doi: 10.1111/emr.12094

Managing fish species under threat: case studies from the Native Fish Strategy for the Murray-Darling Basin, Australia

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Summary The Native Fish Strategy (NFS) for Australia's Murray-Darling Basin was specifically targeted at managing and rehabilitating an entire fish community. Over half of the native fishes (24 of 44 known species) and four fish communities of the Murray-Darling Basin (MDB) are listed as threatened at either national or state level. One of six 'Driving Actions' under the NFS focused on protecting threatened native fish species, and this study reviews a series of NFS case studies during and immediately after the Millennium Drought (1997–2010) which was south-eastern Australia's worst drought on record. Fish rescues, breeding programmes, the creation of an emergency response contingency fund, and expert panels and workshops were all projects that contributed significantly to conserving threatened fishes. The diversity of approaches taken and lessons learned are highlighted, to formulate future directions for threatened fish recovery.

Key words: *blackwater, community advocacy, drought, emergency response, fire, threatened species.*

Introduction

Freshwater ecosystems are threatened globally (Malmqvist & Rundle 2002; Dudgeon *et al.* 2006). In response, rehabilitation programmes have been established for freshwater systems, with fish a popular focal group (Cowx & Welcomme 1998; Bernhardt *et al.* 2005). In Australia, the Murray-Darling Basin (MDB) is one of the largest freshwater ecosystems and supplies 39% of national agricultural production (Lintermans 2007; Koehn & Lintermans 2012). The Native Fish Strategy (NFS) for the MDB was the sole national multijurisdictional freshwater fish programme specifically targeted at managing and rehabilitating an entire fish community (Koehn & Lintermans 2012; Koehn *et al.* 2014a). The MDB has a complex natural resource management framework, as it intersects four states and one territory (hereafter collectively referred to as the 'states'), each with varying legislative processes. For example, threatened and recreational fisheries management are undertaken by different agencies/departments within and between jurisdictions. The federal Murray-Darling Basin Authority (MDBA) provides overarching governance for the region.

Between 1997 and 2010, the MDB experienced the Millennium Drought (van Dijk *et al.* 2013), so called because of a one-in-a-thousand-year severity, causing reductions in stream flow and habitat loss which exacerbated ongoing threats to native fishes including negative interaction with alien species, habitat modification, altered water quality, flow regulation, barriers to fish passage, disease, overexploitation, and inappropriate translocation and stocking (Koehn & Lintermans 2012).

Over half of the native fishes (24 of 44 known species) and four fish communities of the MDB are listed as threatened at either national or state level (Lintermans 2007; Koehn & Lintermans 2012). Many threatened fishes are managed under national or state recovery plans, usually focussed on individual species. Responsibility for the implementation of such recovery plans falls to the states, even for nationally listed species. Consequently, management resources are thinly spread and are usually inadequate. Whilst there have been some positive responses by native fish populations following the end of the drought (see Zampatti & Leigh 2013), wildfires and associated ash, silt and sediment inputs to streams in addition to severe flooding and hypoxic blackwater events following the drought continue to impact depleted native fish populations (e.g. Kearns *et al.* 2012; King *et al.* 2012).

This study reviews a series of NFS case studies of activities directed at nationally and state-listed threatened fish species during and immediately after the Millennium Drought. The review aims to highlight the diversity of approaches taken and lessons learned to better formulate future directions for threatened fish recovery.

Ecological Management & Restoration *Linking science and practice*

Case Study 1: Murray Cod workshop

Murray Cod (*Maccullochella peelii*), is Australia's largest freshwater fish and an icon of the MDB, growing to >110 kg and 1.8 m length (Lintermans 2007). The distribution and abundance of the species has declined significantly over the last 100 years and it was listed as nationally threatened in 2003. Despite this, Murray Cod still supports a major recreational fishery, although commercial fishing for the species ceased in 2003. In response to its listing as a nationally threatened species, a workshop of scientists, managers, anglers and community representatives was convened in 2004 to review current knowledge of the history, status, population trends, threats and management responses relating to Murray Cod. Unlike the other case studies reviewed in this study, the workshop was not a 'crisis management response' to worsening drought, but rather a strategic approach to conserving and managing an iconic threatened species. The workshop developed a vision of 'self-sustaining Murray Cod populations managed for conservation, fishing and culture', formulated a range of 19 priority recommendations intended to facilitate both immediate responses to concerns about the future of the species and identified 15 key knowledge gaps for further research (See Lintermans & Phillips 2005). A 'taskforce' of major stakeholders was formed to assist in the development of a national recovery plan and to guide subsequent research and management initiatives (NMCRT 2010). This stimulated a range of new research projects and joint management approaches, including the formation of a Murray Cod Fishery Management Group to explore innovative partnerships to improve research and management of the species (see Barwick *et al.* 2014).

Case Study 2: The Drought Expert Panel

The Millennium Drought resulted in record low inflows to water storages in the MDB and substantial flow reductions in unregulated rivers and streams (van Dijk *et al.* 2013) which stimulated a range of water conservation management measures to secure water supply for towns and agriculture. At the same time, a number of other *ad hoc* land management interventions (e.g. increasing livestock access to streams) or fisheries management actions (e.g. salmonid stocking to replenish bushfire-affected streams) were also being suggested, with such scenarios having the potential to cause lasting ecological damage and, at the least, hinder fish population recovery. Coordinated management responses were therefore required to secure persistence and then recovery of fish populations.

In response, the MDBA convened an 'Expert Panel' in June 2007 to consider the management of native fish during drought. The panel's report (Lintermans & Cottingham 2007) was intended to inform policy updates and on-ground actions that might be undertaken by the MDBA and other federal and state agencies. Priority recommendations included: (i) identify, catalogue and protect drought refugia; (ii) develop integrated, coordinated Drought Action Plans (DAPs) for Basin-wide responses; (iii) include drought management of recreational fisheries as part of local DAPs; (iv) develop Basin-wide threatened species recovery plans; and (v) intensify pest species management to take advantage of opportunities for control provided by drought. The panel also identified actions that should be *avoided* including (i) automatically using native fish restocking as the fallback management response; (ii) stocking introduced fish predators (e.g. salmonids) which would place additional stress on already-depleted native populations; (iii) increased fishing of depleted populations within or outside of drought refugia; and (iv) increased access by livestock to refugia or riparian zones.

The panel identified that, following the breaking of the drought, long-term monitoring of recovery of fish populations would be required and that it should not be assumed that stocks would automatically recover, or that this would occur quickly. Several research projects into refugia and native fish resistance and resilience were catalysed, a number of regional DAPs were prepared (e.g. see Case Study 4), and the importance of drought refugia received considerable scientific and management attention.

Case Study 3: The Native Fish Strategy Emergency Contingency Fund

As the severity and extent of the drought increased, it became obvious that rapid responses were required to a range of 'crisis' events (e.g. bushfire, habitat desiccation, deterioration of water quality). In late 2007, a NFS Emergency Contingency Fund (NFSECF) was established to provide the capacity to rapidly approve and deliver short-term funding to jurisdictions as an interim measure whilst other jurisdictional resources were organised for ongoing action (e.g. captive maintenance and/or reintroduction). It was initially anticipated that a contingency fund of AUS $50 000 per annum would facilitate 2–3 interventions per year (Pritchard *et al.* 2009). Criteria for NFSECF funding related to the spatial scale of benefits; need for support from threatened species recovery teams; approval from management authorities for donor and recipient sites in the case of translocations; co-investment; and compliance with relevant jurisdictional policies.

Assessment of fund applications by the MDBA NFS team resulted in a total of nine projects being funded between 2008 and 2011, including case studies 4 and 5 given below as relevant examples (see Supporting Information Table 1 for details of all funded projects). Initial projects were largely drought and bushfire related, with later projects associated with extensive blackwater events following the end of the drought in 2010. Projects focused on actions including emergency watering of drying habitats, interventions such as aeration or dilution to address poor water quality, establishment of captive-breeding facilities and fish rescues in relation to bushfire impacts or blackwater events. The need and responsiveness of the NFSECF was highlighted in early 2009 when, within a week, five applications were received for emergency funding across three states. Within 4 days all appli-

cations had been supported, and almost AUS$200 000 allocated.

Case Study 4: Broad-Scale Drying of Critical Fish Habitat on the Lower Murray

The lowermost reaches of the MDB in South Australia contain a suite of threatened small-bodied species, occurring as outlying, genetically distinct refuge populations (see Hammer *et al.* 2013). Rapid, broad-scale and catastrophic habitat loss occurred in the region during the Millennium Drought with the survival of many fishes (and indeed unique habitats and ecosystems) placed in jeopardy (Kingsford *et al.* 2011; Hammer *et al.* 2013). The NFSECF supported short-term, critical projects, including establishing dedicated captive-breeding facilities and a reintroduction plan for rescued Southern Purple-spotted Gudgeon (*Mogurnda adspersa*) (last known individuals for the entire southern MDB: Hammer *et al.* 2012); the installation of water infrastructure to maintain *in situ* pool habitat at Rodwell Creek (singular catchment refuge for River Blackfish (*Gadopsis marmoratus*)); the installation and delivery of critical environmental water at Rocky Gully Wetland (significant refuge for Murray Hardyhead (*Craterocephalus fluviatils*)); and a contribution to a broader multispecies local response known as the 'Drought Action Plan' (Hammer *et al.* 2013). Collective actions ensured the short-term preservation of at least one management unit for each of five key threatened species, including captive programmes for two that became extinct in the wild, and *in situ* habitat works for others such as environmental water provision and earthen levee construction that protected refuge populations (Hammer *et al.* 2013).

Case Study 5: Drought, Fires and Fish

Flow variability and postfire ash/sediment inputs are natural processes under which Australian fishes have evolved (Lyon & O'Connor 2008). However, anthropogenic impacts from habitat fragmentation and population isolation, and increased competition or predation from alien species now hinder the ability of native fishes to recover from such natural stressors. During the Millennium Drought, a catastrophic bushfire in 2009 burnt large areas of forested catchment in north-eastern Victoria, including catchments of streams containing populations of two nationally threatened fish species, Barred Galaxias (*Galaxias fuscus*) and Macquarie Perch (*Macquaria australasica*).

The Barred Galaxias occurs only within the headwater reaches of a single river basin, where it is now severely isolated and fragmented (Raadik *et al.* 2010). Bushfires in early 2009 burnt habitat across 45% of known populations. Given a lack of recolonisation ability, susceptibility to invasion by predatory introduced salmonids, small population sizes and the very high probability of postfire ash/sediment input from the disturbed catchments (see Lyon & O'Connor 2008), adult fish from each impacted population (n = 394 fish from eight populations) were salvaged and brought into captive management in a specialised aquaculture facility (Raadik *et al.* 2009). As Barred Galaxias are an upland, cold-adapted species, a particular challenge was to maintain the fish at temperatures mimicking those in the environment, ranging from 2 to 5°C during late winter–early spring to 12–15°C during summer. Captured fish were kept in captivity until catchment vegetation recovered to reduce the risk of sediment/ash-induced fish kills (captivity varied from 10 to 25 months due to varying rates of catchment recovery).

Key remnant populations of Macquarie Perch in King Parrot Creek and Hughes Creek, Victoria, were targeted for urgent conservation action (Kearns *et al.* 2012). Due to the isolation of the upper King Parrot Creek population and expected postfire sediment mobilisation, a sample of fish (n = 35 adult and subadults) was captured and housed at a nearby government hatchery for 9 months before being released back to the wild when water quality sufficiently improved. The most critical factor during this process was salvaging fish before rainfall caused potential sediment-induced fish kills. In autumn 2009, fish surveys of Macquarie Perch in the lower reaches of Hughes Creek revealed fish to be in poor condition and displaying signs of severe stress as a direct result of low flows. Dissolved oxygen concentrations of <3 mg/L were recorded, and dead fish were present (Kearns 2009). Consequently, 32 adult Macquarie Perch were rescued, held in government aquaculture facilities, and then subsequently re-released into Hughes Creek during December 2009 when water quality had improved.

Discussion

Management of threatened fish by State and federal agencies under the guidance of the NFS has proved challenging, especially in the context of extreme events, with the focus largely being reactive rather than proactive. The case study concerning Murray Cod was an exception, with the 2004 workshop and subsequent formation of the taskforce driving a series of research and management initiatives for this species that will, hopefully, deliver improved management outcomes for recreational angling and conservation. The large temporal and spatial scale of the Millennium Drought had wide-reaching implications for natural resource management and the conservation of freshwater fishes in the MDB (Lintermans 2013). The case studies presented highlight that, in severely modified and drought-affected regions, timely and decisive action will at times be required to prevent local or complete extinction of species. A process should therefore be in place for future ecological emergencies to be swiftly responded to by enabling rapid approval and funding of projects.

Several key lessons emerged to guide future directions in natural resource management and policy concerning aquatic habitats. Rapid availability of emergency funding was critical to ensure that at-risk populations could be salvaged as soon as possible postfire, well before larger fund-

ing became available. It allowed development of numerous and novel recovery tools (captive management, captive breeding and rearing, translocation) in addition to the accumulation of essential knowledge (potential translocation sites and genetic population information) to facilitate or guide conservation management (see Ayres *et al.* 2012; Hames 2012; Kearns *et al.* 2012; Stoessel *et al.* 2012).

Coordinating actions across a diverse stakeholder base was crucial for effective action. Recognition of existing and potential impacts is an important first stage, and documents that present practical examples and guidelines can inform response (Hammer *et al.* 2013). Understanding what not to do during critical situations (i.e. acts that may compound levels of threat) can be just as important (Lintermans & Cottingham 2007).

A key component of the success of several of the case studies was the role of community support. In the Barred Galaxias and Macquarie Perch rescues and subsequent reintroductions, the community rallied and connected with these important fish populations. This connection between people and native fish resulted in major progress in improving the relationship between conservation scientists and trout anglers. Historically, there had been major conflict around issues of trout predation on the Barred Galaxias, but the new preparedness by all parties to help a species in crisis, generated a significant shift in the relationship, with trout anglers revegetating a stretch of Barred Galaxias habitat in Marysville (Dedual *et al.* 2013). For Macquarie Perch, the local community, in partnership with the Goulburn Broken Catchment Management Authority, has been actively involved in implementing recovery actions in King Parrot Creek. Since initial urgent actions, local advocacy for the species has grown and led to the establishment of a multi-agency group planning and implementing a suite of riparian restoration projects and education activities. In-kind contributions from community groups and schools improved the capacity and awareness of the Southern Purple-spotted Gudgeon breeding programme (Hammer *et al.* 2012). The involvement of a diverse cross-section of people, passionate about Murray Cod, was critical to the completion and wide acceptance for the relevant national recovery plan (NMCRT 2010).

Future Directions

The recent crises and management responses associated with drought, bushfire and blackwater (see King *et al.* 2012) in the MDB have provided a forewarning of what climate change might bring to temperate regions, as the frequency of extreme events is forecast to rise (Ficke *et al.* 2007; Morrongiello *et al.* 2011). Such a scenario clearly reinforces the need for a future overarching programme like the NFS to coordinate management responses to such environmental changes. The allocation or protection of environmental flows under the NFS was identified as a key component for restoration of native fish to their estimated pre-European settlement levels (Koehn & Lintermans 2012). However, this action is limited particularly during times of drought, where conflicts emerge between environmental and human requirements for freshwater (Poff *et al.* 2003). As such, it is important to draw upon our knowledge of flow regimes and critical components of life-history strategies for threatened species in the MDB (i.e. King *et al.* 2009; Koehn *et al.* 2014b in an effort to sustain these fish communities facing similar circumstances into the future.

Despite the vagaries of government funding cycles, and the episodic nature of extreme events, contingency planning and mechanisms for the rapid availability of funding to support the most critical natural values during future extreme events (i.e. fire or drought) is essential. This can be achieved by planning both within the individual species recovery planning process and within broader plans that deal primarily with the extreme event.

Community 'ownership' of the threatened species in question can clearly assist resource managers to achieve the groundswell of support and capacity needed to ensure that urgent (e.g. rescue) and longer-term recovery actions (e.g. stream rehabilitation) can occur. The NFS played a key role in engaging with local communities to increase awareness of threatened fishes (see Hames *et al.* 2014; Hames 2012). Local communities were a valuable asset that contributed to the recovery of threatened species, both through direct actions such as on-ground works, or indirectly including increasing awareness of threatened species and avoiding undertaking activities that could further jeopardise populations. Engaging local communities can also play a key role as 'sentinels' to alert government authorities of local threats and contribute knowledge that might initiate or support emergency recovery actions (e.g. Granek *et al.* 2008). A commitment to developing and maintaining long-term relationships between government agencies and communities is essential to enable quick, effective response to ecological emergencies such as the Millennium Drought in the MDB.

In conclusion, the NFS galvanised jurisdictions, policy, management, research and on-ground actions and played a critical role in coordinating and facilitating timely responses to pressing management needs for a range of threatened fish species and populations.

Acknowledgements

We thank the MDBA Native Fish Strategy for their support of threatened fish recovery over the years, and in particular for assisting with emergency contingency funding for a range of interventions reported in this paper. Many organisations assisted with the implementation of the threatened fish rescue and recovery actions detailed herein including SARDI Aquatic Sciences, Native Fish Australia, SA MDB NRM Board, the Living Murray programme, Healthy Rivers Australia, SA Department For Water, PIRSA Fisheries, Commonwealth Environment Water Holder, Commonwealth and Vic governments 'Rebuilding Together – Statewide Bushfire Recovery Plan (for funding), Victorian Department of Primary Industries, Arthur Rylah Institute

for Environmental Research, Parks Victoria, staff from Lake Mountain Resort; Caring for our Country Bushfire Recovery Program (for funding), Goulburn Broken Catchment Management Authority, Australian Trout Foundation, Strath Creek Landcare Group, Triangle Arts Group, Flowerdale Environment Engine, and Strathbogie Conservation Management Network.

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