

## What is needed to restore native fishes in Australia's Murray–Darling Basin?

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**Abstract.** The Murray–Darling Basin (MDB) is Australia's food bowl, contributing 40% of agricultural production and supporting a population of over 4 million people. Historically, the MDB supported a unique native fish community with significant cultural, subsistence, recreational, commercial and ecological values. Approximately one-quarter of the MDB's native species are endemic. Changes to river flows and habitats have led to a >90% decline in native fish populations over the past 150 years, with almost half the species now of conservation concern. Commercial fisheries have collapsed, and important traditional cultural practices of First Nations People have been weakened. The past 20 years have seen significant advances in the scientific understanding of native fish ecology, the effects of human-related activities and the recovery measures needed. The science is well established, and some robust restoration-enabling policies have been initiated to underpin actions. What is now required is the political vision and commitment to support investment to drive long-term recovery. We present a summary of 30 priority activities urgently needed to restore MDB native fishes.

**Keywords:** Basin Plan, environmental water, native fish recovery strategy, rehabilitation, watering management.

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### Introduction

Australia's Murray–Darling Basin (MDB) is one of the most regulated (Grill *et al.* 2019) and at-risk river systems in the world (Wong *et al.* 2007). Its rivers and catchments are mostly in poor ecological condition (Davies *et al.* 2012), and native fish

populations have declined by >90% over the past 150 years (Koehn and Lintermans 2012). Recent surveys indicate this decline is continuing (Murray–Darling Basin Authority 2020). Almost half the MDB species are of conservation concern, and many have fragmented populations. High levels of water

extraction and flow regulation, the ‘Millennium Drought’ (1997–2010), habitat alteration and pest species have had severe effects. ‘Record drought’ conditions (2018–20) and subsequent bushfires (late 2019–20) culminated in major fish kills across the MDB (Vertessy *et al.* 2019; Legge *et al.* 2020). Climate change predictions indicate that such extremes will occur more frequently and become more intense, affecting already stressed river systems. There is now an even more urgent need to take dramatic actions to protect and restore MDB fishes. Many voices are now showing concern (e.g. Australian Academy of Science 2019; Walker 2019), and researchers, stakeholders, communities and natural resource agencies must coordinate their activities and act decisively to avoid the likely extinction of multiple MDB fish species over the next few decades.

Because the decline of MDB native fish populations has occurred over more than a century, a long-term strategy is needed for recovery (Koehn and Lintermans 2012). Restoration requires knowledge, policy and funded actions over appropriate time scales, so planning and actions are urgently needed to allow this long-term recovery process to begin. The compendium of knowledge of freshwater fishes provided in Koehn *et al.* (2020) indicates that our scientific knowledge base is robust, and improving. Although the MDB Plan (Basin Plan; Murray–Darling Basin Authority 2011) provides a much-needed framework for water reform, including the recovery of water for the environment to support native fishes, there are many additional non-water-related threats that affect recovery. Hence, the Basin Plan must be complemented with additional measures. The value of addressing additional threats through parallel restorative actions has been recognised (Koehn and Lintermans 2012; Baumgartner *et al.* 2020) and many are now included in the Native Fish Recovery Strategy (NFRS; Murray–Darling Basin Authority 2020).

Although Koehn *et al.* (2020) provide a contemporary scientific knowledgebase for restoration, it is a large publication, with knowledge condensed into tables and conceptual models for only nine representative fish species. Here, the authors have distilled the key restoration messages identified to provide a brief, clear perspective to guide restoration actions for all MDB fishes that can expedite the recovery of their populations. This perspective is aimed at policy makers, water and fish managers, stakeholders, communities and governments and their agencies.

### Remedial actions to address key threats

Restoring MDB native fishes requires: (1) coordinated policy settings under which actions can be implemented; (2) sound supporting science; (3) prioritised actions; (4) commitment and investment; and (5) stakeholder and community support. We argue that the policy settings and management frameworks, such as the Basin Plan and NFRS, and the supporting science are strong. The NFRS is broadly accepted (Murray–Darling Basin Authority 2020) and it is now political commitment, and implementation of restoration actions that is critical.

The actions required for the restoration of native fish populations can be categorised into: (1) flow management; (2) water infrastructure; (3) other restoration (actions to be implemented in parallel with appropriate flow management); and (4) support and engagement. The 30 identified actions detailed below are

not independent from each other or from existing river operations, and should be implemented in a coordinated manner, with the Basin Plan and NFRS providing policy support and stakeholder agreement for them.

### Flow management

Flow alteration causes a raft of threats to fishes, and key flow components need to be restored.

1. Design, implement and manage coordinated, optimised flow regimes (multiyear or decadal) for all water (environmental water, stock and domestic, irrigation deliveries, protection of natural flows) that permanently support native fishes and ecosystem processes at the appropriate scales
2. Incorporate specific, designed flow components into annual flow hydrographs that restore hydrodynamic diversity, cue spawning, movements and dispersal, including for diadromous fishes at the Murray River mouth
3. Allow overbank flows to restore and support riverine productivity and food webs, connect floodplain habitats, including fish nursery areas, and maintain temporary, seasonal and perennial wetlands through relaxation of ‘constraints’ (see Murray–Darling Basin Authority 2013).
4. Develop and implement preventative strategies to minimise fish kills and poor water quality: real-time water quality monitoring at high-risk sites; maintaining adequate flows; the use of flushing flows, including periodic reductions in floodplain carbon to minimise hypoxic blackwater events
5. Protect free-flowing tributaries and anabranches, drought refugia, remnant waterholes and off-channel wetland habitats from water extraction (e.g. moratorium on pumping) through policy, strategic planning, conjunctive groundwater management with consideration of climate change environmental projections (Pitcock and Finlayson 2011) and the provision of water
6. As a minimum, maintain adequate base flows across the year in perennial rivers to support existing populations, recent recruits and connectivity between rivers (source to sea), floodplains and wetlands
7. Manage water levels in lakes and reservoirs to achieve desired outcomes for native fishes (e.g. protect fringing vegetation as habitats for small fishes such as pygmy perch (*Nannoperca* spp.), facilitate river connectivity for Macquarie perch *Macquaria australasica* spawning migrations in impoundments)
8. Ensure all water use planning and management uses appropriate contemporary fish ecology, appropriate spatial scales and suitable flow records that incorporate climate change projections

### Water infrastructure

The management of water infrastructure can be improved to reduce effects on fish.

9. Provide effective fish passage for all life stages (upstream, downstream and laterally to floodplain channels and wetlands) at priority barriers and remove redundant structures
10. Replace undershot riverine weirs with overshot weirs to reduce larval mortality

11. Protect existing flowing (lotic) habitats and in regions where unnatural lentic weir pools now predominate (e.g. lower Murray River), restore such habitats to increase hydrodynamic habitat diversity by weir pool lowering and increased discharge
12. Prevent the large-scale loss of fish (especially early life stages and small species) through pumps and irrigation diversion infrastructure
13. Ameliorate cold water pollution released from priority impoundments
14. Assess whether planned new infrastructure is needed; explore alternative water supply strategies (e.g. off-stream storages) and ensure new structures do not further compromise fish populations by explicitly considering and remediating effects on the entire life cycle (from eggs to adults)

#### *Other restoration*

A range of other restoration actions can complement those for water management and infrastructure, as detailed below.

15. Protect existing threatened species populations and create additional populations through translocations or hatchery stocking; establish hatchery facilities for the production and stocking of conservation-dependent species
16. Increase instream structural woody habitats at priority sites
17. Eliminate stock access and control terrestrial animal (feral and stock) effects, particularly at sensitive river and wetland sites
18. Protect and restore macrophyte habitats and riparian vegetation
19. Implement threatened species recovery plans, overseen by active, suitably funded recovery teams
20. Undertake sustained, strategic control of alien fishes (e.g. redfin perch *Perca fluviatilis*, carp, eastern gambusia *Gambusia holbrooki* and salmonid species) using pest management principles
21. Implement a Basin Alien Fishes Plan, complete a National Pest Fish Strategy and proactively prevent new incursions (e.g. Tilapia; *Oreochromis mossambicus* and *Tilapia mariae*)
22. Monitor fish population structures and quantify losses due to extreme events (such as fish kills), river operations and angler harvest of recreational species (Murray cod *Maccullochella peelii*, golden perch *Macquaria ambigua*, silver perch *Bidyanus bidyanus*, Macquarie perch, freshwater catfish *Tandanus tandanus* and incidental catch of trout cod *Maccullochella macquariensis*), including catch-and-release mortalities, to ensure population sustainability
23. Establish and resource a threatened fish rescue and recovery facility to house, breed and ultimately return rescued fish to the wild following extreme events such as bushfires and drought
24. Adequately fund and implement the NFRS for the MDB

#### *Support and engagement*

All actions require public, agency and stakeholder support. We need to ensure the public are champions for the restoration of MDB fishes.

25. Build public support for the restoration of MDB fishes from relevant stakeholder groups, including recreational fishers,

peak agriculture groups, irrigation and rural communities, First Nations People and the general public

26. Ensure fish are prioritised equally compared with terrestrial flora and fauna, through inclusion in water and natural resource (including national parks) management plans, the development of a National Freshwater Fish Action Plan and inclusion in the National Threatened Species Strategy (Department of Environment and Energy 2016 (revision due in 2021); see Lintermans *et al.* 2020)
27. Ensure that the concerns and values of First Nations People are represented in all plans and policies that relate to water use, flows, fish and conservation management
28. Establish fish champions (local, regional, Basin-wide) to drive advocacy for native fish restoration and embed native fish recovery in government agendas relating to water resource management
29. Provide material for inclusion into the Australian educational curriculum regarding native freshwater fishes, their plight, and recovery potential
30. Promote awareness of MDB fishes and their values to the Australian public through traditional and social media

#### **Moving forward**

The MDB and its fishes are under great stress and without urgent action there will be species extinctions in the coming decades. We must act quickly to address key threats, through committed and sustained recovery efforts (Koehn and Lintermans 2012). Consideration needs to be given to all fishes across the MDB, from alpine regions, through lowland rivers to the sea, including lesser known small-bodied (Lintermans *et al.* 2020), diadromous and estuarine species. The Basin Plan and the new NFRS, together with threatened species recovery plans, already provide policy and stakeholder agreement for such actions. The information provided in the compendium by Koehn *et al.* (2020) provides a contemporary knowledge base to support restoration.

Immediate commitment is needed now from policy makers, management agencies, community and, most importantly, governments, because they are the final arbiters of implementation. It is not the science or the policy structure that is preventing meaningful fish recovery programs, it is a lack of action and political will. Provision of additional, relevant and accurate information on the plight of MDB fishes to the public will result in support, given that Australians care deeply about their environment and its protection (Samuel 2020). Unfortunately, misinformation has contributed to an 'increasingly toxic' and 'divisive' public debate surrounding environmental water (Interim Inspector-General of Murray–Darling Basin Water Resources 2020). This needs to be addressed with improved messaging about the benefits to all Australians and their river systems of environmental water.

We must also learn from past actions that have had severe effects. We cannot continue to impose more impoundments (dams and weirs) and barriers to fish movements and riverine connectivity. Additional water extraction, including excessive floodplain harvesting (capture of overbank flows) cannot continue to compromise the basic integrity of flowing rivers and their habitats. The NFRS urgently requires adequate funding, support and government acceptance to begin true restoration.

Implementation of the Basin Plan is yet to fully occur, and further refinements to the adequacy and delivery of environmental water is required (Byron 2017). Careful implementation is needed to ensure the intended outcomes of the Basin Plan are achieved. Indeed, the adequacy of the Basin Plan measures for fish objectives should be reassessed before its revision in 2026. However, there are major opportunities through refined water delivery of water to reinstate hydrodynamic components and provide more ecologically beneficial flow regimes. Together with other actions, we provide a way forward that can guide others to restore riverine fish populations, both nationally and internationally.

## Conclusion

The science and knowledge of MDB fishes is considerable and growing. Knowledge is not a constraint to species and ecosystem restoration, but additional information will help maximise outcomes. Two key policy frameworks in the Basin Plan and NFRS provide a solid basis from which recovery can begin. Contemporary science needs to reach managers and policy makers, be accepted and incorporated to improve water and fish management and to build community support. The challenge now is to have the long-term political will, commitment and adequate resourcing to implement the necessary actions. Providing a legacy of native fish recovery in the MDB, rather than extinctions, is our moral obligation to Australia's future generations.

## Conflicts of interest

Lee J. Baumgartner is an Associate Editor of *Marine and Freshwater Research* but did not have Associate Editor-level access to this manuscript while in peer review, as is the standard practice. *Marine and Freshwater Research* encourages its editors to publish in the Journal. The other authors declare that they have no conflicts of interest.

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