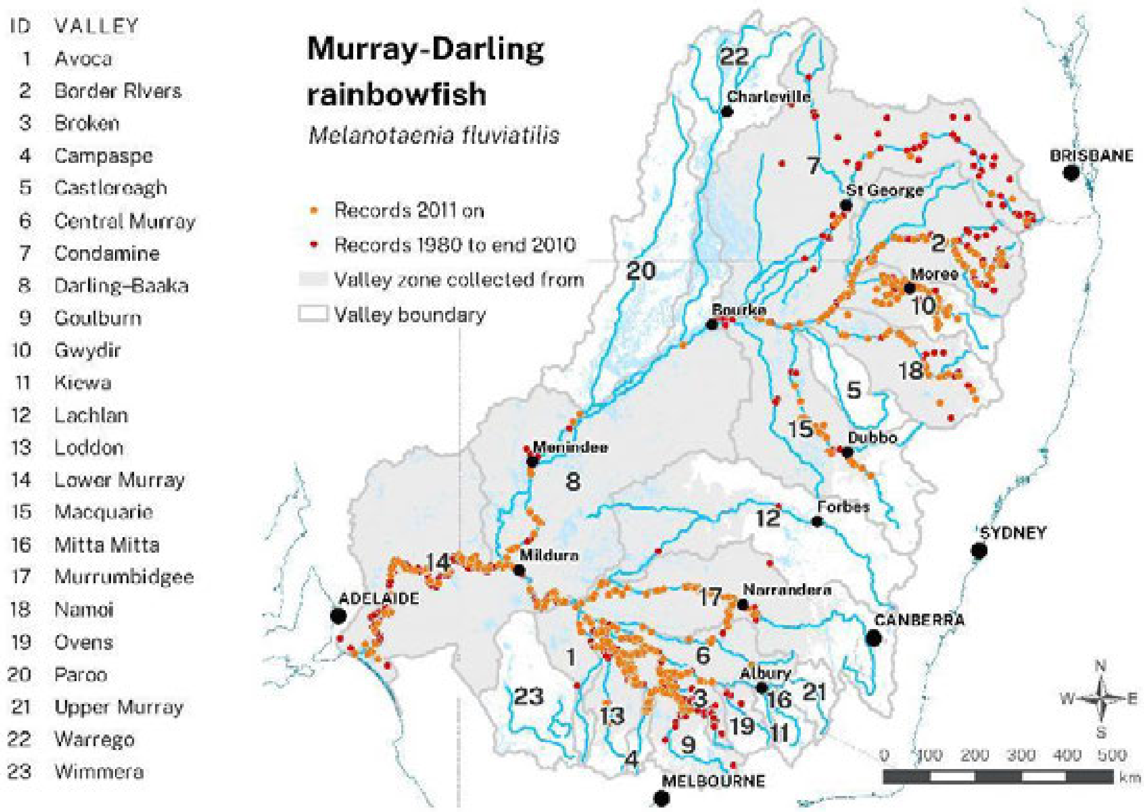
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	EN	–	–	–

EN = Endangered; LC = Least Concern; – = not assessed

Distribution (presence):

This species is the southernmost of the rainbowfishes occurring in both the Northern and Southern Basins. In the Southern Basin it is generally restricted to the lowlands but is more widespread in the Northern Basin and may also be found in more upland reaches (e.g. above Warwick on the Condamine; and at Mingoola on the Dumeresq) (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- In the Southern Basin the species prefers slow-flowing rivers, wetlands and billabongs. In the lower Murray in South Australia, the species was more abundant in permanent (rather than ephemeral) wetlands, and less abundant in small shallow wetlands.
- During low flows in the lower Murray, the species' presence in the main channel has been associated with fine woody debris and submerged macrophytes (Lintermans 2023). It is readily captured in channel habitats by the dedicated fish monitoring programs (SRA/MDBFS) but the lack of sampling by these programs in off-channel habitats such as wetlands precludes analysis of trends in such habitats.
- SRA/MDFS data suggest that the abundance and distribution of Murray–Darling rainbowfish has increased in recent years (Figure 30).

Overall:

- A widespread and sometimes locally abundant species that is not of conservation concern in the north but appears to have declined in the south.

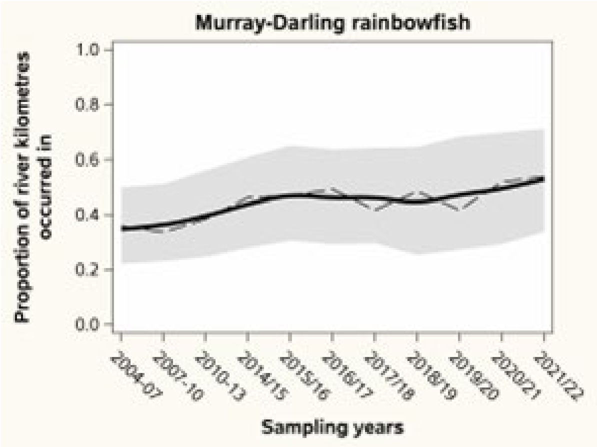


Figure 29. Estimate of proportion of river kilometres inhabited by Murray–Darling rainbowfish

Species: *Melanotaenia splendida tatei*

Common name: Desert rainbowfish

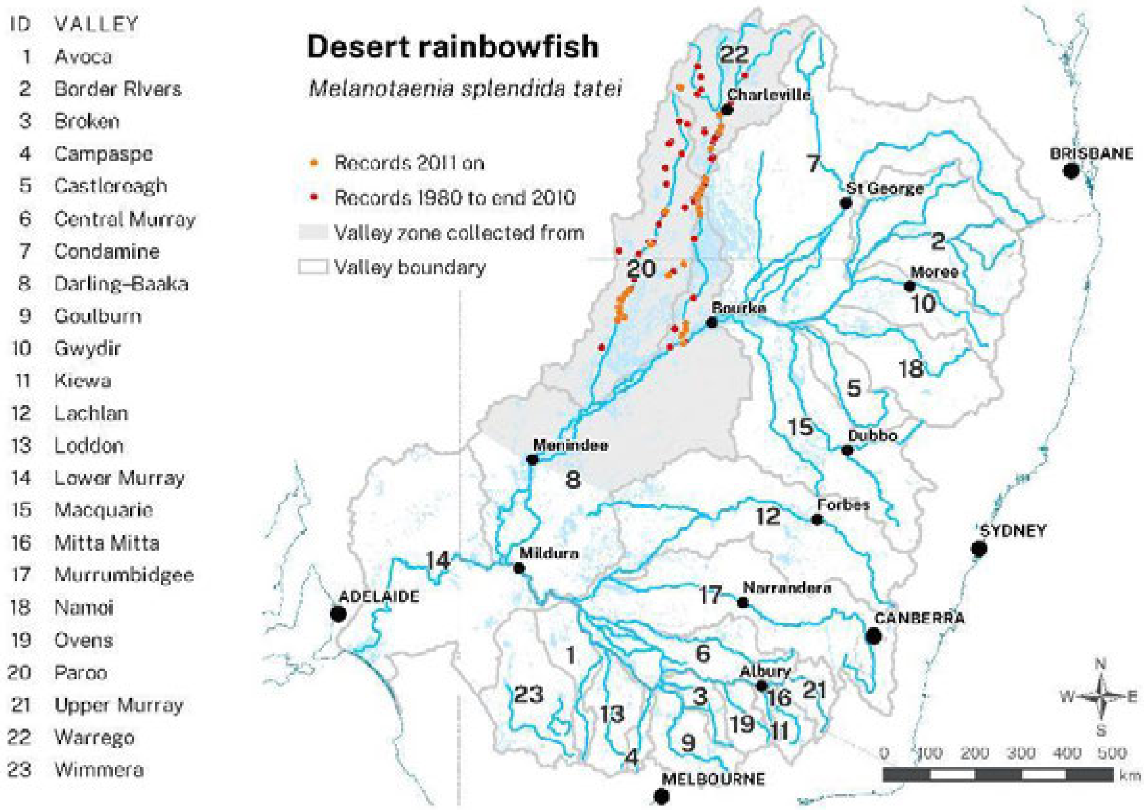
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

Desert rainbowfish is an arid-adapted species, found in a variety of slow-flowing and still habitats, including ephemeral rivers, waterholes, lakes, flowing bores and stock dams. These habitats are often quite turbid and highly variable in terms of permanence. It is only found in the Northern Basin. It is the only rainbowfish present in the Paroo and Warrego valleys, and can overlap (and hybridise) with Murray–Darling rainbowfish; hybrids have been identified in the lowermost Warrego River and the Darling-Baaka River from around the Bogan River down to at least Menindee (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Barwon–Darling	✓	✓
Southern Basin		–	–
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Found in a variety of slow-flowing and still habitats, including ephemeral rivers, waterholes, lakes, flowing bores and stock dams. It is represented in the dedicated fish monitoring programs (SRA/MDBFS) but the lack of sampling by these programs in off-channel habitats (wetlands, lakes, stock dams) and ephemeral habitats precludes analysis of trends in such places.
- There are insufficient data to assess trends in abundance and recruitment.

Overall:

- A locally abundant species that is not of conservation concern. Misidentification as Murray–Darling rainbowfish may obscure status and distributional changes.

Species: *Mogurnda adspersa*

Common name: Southern purple-spotted gudgeon, purple-spotted gudgeon

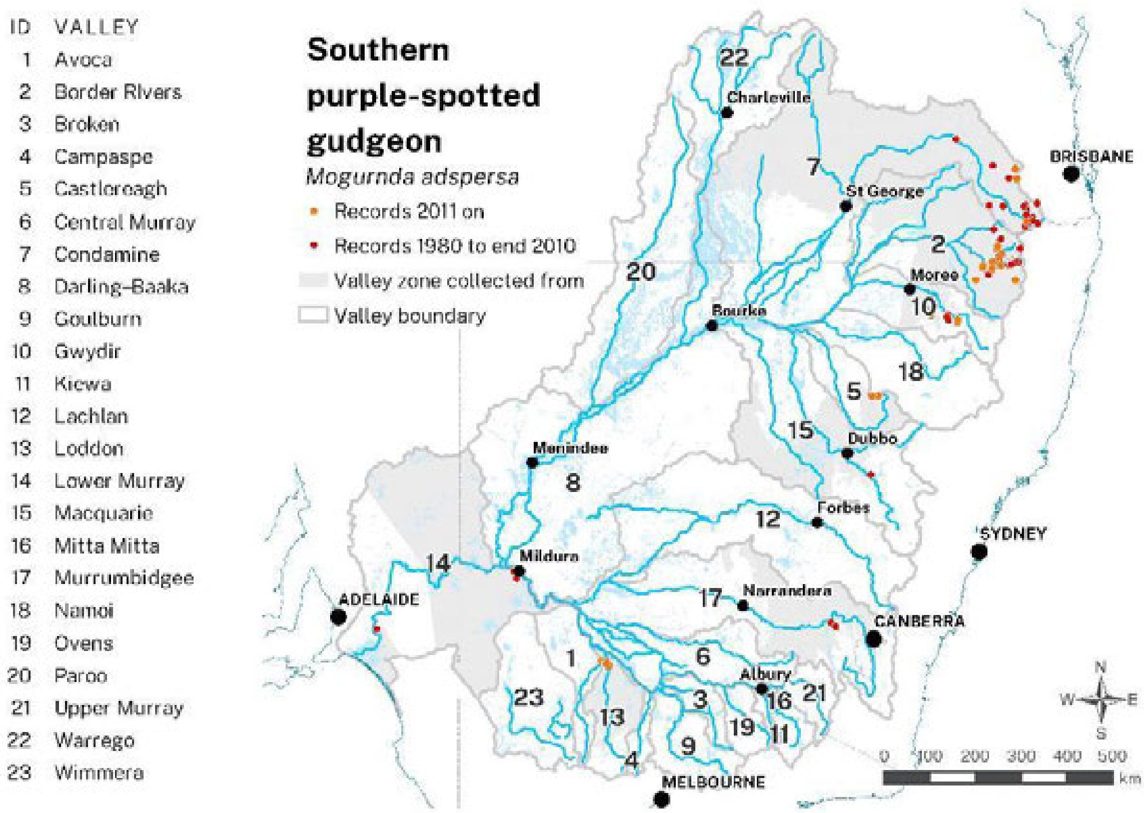
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	CE	CE	EN	–	–

CE = Critically Endangered; EN = Endangered; LC = Least Concern; – = not assessed

Distribution (presence):

Historically, southern purple-spotted gudgeon was broadly distributed across coastal areas of Queensland and New South Wales as well as patchily occurring in the MDB. In the southern MDB, it was once widespread and common in wetland and fringing river habitat in the Lachlan, Murrumbidgee and Murray catchments (including lower Murray) but has since experienced substantial decline and is now thought extinct in Victoria and South Australia. It was rediscovered in 1995 in Victoria, lost again and rediscovered again in 2019 in the Kerang Lakes, and rediscovered in the lower Murray in 2002 (Lintermans 2023). Reintroductions have occurred into various valleys in NSW, South Australia and Victoria as part of recovery actions for the species (Whiterod et al. 2019, Zukowski et al. 2021, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Castlereagh	X	✓
	Macquarie	✓	X
Southern Basin	Murrumbidgee	✓	X
	Lower Murray	✓	✓
	Loddon	X	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Generally a benthic species, usually associated with dense cover such as aquatic vegetation, cobble and rocks. Found in slow-moving or still waters of creeks, rivers, wetlands and billabongs and typically found very close to the banks, often in surprisingly shallow water a few centimetres deep (especially juveniles) (Lintermans 2023).
- Its preference for dense cover and wetland or lacustrine habitats means it is not sampled well by the dedicated MDB fish monitoring programs (SRA/MDBFS).
- Historically, southern purple-spotted gudgeon was broadly distributed across coastal areas of Queensland and New South Wales as well as patchily occurring in the MDB (Whiterod et al. 2019, 2021c). In the southern MDB, it was once widespread and common in wetland and fringing river habitat in the Lachlan, Murrumbidgee and Murray catchments (including lower Murray) but has since experienced substantial decline.
- The future of the species remains precarious in the southern MDB but has been improved with its rediscovery in the Kerang Lakes region in late 2019.
- It is only known from few locations, which are mostly sites used for reintroductions. In the lower Murray, it does persist but has yet to re-establish a self-sustaining sub-population. In NSW, reintroductions have not been successful with the southern MDB; however, there has been the successful establishment of an additional population within the Castlereagh River in the northern MDB. Encouragingly, healthy backup populations are maintained for the species.
- Backup sub-populations were held at the Murray–Darling Freshwater Research Centre (MDFRC) since the Millennium drought, and captive breeding has occurred more recently at the Arthur Rylah Institute for Environmental Research.

Overall:

- The future of the species remains precarious in the southern MDB but has been improved with its rediscovery in the Kerang Lakes region in late 2019.

- It is only known from a few locations, which are mostly sites used for reintroductions. In the lower Murray, it does persist but has yet to re-establish a self-sustaining sub-population. In NSW, reintroductions have not been successful within the southern MDB.
- This species has declined in the Queensland MDB

Species: *Mordacia mordax*

Common name: Short-headed lamprey

Conservation status:

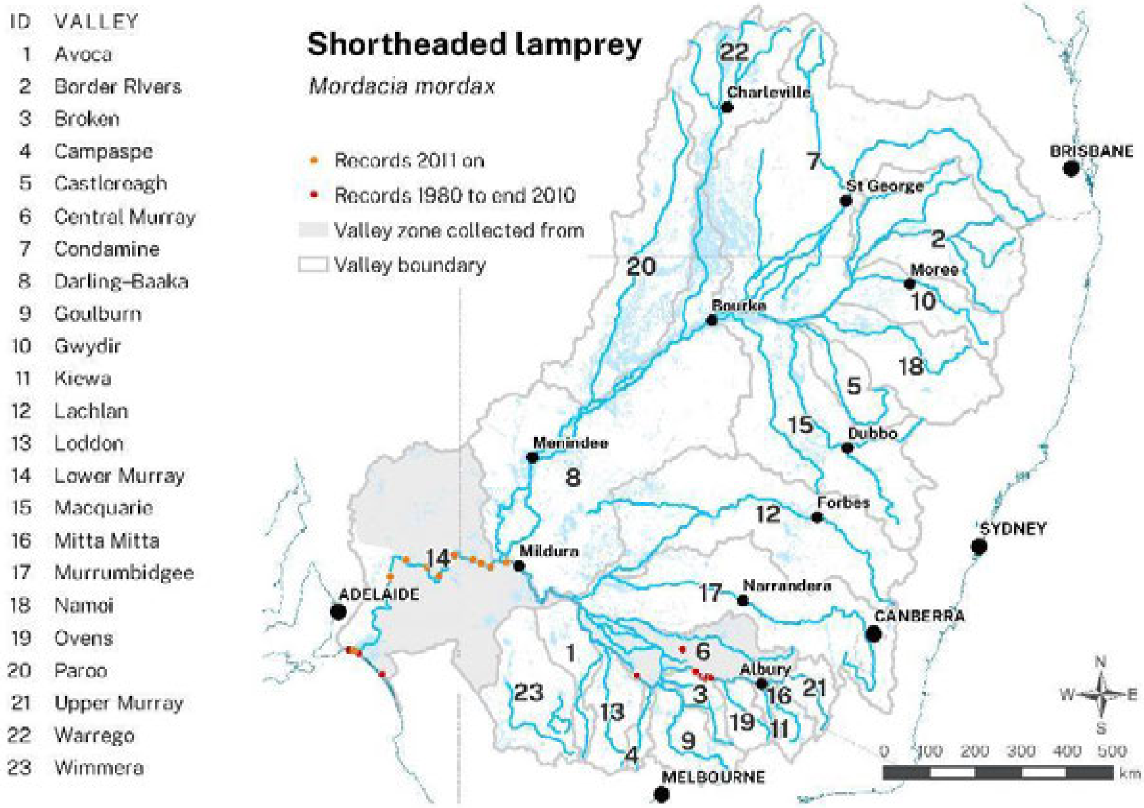
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	VU	EN	–	–	–	–

EN = Endangered; LC = Least Concern; VU = Vulnerable; – = not assessed

Distribution (presence):

Short-headed lamprey is one of only two anadromous fish species in the MDB and is generally found in South Australia and in NSW in the lower and mid-Murray and occasionally recorded as far upstream as Yarrawonga and even Narrandera on the Murrumbidgee (Lintermans 2023). The species had declined significantly in distribution and abundance prior to 1980 (Bice et al. 2020, Lintermans 2007) with the last records from the Darling catchment in the 1960s (Lintermans 2007). Recent improvements to fish passage, including fishways on the barrages and the completion of the Sea to Hume fish passage program, means the species is likely to be recorded in more upstream locations in coming years. Monitoring of movement of a single PIT-tagged individual in 2019 recorded it exiting Lock 10 fishway 825 km upstream of the barrages (Bice et al. 2020a, 2020b). The 2019/20 catch of this species in the CLLMM monitoring program was the highest since the program's first year in 2006/07 (Bice et al. 2020a, 2020b). Historical records (pre-1980) are known from the lower Murray, Central Murray, Avoca, Lachlan, Goulburn, and Ovens valleys (Lintermans 2023).

The species has been recorded in one less river valley in 2011–2022 compared with 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Central Murray	✓	X
	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- Most of the adult life is spent at sea. Young adults migrate upstream from the sea from late winter to early summer to breed in rivers. The spawning run can involve distances of hundreds of kilometres (Bice et al. 2019, 2020a, 2021, Lintermans 2023).
- The species is a primary target of the CLLMM fish monitoring program but no individuals were captured in the SRA (2004–2013) or the MDBFS (2014–22).

Overall:

- A species that is rarely recorded in conventional MDB sampling programs and considered rare in South Australia. Recent improvements to fish passage including fishways on the barrages and the completion of the Sea to Hume fish passage program means the species is likely to be recorded in more upstream locations in coming years.

Native fish status assessment 2023

Species: *Nannoperca australis*

Common name: Southern pygmy perch

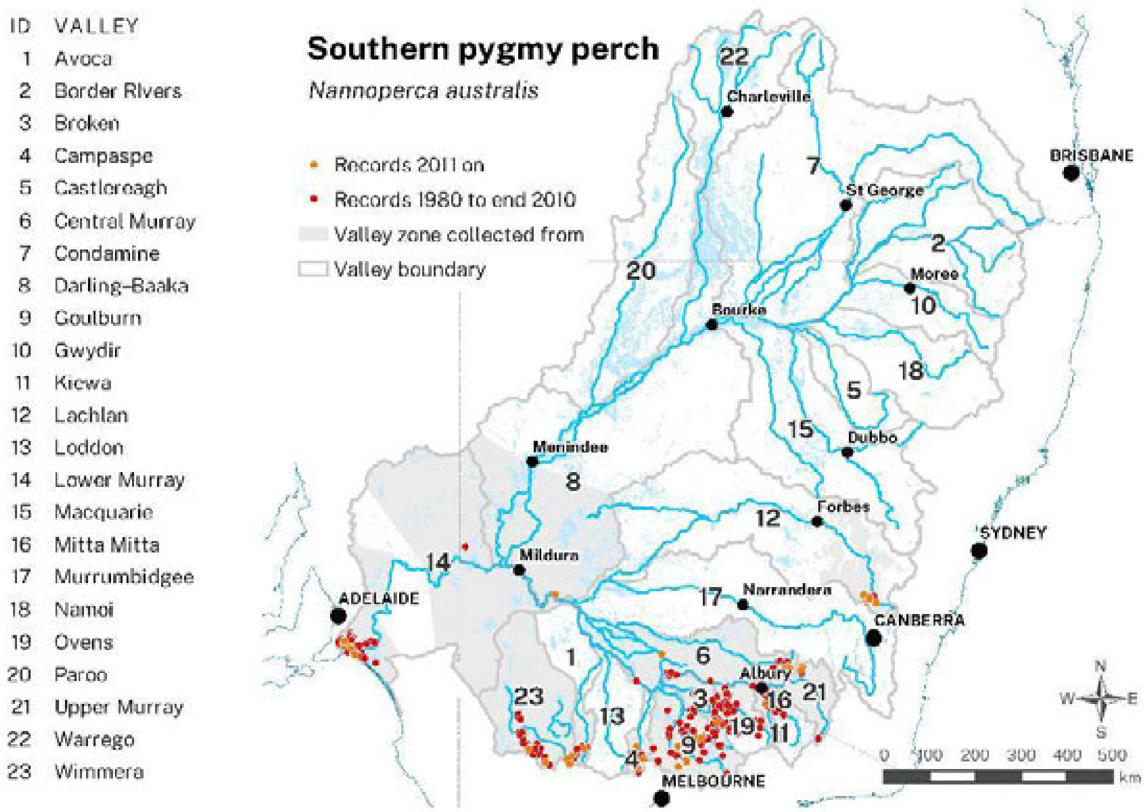
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
NT	–	EN	VU	EN	–	–

EN = Endangered; NT = Near Threatened; VU = Vulnerable; – = not assessed

Distribution (presence):

Historically, the species occurred in the Southern Basin in the lower Murrumbidgee and Murray catchments (and tributaries). In 2002 it was discovered in the upper Lachlan catchment (Lintermans and Osborne 2002), where it persists. Loss of habitat, alien species interactions and the Millennium drought resulted in widely distributed sub-populations becoming fragmented, with local extirpation occurring at a number of sites in the middle and upland Murray catchment sites. At other sites sub-populations are contracting as alien species (particularly redfin perch) continue to expand (Zukowski et al. 2021, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Darling	X	✓
	Lachlan	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- The Southern pygmy perch prefers slow-flowing or still waters, usually with dense aquatic vegetation and plenty of cover. It has been recorded from small streams, well-vegetated lakes (or wetlands within), billabongs and irrigation channels (Lintermans 2023).
- While sampled by the dedicated MDB fish monitoring programs (SRA/MDBFS) representation in the SRA/MDBFS (2014–15 to 2021–22) is poor, having only been recorded from four river valleys. The limited data from this source suggests that the abundance and distribution of the species is relatively stable (Figure 31).
- Historically, the species occurred in the Southern Basin in the lower Murrumbidgee and Murray catchments.
- Loss of habitat and the Millennium drought resulted in widely distributed sub-populations becoming fragmented, with local extirpation occurring from middle and upland Murray catchment sites (Whiterod et al. 2019), 2021c. Since the Millennium drought, the range of the species has continued to decline across the southern MDB, but in the 2 years to 2021 the overall status of the species remained stable.

Overall:

- The species declined in range during the Millennium drought. This decline is thought to have continued across the southern MDB since the drought with populations in NSW also impacted by the 2017–19 severe drought, but the overall status of the species has remained stable in the past 2 years (to 2021) (Zukowski et al. 2021).

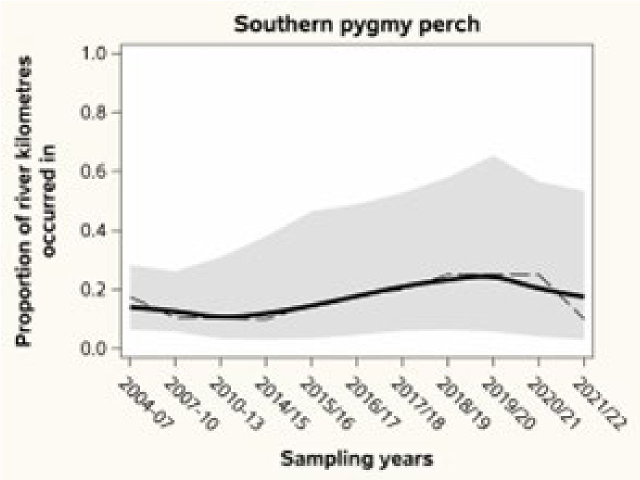


Figure 30. Estimate of proportion of river kilometres inhabited by southern pygmy perch

Native fish status assessment 2023

Species: *Nannoperca obscura*

Common name: Yarra pygmy perch

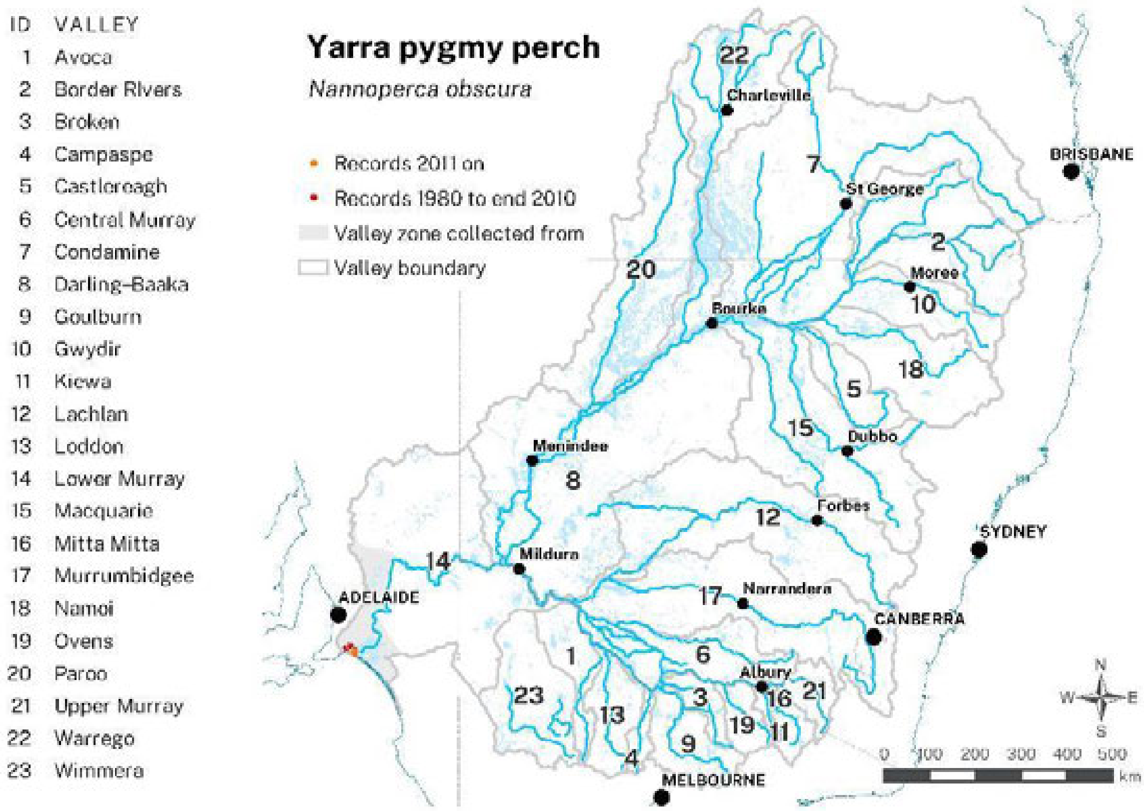
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
EN	VU	CE	VU	–	–	–

CE = Critically Endangered; EN = Endangered; VU = Vulnerable; – = not assessed

Distribution (presence):

Found mainly in coastal catchments, Yarra pygmy perch were restricted to the lower reaches of the southern MDB where a population existed in the Lower Lakes (Hammer et al. 2013b, Zukowski et al. 2021). Its habitat in the Lower Lakes was severely reduced during the Millennium drought and the last wild Yarra pygmy perch were detected in February 2008. Reintroduction efforts to the Lower Lakes in 2011–2015 were ultimately not successful (Wedderburn et al. 2022) and the species is now extinct in its natural habitat in the MDB.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- The MDB population was confined to shallow littoral zones with dense aquatic macrophytes in Lake Alexandrina. It has not been captured by the MDB fish monitoring programs (SRA/MDBFS).
- Found mainly in coastal catchments, Yarra pygmy perch were restricted to the lower reaches of the southern MDB.
- Its habitat in the Lower Lakes and tributaries was severely reduced during the Millennium drought and the species became extinct, last being detected in February 2008 (Whiterod et al. 2019, 2021c).
- Small-scale backup populations persist, and genetic rescue is being trialled.

Overall:

- Small-scale backup populations persist, and genetic rescue is being trialled, but the situation for the species remains dire (Zukowski et al. 2021). As of 2021, Yarra pygmy perch had not been detected in the MDB for 6 years, since reintroductions failed, and is likely the first species lost to the Basin in the assessment period. The backup populations continue to be in peril with potentially <1 000 individuals in total remaining across the captive facilities and surrogate refuges.

Native fish status assessment 2023

Species: *Nematalosa erebi*

Common name: Bony herring, bony bream, hairback herring

Conservation status:

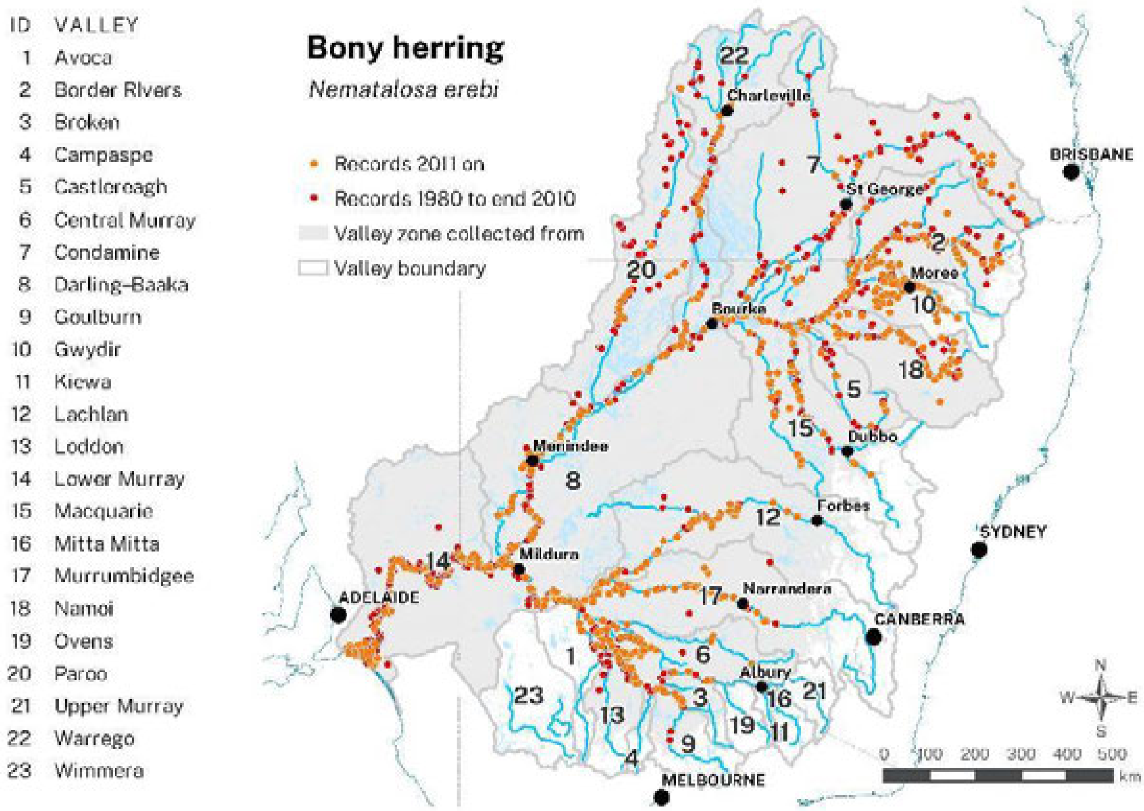
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

Bony herring is a common species that is widely distributed in the lower elevational zones of both the Northern and Southern Basins (Lintermans 2023). It vies with spangled perch for the distinction of being the most widespread of Australia's native freshwater fish species (Lintermans 2023). The species is largely absent from upland habitats, probably due to low water temperatures, but is known from the majority of lowland rivers where it is usually the most abundant large-bodied native species (Lintermans 2023). It is particularly common in the Darling-Baaka and lower Murray and is commercially fished in Lake Alexandrina.

The species has been recorded in two fewer river valleys, both in the Southern Basin, in 2011–2022 compared to 1980–2010. In both these valleys abundance was low in 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Ovens	X	✓
	Broken	✓	X
	Goulburn	✓	✓
	Campaspe	✓	X
	Loddon	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- A hardy fish, tolerating high temperatures, high turbidity, high salinity and low dissolved oxygen. However, they are not tolerant of low water temperatures (die-offs of this species are commonly reported in winter) and so are absent from upland streams in the Southern Basin (Lintermans 2023).
- It is usually the most abundant large-bodied native species in lowland rivers and is the second-most abundant native fish overall behind carp gudgeons (all species combined) in the MDBFS (2014–15 to 2021–22).
- SRA/MDBFS data indicate that the abundance and distribution of bony herring has had a positive trend in recent years (Figure 32).
- Has been subject to large fish deaths in the lower Darling-Baaka River (2019–20; 2023).
- It is commercially fished in Lake Alexandrina, South Australia.

Overall:

- A species that is widespread and abundant across the lowland rivers of the Basin.

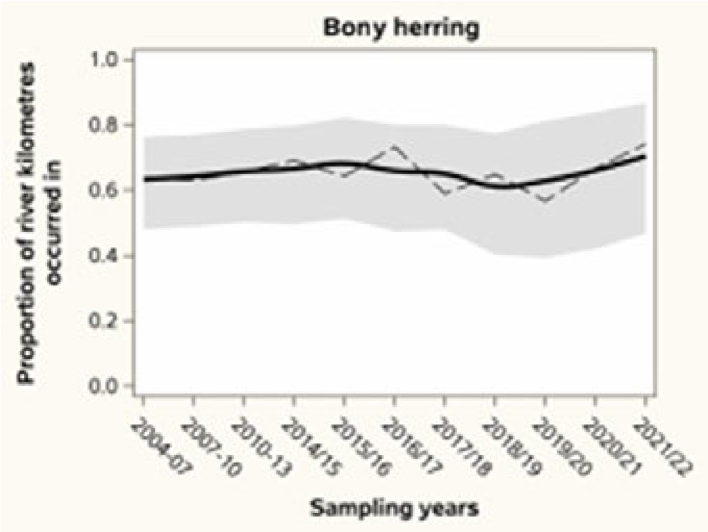


Figure 31. Estimate of proportion of river kilometres inhabited by bony herring

Species: *Neosilurus hyrtlii*

Common name: Hyrtl's tandan Hyrtl's catfish, yellow-finned catfish, moonfish

Conservation status:

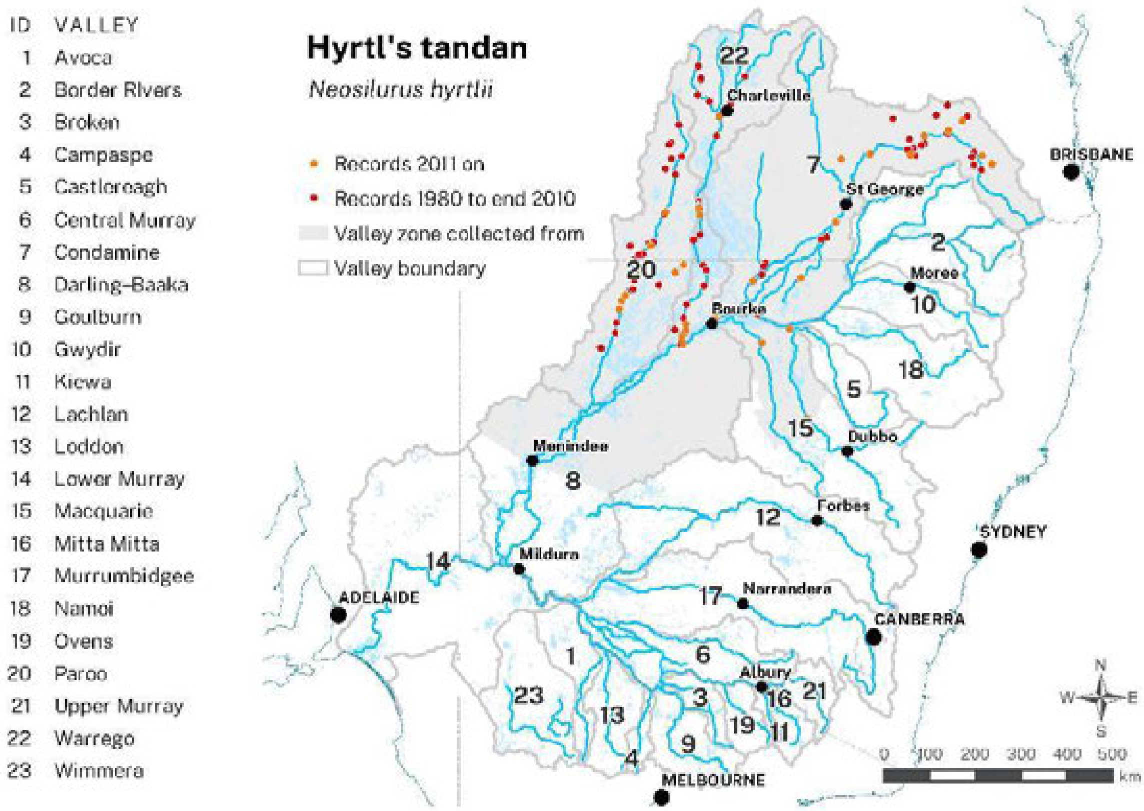
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

This medium-sized species is widespread in northern and central Australia in Western Australia, the Northern Territory and Queensland (Allen et al. 2002, Larson and Martin 1989, Wager and Unmack 2000), but within the Basin is only found in the north, having been recorded from the Paroo, Warrego, Culgoa, Balonne, Bogan, Barwon, Darling, Macquarie and Condamine rivers in northern NSW and Queensland, and the Menindee Lakes (Lintermans 2023). Not all of these locations are present in the combined dataset (e.g. Bogan), and so the table below slightly under-represents the distribution.

The records for the Southern Basin are for two individual fish caught in the period 1980–2010 and one fish caught since 2010; all caught in the lower Darling-Baaka after flood events.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Macquarie	X	✓
Southern Basin	Lower Darling	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- The species occurs in a variety of habitats, including flowing waters and still areas such as billabongs and lagoons. Individuals were captured in four valleys (Paroo, Warrego, Condamine–Balonne, Barwon–Darling) in the SRA (2004–2010) and MDBFS (since 2011) surveys.
- There were insufficient data to accurately assess trends in abundance and recruitment.

Overall:

- A widespread and sometimes abundant species, across the Northern Basin, with occasional records in the northern part of the Southern Basin (lower Darling-Baaka).

Native fish status assessment 2023

Species: *Percalates colonorum*

Common name: Estuary perch

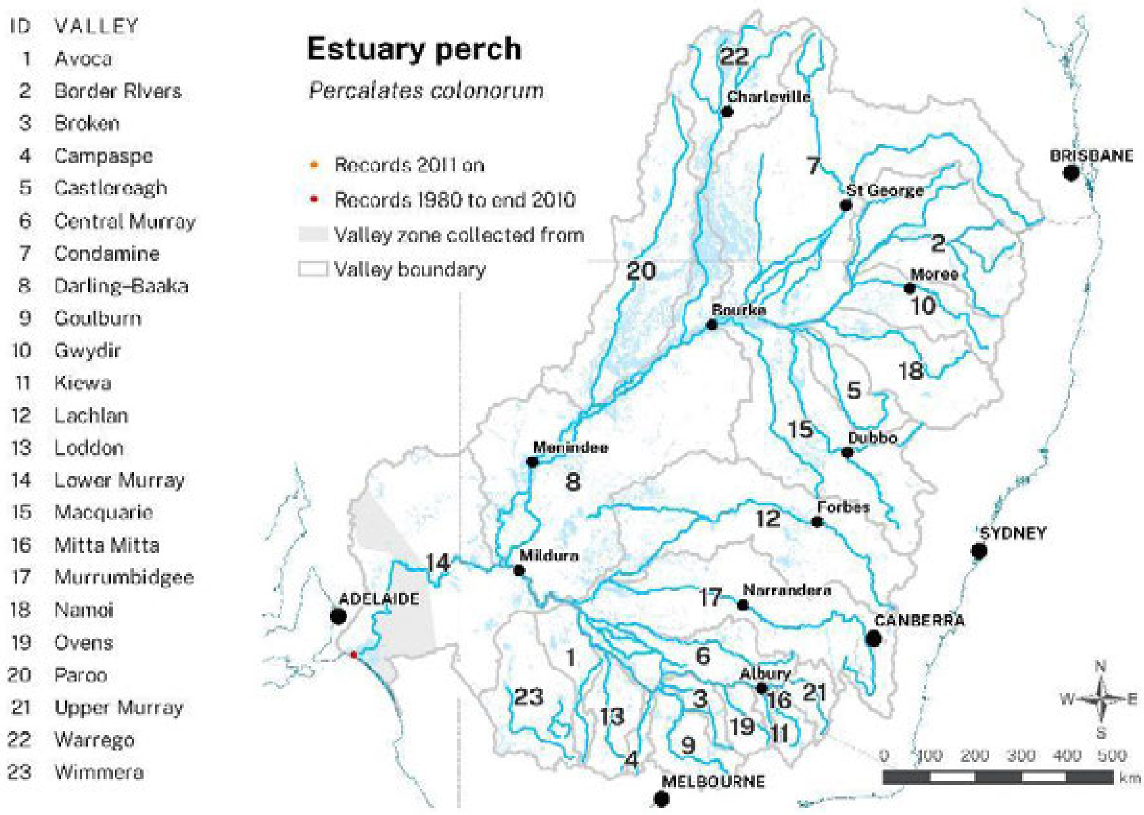
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	R	–	–	–	–

LC = Least Concern; R = Rare; – = not assessed

Distribution (presence):

The estuary perch predominantly lives in tidal or estuarine waters but will penetrate significant distances upstream into fresh waters. It has only been recorded in the lower Murray, Lower Lakes and Coorong with very only three records captured in the combined dataset (the most upstream being in the Murray River at Nildottie).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- Predominantly a tidal or estuarine species. No individuals have been recorded in the SRA/MDBFS data bases.
- There is insufficient information available to accurately assess trends in abundance and recruitment.

Overall:

- Estuary perch is in decline in several parts of its coastal range, as well as in the Lower Lakes and Coorong in the MDB.

Native fish status assessment 2023

Species: *Philypnodon grandiceps*

Common name: Flat-headed gudgeon, flathead gudgeon, big-headed gudgeon

Conservation status:

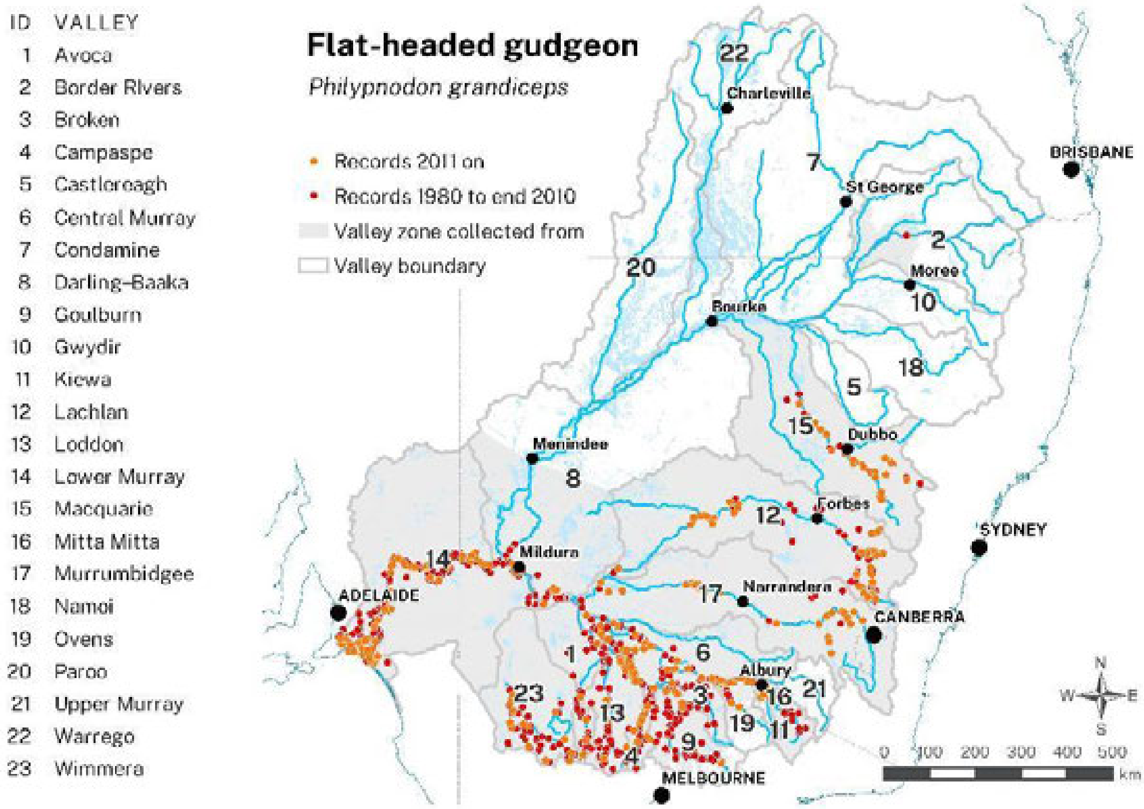
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

Found across most of the southern half of the MDB, and the Macquarie River in the Northern Basin. There are very rare records from the Darling-Baaka (downstream of Toorale) and Macintyre rivers, but whether these represent remnant populations or translocated fish is unknown. It is largely absent from upland areas and is not present in the ACT or Queensland portions of the Basin.

Border rivers record was for a single fish recorded in the 1980–2010 period.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Border Rivers	✓	X
	Macquarie	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Ovens	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- A generalist, benthic species found in slow-flowing areas in a range of aquatic habitats from lowland rivers, streams, wetlands and lakes, billabongs and dams, it is often found in weedy or muddy areas with abundant cover in the form or rocks or logs (Lintermans 2023).
- SRA/MDBFS data suggest that the species has had variable but overall relatively stable abundance and distribution (Figure 33), with declines between 2004–2018 offset by increased populations since 2019.

Overall:

- A widespread species in the Southern Basin, and relatively common in the Macquarie.

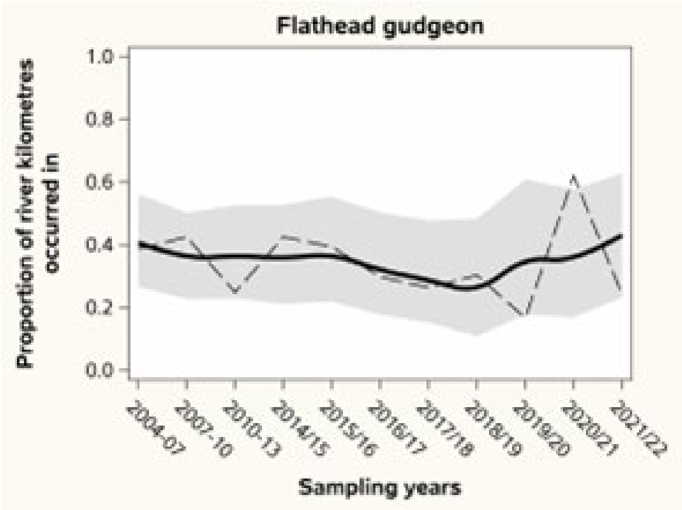


Figure 32. Estimate of proportion of river kilometres inhabited by flathead gudgeon

Native fish status assessment 2023

Species: *Philypnodon macrostomus*

Common name: Dwarf flat-headed gudgeon

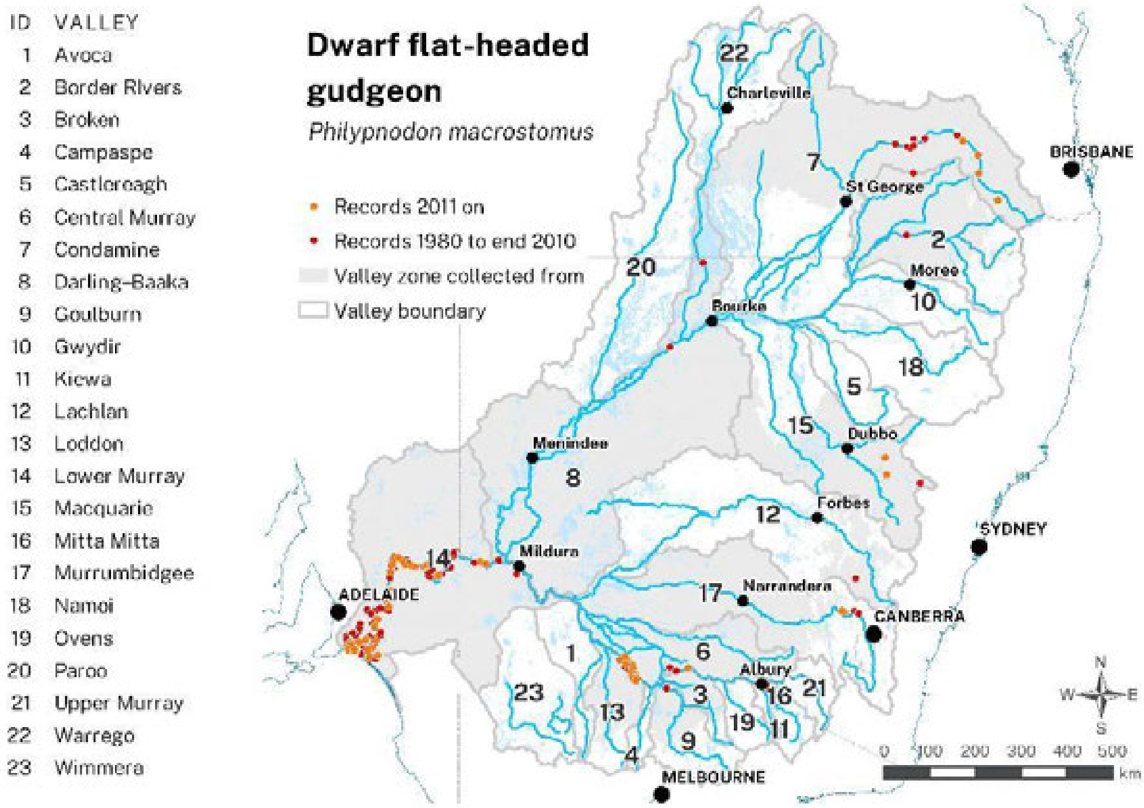
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

Dwarf flat-headed gudgeon is patchily distributed across the MDB. Its distribution has declined; since 2011, and the species has not been recorded in seven of the 13 valleys where it was present between 1980 and 2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Warrego	✓	X
	Condamine–Balonne	✓	✓
	Border Rivers	✓	X
	Macquarie	✓	✓
	Barwon–Darling	✓	X
Southern Basin	Lower Darling	✓	X
	Lachlan	✓	X
	Murrumbidgee	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Broken	✓	X
	Goulburn	✓	X
	Loddon	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- With more specialised habitat preferences than flat-headed gudgeon, dwarf flat-headed gudgeon are predominantly found in off-channel wetlands and small anabranches and streams, where it is found in relatively calm waters and over mud and rock substrates or in weedy areas (Lintermans 2023).
- It is poorly sampled in the MDBFS with only 37 recorded in the MDB Fish Survey to date (2014–15 to 2021–22) from only two valleys. However, it was recorded in six fewer river valleys since the Millennium drought compared with the 1980–2010 period.
- There were insufficient data with which to accurately assess trends in abundance and recruitment.

Overall:

- A relatively widespread species prior to 2011 but not well represented in the dataset since. Despite the scarcity of records since 2010, the species is not of conservation concern.

Native fish status assessment 2023

Species: *Porochilus argenteus*

Common name: Silver tandan, silver catfish, central Australian catfish

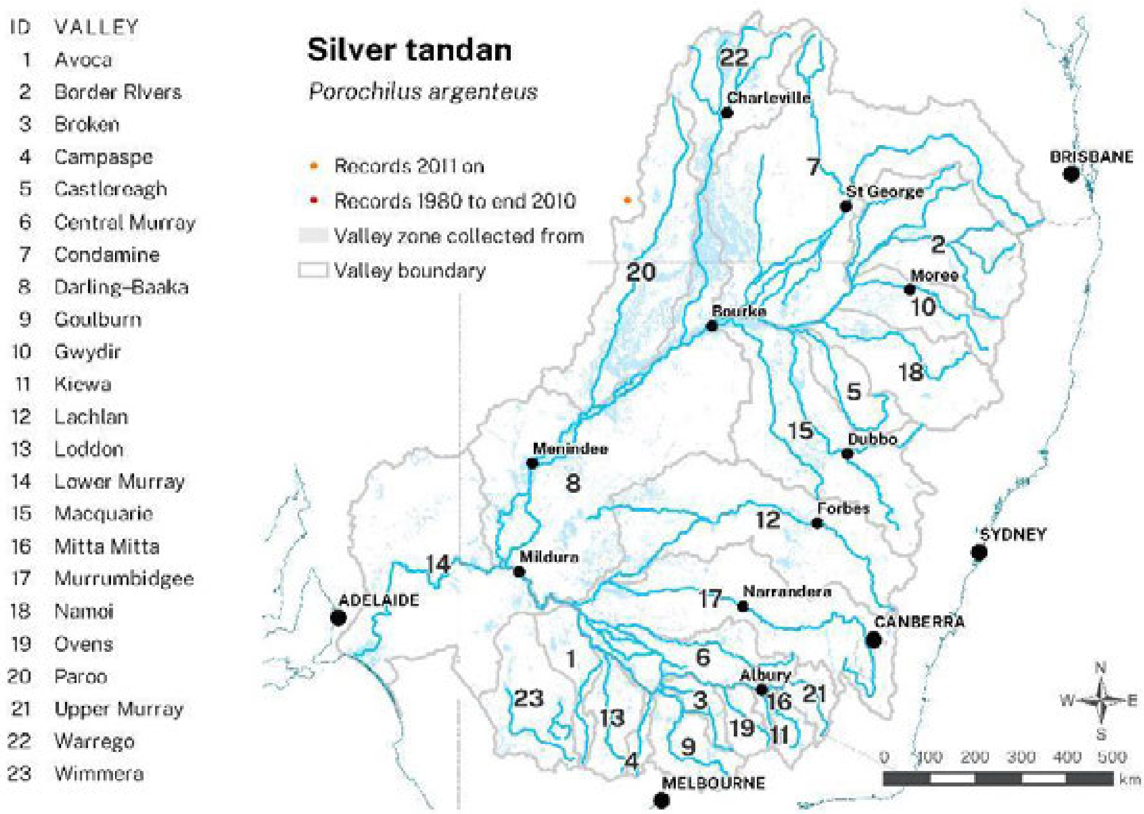
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

A widespread species across norther Australia but only recorded from a single site in the MDB at the western edge of the Paroo catchment (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	X	✓
Southern Basin		–	–
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Outside the MDB it is commonly found in turbid waterholes in smaller creeks through to larger rivers, but has been collected from a wide variety of habitats including ring tanks, flowing bores, and pools associated with artesian springs (Lintermans 2023).

Overall:

- A rare species in the MDB, but common and widespread in northern Australia.

Native fish status assessment 2023

Species: *Porochilus rendahli*

Common name: Rendahl's tandan

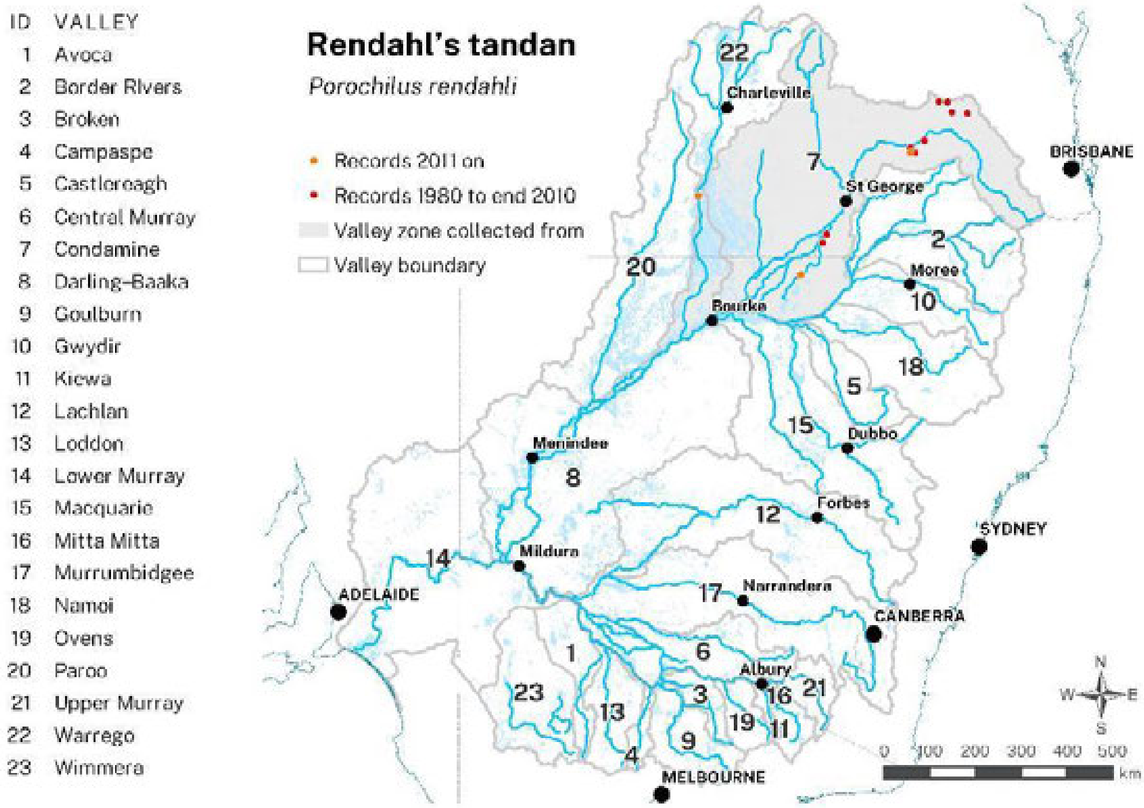
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

A species that has only been recognised in the Basin since the early 2000s and is restricted to the Condamine–Balonne and Warrego valleys (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Warrego	X	✓
	Condamine–Balonne	✓	✓
Southern Basin		–	–
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- No individuals were captured in SRA/MDBFS surveys since 2011. Electrofishing is probably not a representative sampling technique.
- There are insufficient data from which to accurately assess trends in abundance and recruitment.

Overall:

- A species with a restricted distribution in the Northern Basin, it is not of conservation concern.

Native fish status assessment 2023

Species: *Pseudaphritis urvillii*

Common name: Congolli

Conservation status:

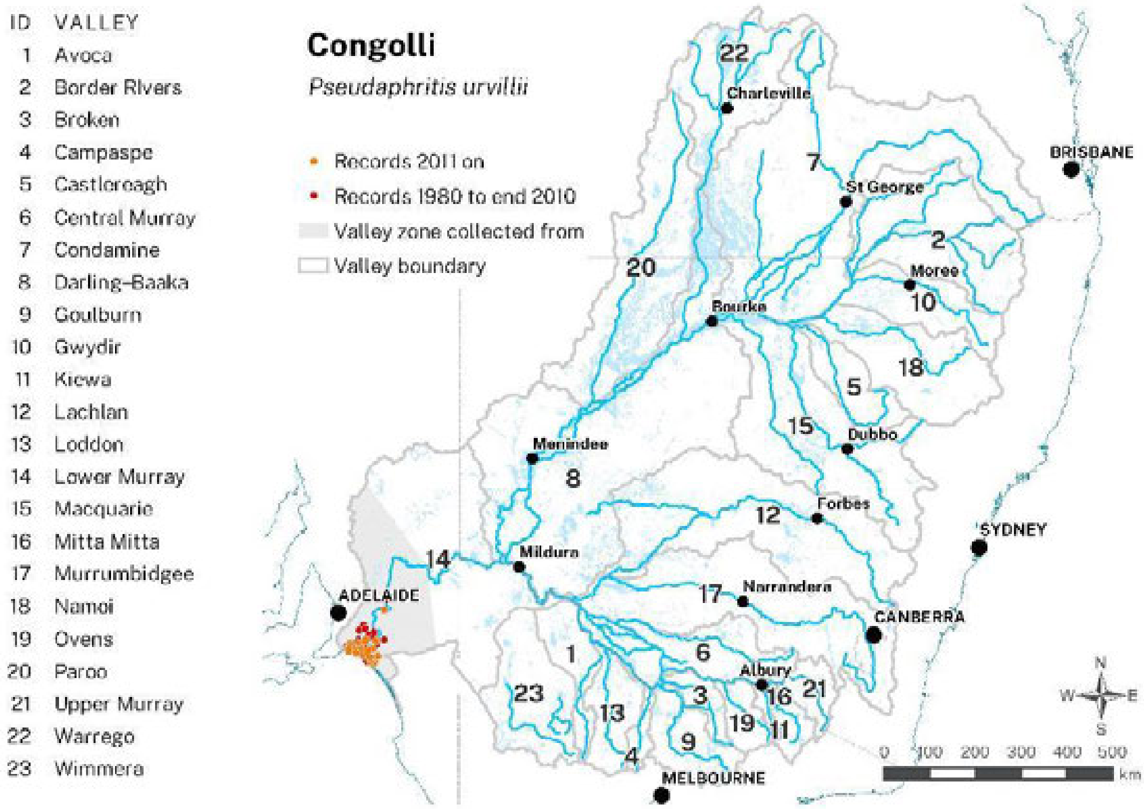
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	New South Wales	ACT	Queensland
LC	–	R	–	–	–	–

LC = Least Concern; R = Rare; – = not assessed

Distribution (presence):

The congolli is found predominantly in coastal rivers in south-eastern Australia. In the Murray–Darling Basin it almost exclusively occurs in the lower Murray drainage, where it has been recorded in the Murray River as far upstream as Echuca but is most common in streams of the Mount Lofty Ranges and the Lower Lakes (Alexandrina and Albert) (Lintermans 2023).

Central Murray record was from a single fish in the period 1980–2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Central Murray	✓	X
	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- A diadromous species, in the lower Murray the species occurs in terminal wetlands and a few lowland stream habitats, where it is often found partially buried in leaf litter or sand, or associated with cover such as logs, rocks and overhanging banks (Lintermans 2023). No individuals were recorded from the SRA/MDBFS surveys. Collected in barrage fish traps.

Overall:

- A common fish of coastal streams outside the MDB, within the MDB its abundance has been greatly reduced by migration barriers formed by the barrages.

Native fish status assessment 2023

Species: *Pseudogobius olorum*

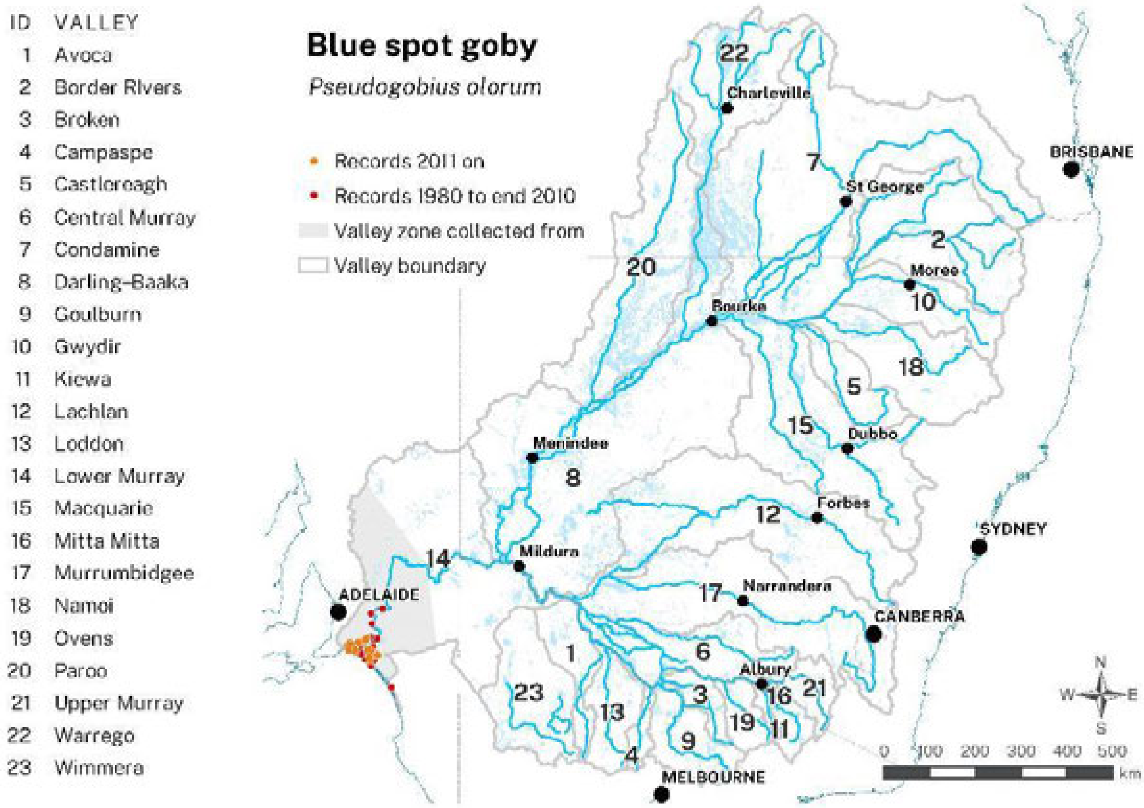
Common name: Western blue-spot goby

Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	New South Wales	ACT	Queensland
–	–	–	–	–	–	–

Distribution (presence):

The western blue-spot goby is really an estuarine generalist and occupies brackish estuaries and associated freshwater streams and lakes. In the MDB, it has only been recorded from the Lower Lakes (and associated wetlands) and the Coorong (Smith et al. 2009, Wedderburn and Suitor 2012, Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- A benthic, burrowing species, usually recorded over mud or rock substrates, occasionally in weedy areas. This species has not been collected as part of the SRA/MDBFS surveys.
- There are insufficient data from which to accurately assess trends in abundance and recruitment.

Overall:

- A common and widespread estuarine species, it is not of conservation concern.

Native fish status assessment 2023

Species: *Retropinna semoni*

Common name: Australian smelt

Conservation status:

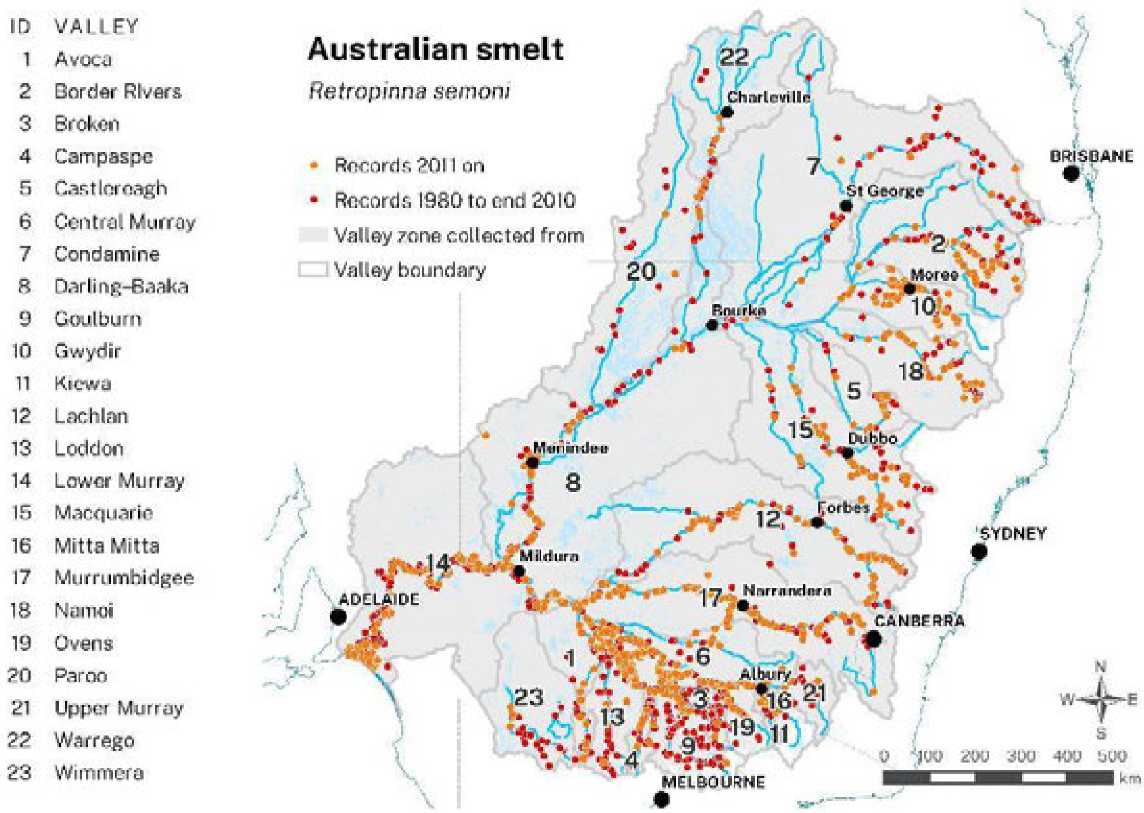
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	New South Wales	ACT	Queensland
LC	–	–	–	–	–	–

LC = Least Concern; – = not assessed

Distribution (presence):

A widespread and abundant small-bodied species occurring in all 23 valleys in the Basin, and the Lower Lakes (Lintermans 2023). Although there are five putative taxa within the currently described Australian smelt/Tasmanian smelt group, only one of these ‘taxa’ occurs within the Basin, although there is some genetic divergence between the upper Murray–Darling and lower Murray specimens (Hammer et al. 2007). This species is now extremely rare in the Paroo, with only two records since 1997.

The species has been recorded in all 23 river valleys and the CLLMM both pre- and post-2010.



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	✓
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	✓
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	✓
	Upper Murray	✓	✓
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Kiewa	✓	✓
	Broken	✓	✓
	Goulburn	✓	✓
	Campaspe	✓	✓
	Loddon	✓	✓
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

Population dynamics:

- Typically a schooling, pelagic species in the Southern Basin, commonly recorded from slow-moving or still water in a variety of habitats (e.g. river channel, wetlands, lakes). In Queensland it is commonly encountered in riffles and along shorelines in association with fringing vegetation (Lintermans 2023).
- Individuals were captured in 22 valleys in the SRA (2004–2010) (missing the Paroo), with the species recorded from all 23 valleys by the SRA/MDBFS surveys since 2011.

- SRA/MDBFS data suggest that the abundance and distribution of the species has remained relatively constant in recent years (Figure 34).

Overall:

- A widespread and abundant species, across the Basin.

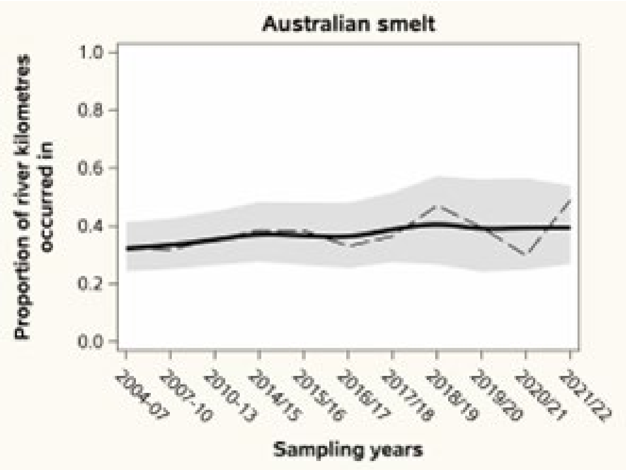


Figure 33. Estimate of proportion of river kilometres inhabited by Australian smelt using the SRA/MDBFS dataset

Native fish status assessment 2023

Species: *Tandanus tandanus*

Common name: Freshwater catfish

Conservation status:

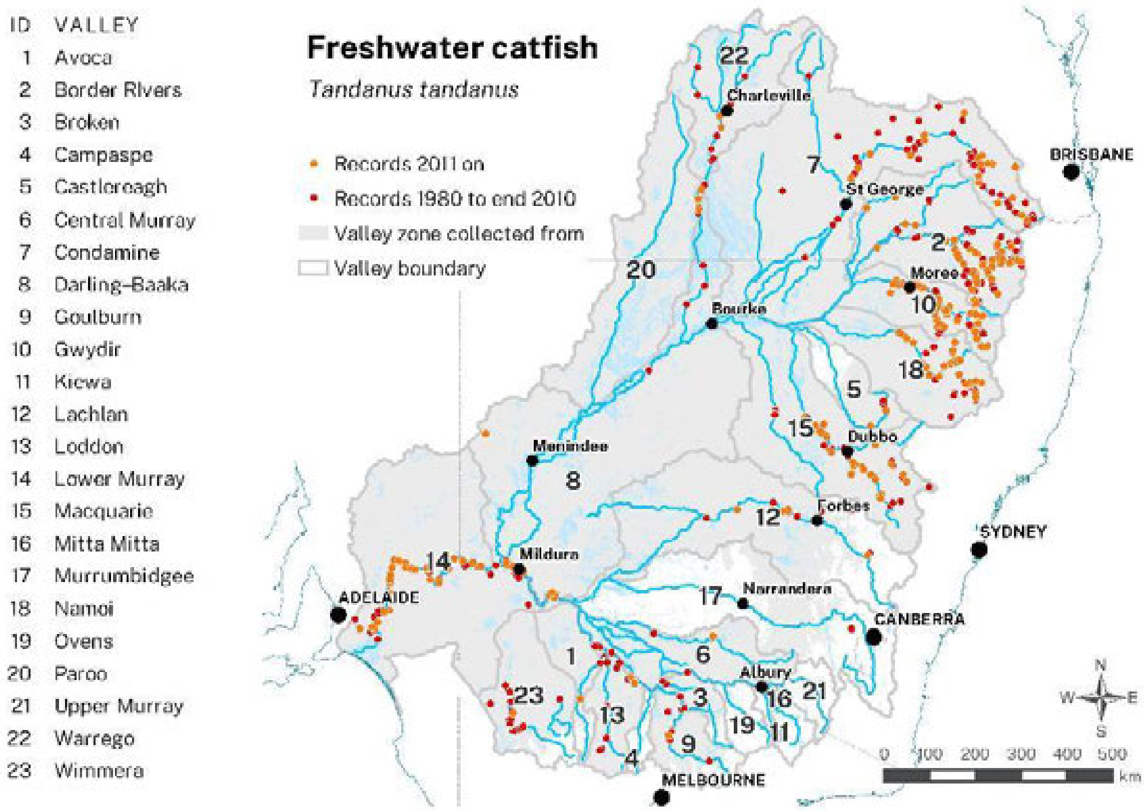
International (IUCN)	National (EPBC-listed)	South Australia	Victoria	New South Wales	ACT	Queensland
LC	–	EN	EN	EN	–	–

EN = Endangered; LC = Least Concern; – = not assessed

Distribution (presence):

Freshwater catfish is a large-bodied, widely distributed, threatened species that occurs in both the Northern and Southern Basins. It has declined across its range in the MDB in recent decades (Lintermans 2023). The presence of coastal populations of this species in Queensland and NSW has hampered national (and international) recognition as a threatened species, but there is no doubt the species has declined and is threatened within the Basin (Clunie and Koehn 2001b, Gilligan and Clunie 2019, Lintermans 2023).

The species was recorded in 19 river valleys (1980–2010) but only in 14 of these valleys since 2010 (absence in two Northern and three Southern Basin valleys).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin	Paroo	✓	X
	Warrego	✓	✓
	Condamine–Balonne	✓	✓
	Border Rivers	✓	✓
	Gwydir	✓	✓
	Namoi	✓	✓
	Castlereagh	✓	✓
	Macquarie	✓	✓
	Barwon–Darling	✓	X
Southern Basin	Lower Darling	✓	✓
	Lachlan	✓	✓
	Murrumbidgee	✓	X
	Central Murray	✓	✓
	Lower Murray	✓	✓
	Mitta Mitta	✓	✓
	Broken	✓	X
	Goulburn	✓	✓
	Loddon	✓	X
	Avoca	✓	✓
	Wimmera	✓	✓
Coorong, Lower Lakes and Murray Mouth		–	–

– = species absent from basin

Population dynamics:

- Freshwater catfish is a benthic species that prefers slow-flowing streams and lake systems in the southern MDB but occurs in upland streams in the Border rivers area
- It is not well sampled by the SRA/MDBFS surveys; total abundances were very low (≤10) in seven out of 12 surveys pre-2011 and seven out of 11 surveys post-2011.
- The low catch rates are reflected in the SRA/MDBFS data, which suggests freshwater catfish persist at relatively low abundance and distribution (Figure 35).

Overall:

- A widespread species across the Basin, it has suffered significant declines.

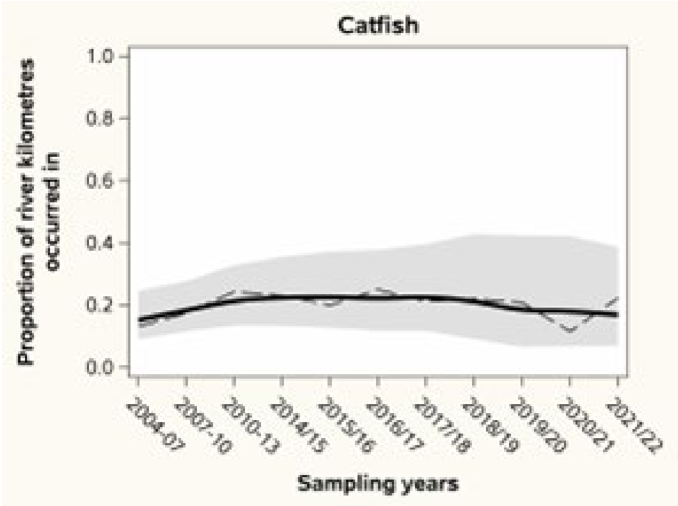


Figure 34. Estimate of proportion of river kilometres inhabited by freshwater catfish

Native fish status assessment 2023

Species: *Tasmanogobius lasti*

Common name: Lagoon goby

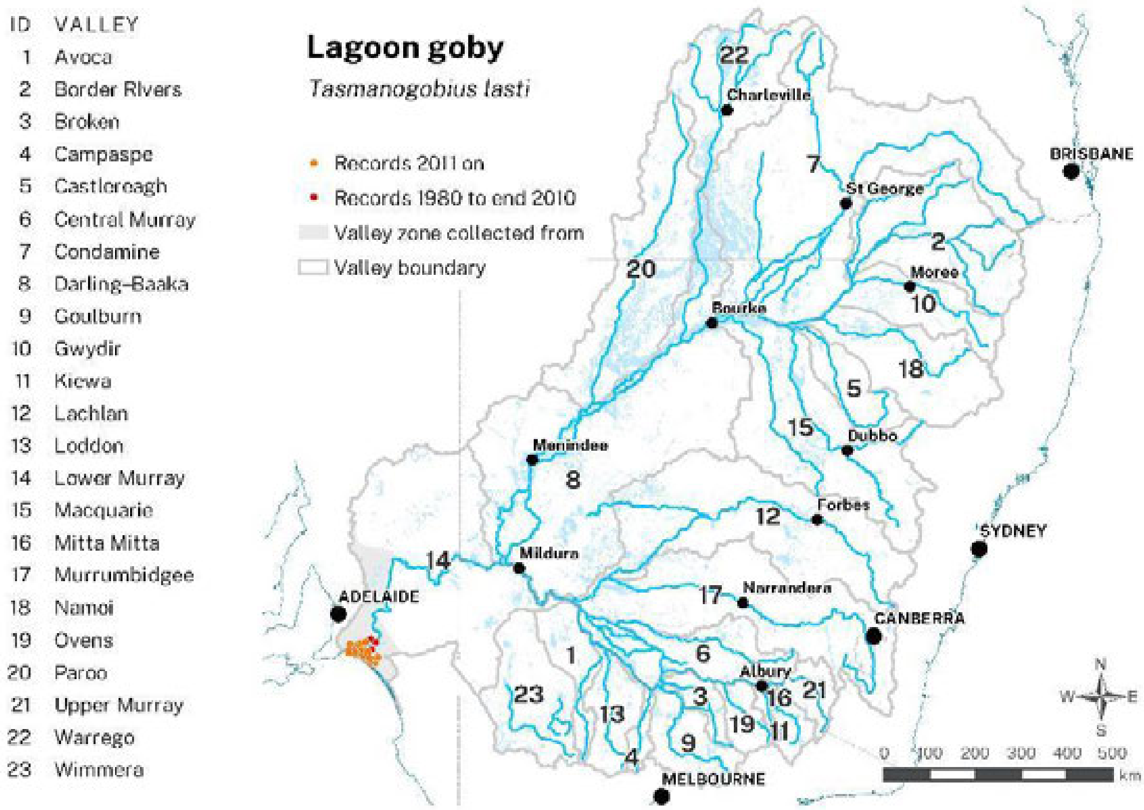
Conservation status:

International (IUCN)	National (EPBC-listed)	South Australia	Victoria	NSW	ACT	Queensland
–	–	–	–	–	–	–

– = not assessed

Distribution (presence):

The lagoon goby is a common and widespread estuarine species in coastal streams of Victoria, South Australia and Tasmania. In the Basin it is only present in the lower Murray River where it is known mainly from the lower swamps (Mannum to Wellington), Lower Lakes (Alexandrina and Albert) and Coorong, where it occurs in about one-third of wetlands sampled. Its distribution extends to wetlands upstream of Mannum, but not as far as Overland Corner (Lintermans 2023).



	Valley/CLLMM	Presence 1980–2010	Presence 2011–2022
Northern Basin		–	–
Southern Basin	Lower Murray	✓	✓
Coorong, Lower Lakes and Murray Mouth	CLLMM	✓	✓

– = species absent from basin

Population dynamics:

- Really an estuarine species in areas of freshwater discharge but is also found, and can complete its lifecycle in, freshwater streams and lakes. It is usually recorded in still or slow-flowing habitats with mud or silty sand substrates. It is a benthic, burrowing species (Lintermans 2023).
- No individuals were recorded from the SRA/MDBFS surveys.
- There are insufficient data from which to accurately assess trends in abundance and recruitment.

Overall:

- A common species restricted to the Coorong, Lower Lakes and associated wetlands.