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Demonstration reaches: Looking back whilst moving forward with river rehabilitation under the Native Fish Strategy

By Craig A. Boys, Jarod Lyon, Brenton Zampatti, Andrew Norris, Adam Butcher, Wayne Robinson and Peter Jackson

Summary 'Demonstration reaches' are sections of river where multiple threats to native fish are addressed through river rehabilitation and strong community participation. They are an important way of promoting the key driving actions of the Murray-Darling Basin Authority's Native Fish Strategy (NFS) by using on-ground community-driven rehabilitation. Measuring rehabilitation success against well-defined targets and using this information to adaptively mange activities is fundamental to the demonstration reach philosophy. Seven years on from the establishment of the first demonstration reach, there are now seven throughout the Murray-Darling Basin (MDB), all in differing states of maturation and but all applying a standardised framework for monitoring native fish outcomes. In this study, we reflect on the role that demonstration reaches have played within the NFS, synthesise some key findings from 32 monitoring and evaluation outputs, and highlight some of the successes and barriers to success. We make recommendations as to how to strengthen the demonstration reach model to ensure it remains a relevant approach for fish habitat rehabilitation beyond the NFS and MDB.

Key words: *fish habitat, fish passage, monitoring, Murray-Darling Basin, re-snagging, river rehabilitation.*

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Introduction

The Native Fish Strategy (NFS) has set an ambitious target to rehabilitate native fish species in the Murray-Darling Basin (MDB) back to 60% or better of their estimated pre-European settlement population levels over a 50-year timeframe (MDBC 2004). To demonstrate how this may be achieved, several 'demonstration reaches' have been established where a number of the driving actions of the NFS (Koehn & Lintermans 2012) are addressed simultaneously through river rehabilitation and strong community participation (Box 1 and Fig. 1) thus providing a model for future actions elsewhere. The demonstration reach approach recognises that there is no single solution for addressing native fish declines, but rather promotes adaptive management (Downs & Kondolf 2002) where a combination of actions are used to target a range of threats (Phillips 2002; Barrett 2004). In 2006, the first NFS demonstration reach was established on the Darling River between Bourke and Brewarrina in New South Wales. There are now seven reaches in differing stages of development (Fig. 2 and Table 1), all of which have received government and/or private investment to support rehabilitation.

Evaluation is essential to progressing the science and management of river rehabilitation (Palmer *et al.* 2005). Significant emphasis was placed on the need to monitor and evaluate demonstration reaches (Barrett 2004) and to assist with this a monitoring framework was developed (Boys *et al.* 2009). All seven established reaches now have operational monitoring programmes, some of which have advanced to a state where preliminary results are now available. To date, there has not been an attempt to formally capture and document the principal lessons across all of these monitoring programmes. In this paper, we outline

Box 1. Key features of a demonstration reach (Adapted from: Barrett 2004; Boys et al. 2009)

A rehabilitation project was considered suitable as a demonstration reach if it satisfied the following criteria:

1. It addressed multiple threats to native fish as identified under in the NFS, including some of the following: flow regulation, habitat degradation, barriers to fish passage, alien species, disease, over-exploitation and translocation and stocking.
2. It was close to a significant human population and accessible and visible to the public to gain strong community support.
3. It would be suitable for trialling rehabilitation techniques and providing solutions to problems which could be applied to other sites in the basin.
4. There was the opportunity to work in parallel with existing tenures and management programmes at local, State and Commonwealth level.
5. It was suitable for testing scientific hypotheses and monitoring results. Ideally, this would involve comparison to nearby, untreated, control reaches.

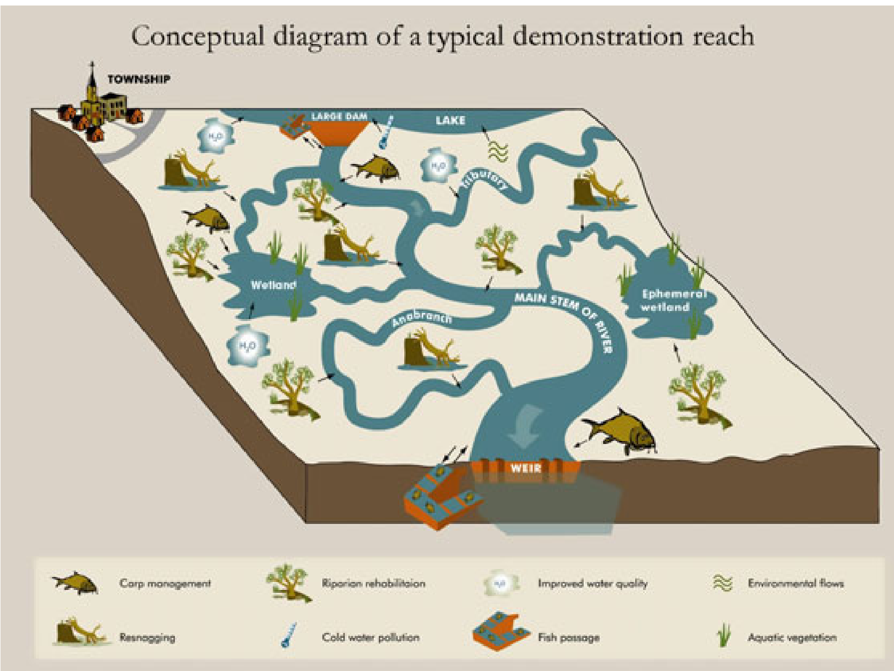

Figure 1. Demonstration reaches show-case river restoration techniques which address multiple key-threatening processes to native fish within the same stretch of river (source: MDBA).

the general monitoring and evaluation framework applied across all reaches and briefly review information from 32 reports of preliminary results for key rehabilitation actions. We reflect on some of the successes, failures and barriers to success with the broad aim to provide commentary on the current state of demonstration reach monitoring. We provide some recommendations that we believe are important if demonstration reaches are to remain a relevant tool for promoting the recovery of native fish and their habitats, with the potential for extension to river systems outside the MDB.

Framework for Monitoring and Evaluating Demonstration Reaches

The framework for monitoring and evaluation at demonstration reaches (Boys *et al.* 2009) was intended to be prescriptive enough to ensure a minimum standard of monitoring was upheld, but flexible enough to meet the challenges unique to each individual reach. Therefore, whilst a standardised approach was promoted across the MDB, it could be adapted to the relevant threats and rehabilitation needs of each reach and align with the goals set by the local community. The framework described the steps involved in establishing a monitoring programme within demonstration reaches and was based on an adaptive management approach, with built in feedback loops (Fig. 3). It was acknowledged that the unpredictable nature of river systems, along with project-specific factors such as stakeholder preferences, available resources and timeframes may combine to greatly constrain the monitoring approaches that could be applied. However, it was also noted that a well-designed monitoring programme can greatly reduce uncertainty and enhance the likelihood of learning success.

The framework promoted the establishment of conceptual stressor-response models to enable quantifiable hypotheses of system recovery to be established and refined (Boys *et al.* 2009). Hypotheses were then tested using a suite of biological (e.g. fish abundance) and physical (e.g. water quality, geomorphology and hydraulic) indicators. The experimental designs of different demonstration reaches varied in nature and inferential

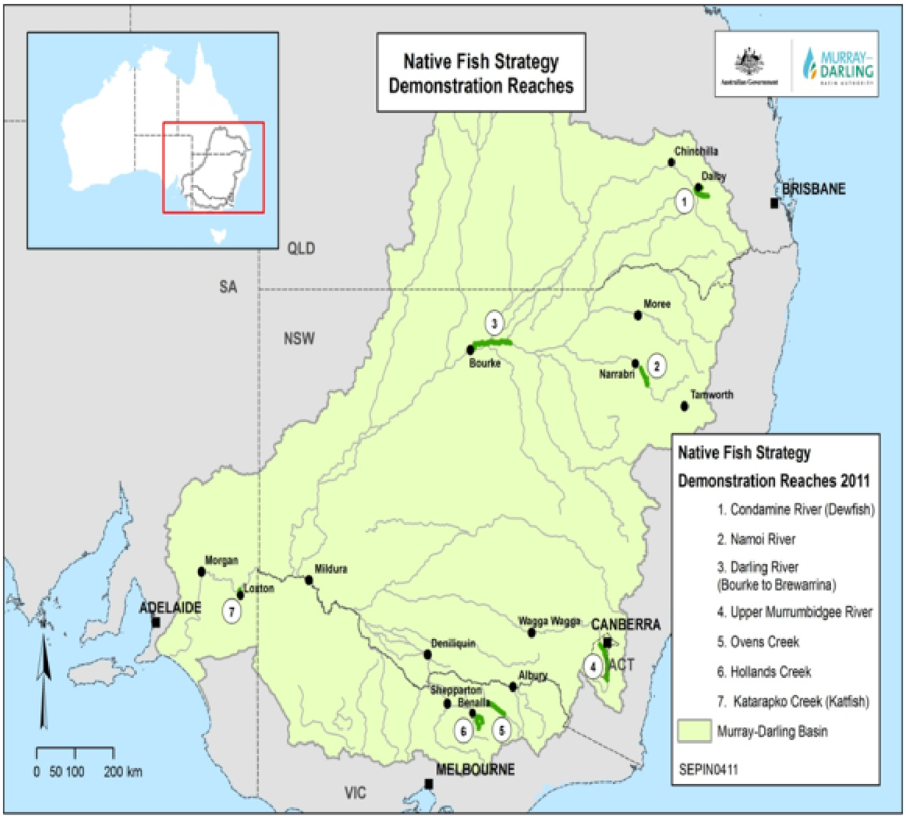

Figure 2. Location of Native Fish Strategy demonstration reaches (source: MDBA).

strength, but most were multivariate, multiscalar and asymmetrical, and incorporate some degree of pre-intervention monitoring and use of control reaches for comparison. All reaches have attempted to measure an overall change in condition across the 'whole-of-reach scale', but in many reaches, there has also been an attempt to 'unpack' the relative contribution of different rehabilitation activities by undertaking intervention-based monitoring (Table 2). With this monitoring (c.f. Boys *et al.* 2009), individual activities (e.g. resnagging or fishway construction) have been treated as manipulative experiments, with their own stressor–response relationships, indicators, experimental designs and reporting timelines.

Overview of Preliminary Findings

In this section, we illustrate some of the key findings that have been reported from demonstration reaches, relating either to changes in overall condition at the reach-scale, or specific responses associated with some (but not all) of the interventions undertaken (Table 2). To do this, we reviewed all scientific outputs from the monitoring and evaluation programmes of the respective reaches (a full compendium of these outputs is outlined in Table S1). At the time of publication, 32 research outputs were obtained. The majority of these (31) were technical reports typically produced for funding bodies or to assist reach managers to adaptively manage activities. Only a proportion of these (47%) were freely available to the general public as online material or in print.

Reach-scale condition

Several reaches have started reporting against reach-scale condition targets. Typically, this has involved some metric of the fish assemblage, and across different reaches, the responses have varied. For example, three of the seven reaches have reported measurable reach-scale responses in key fish indicators. In the Ovens River reach, preliminary analysis suggests that Murray Cod (*Maccullochella peelii*) abundance has substantially increased relative to nearby untreated control reaches (Raymond *et al.* 2013b). Similar observations have been made for Macquarie Perch (*Macquaria australasica*) in the Hollands Creek reach (Raymond *et al.* 2013a). In the Dewfish reach in the Condamine catchment, the abundance of large-bodied native fish species, particularly Golden Perch (*Macquaria ambigua*), has signifi-

Table 1. There are currently seven Native Fish Strategy demonstration reaches in operation throughout the Murray-Darling Basin, all of which are at various stages of implementation

Reach	Description and location
Bourke to Brewarrina	Approximately 200 km section of the main channel of the Barwon–Darling River in western NSW (an unregulated dry land, lowland river) between the townships of Bourke and Brewarrina, New South Wales (NSW).
Namoi	approximately 150 km section of the main channel of the Namoi River (a regulated lowland river) between Mollee Weir and Gunnedah, NSW.
Dewfish	Approximately 37 km section of the main channel of the Condamine River (dry land, lowland) near Dalby (Queensland) and the lower reaches of two major tributaries (20 km of Myall Creek and 64 km of Oakey Creek).
Hollands Creek	Approximately 15 km section of main channel of Hollands Creek (unregulated, slopes) near township of Tatong, Victoria
Ovens River	~20 km section of main channel of Ovens Creek (unregulated, lowland) near township of Wangaratta, Victoria
Upper Murrumbidgee	Approximately 100 km section of the Murrumbidgee River (unregulated, upland) extending from the township of Bredbo in southeast New South Wales downstream to Casuarina Sands in the ACT
Katfish Reach	Anabranch system of the River Murray (regulated, lowland) which bypasses Lock and Weir No. 4 downstream of Berri South Australia

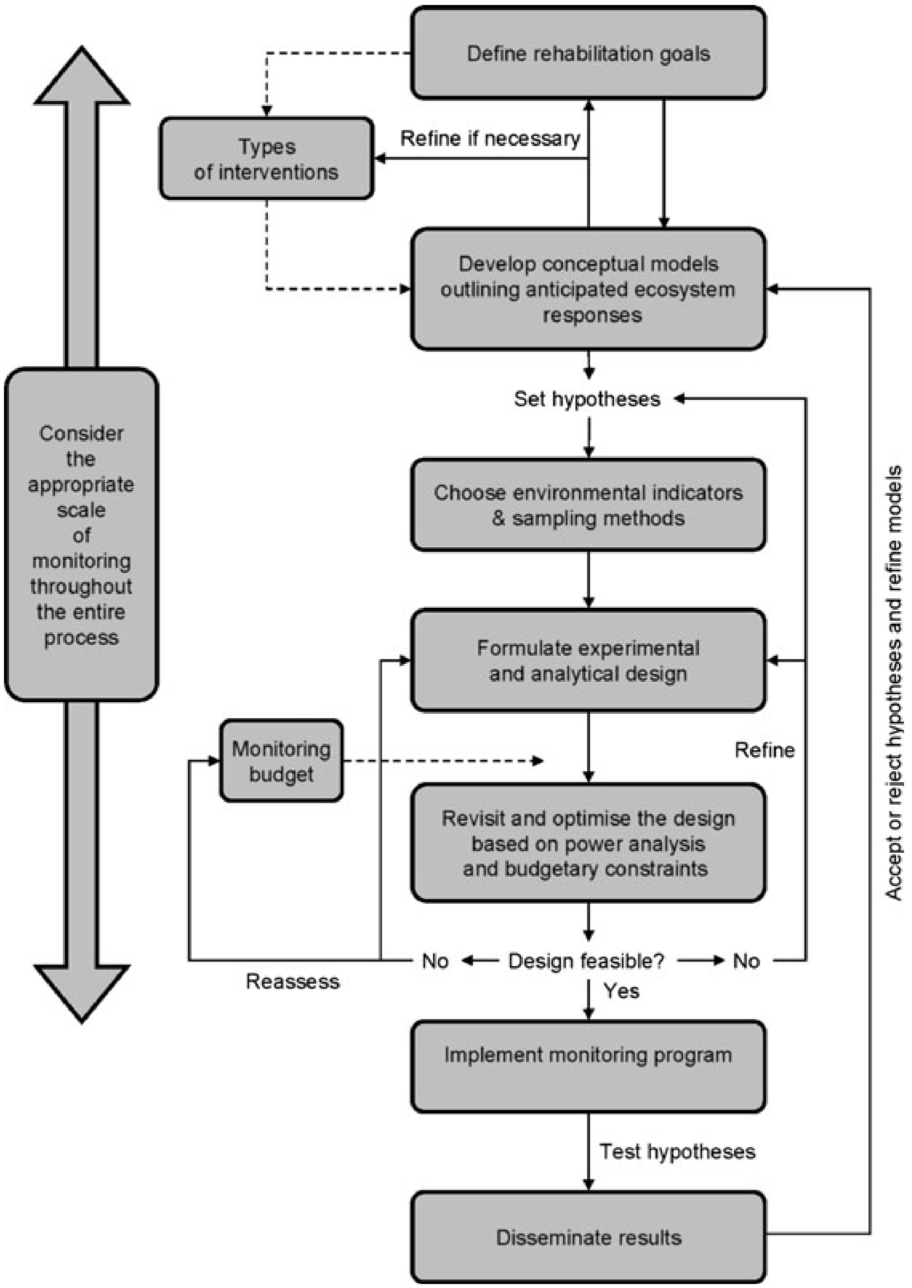

Figure 3. Adaptive management approach to developing and implementing ecologically effective monitoring at demonstration reaches (adapted from Boys *et al.* 2009).

cantly increased at two sites relative to nearby untreated control and reference sites (Norris *et al.* 2011, 2012a,b).

At the other four reaches, overall change in reach condition was either not reported or was considered to have little association with the demonstration reach activities, For example, in the very large (200 km) Bourke to Brewarrina reach, 2 years of pre-intervention and 3 years of post-intervention monitoring failed to detect a response in key native fish indicators (such as species diversity, abundance and 'nativeness': i.e., proportion of native fish to alien fish) that could be attributed to rehabilitation interventions (Boys *et al.* 2013b). The authors suspect that this result was not helped by the large amount of interannual variability in fish abundance associated with episodic floods in the Barwon–Darling River. But they also suggest the vast size of the reach and correspondingly limited scale of interventions may have limited ecological responses to the rehabilitation activities.

Resnagging

Resnagging (or the reintroduction of large wood) was the second most frequently applied intervention in demonstration reaches (after riparian works) but was the most frequently evaluated (studied in five of the seven reaches: Table 2). Resnagging has become a common part of river restoration programmes elsewhere (Reich *et al.* 2003; Kail & Hering 2005; Kail *et al.* 2007), but there is still some uncertainty as to how best to apply it to effectively address instream habitat loss (Lester & Boulton 2008). Whilst some studies report enhanced fish and macroinvertebrate diversity (Hilderbrand *et al.* 1997; Brooks *et al.* 2001; Bond & Lake 2005; Nicol *et al.* 2005; Lester *et al.* 2007), other studies report negative effects on geomorphology or biotic diversity (Spanhoff *et al.* 2006).

Consistent with the broader literature, preliminary responses to resnagging efforts in the NFS demonstration reaches reflect considerable variability. For some reaches, a significant change in key fish indicators has been detected in response to resnagging works. In the Dewfish reach, resnagging has resulted in significant increases in Bony Bream (*Nematalosa erebi*), Golden Perch (*Maquaria ambigua*) and Freshwater Catfish (*Tandanus tandanus*) compared with untreated control and reference sites (Norris *et al.* 2011, 2012a,b). Furthermore, Murray Cod have begun to return to an area where they had not previously been captured during pre-intervention surveys (Norris *et al.* 2012b). With respect to all these species, the increase in abundance may have resulted from the recruitment of individuals from nearby reaches (aggregation), and additional time will be required to determine whether resnagging will lead to long-term improvements in their overall populations (Norris *et al.* 2012b). Not all reaches, however, reported improvements following resnagging. In the Bourke to Brewarrina reach, no significant effect of resnagging was

Table 2. Monitoring and evaluation programmes have been tailored to each reach, reflecting both the types of interventions undertaken and resource availability. The interventions undertaken in each reach are indicated by a square. Although all reaches have conducted reach-scale monitoring of overall condition, not all interventions were monitored individually (indicated by a cross), with only some evaluated through manipulative experiments (indicated by a tick).

Reach	Resnagging	Alien species control	Riparian restoration	Fish passage	Instream habitat*	Fish screening at water diversions	Eflows	Native fish re-stocking
Bourke to Brewarrina	☑	☒	☒	☒				
Namoi		☒	☒	☑	☒	☑		☑
Dewfish	☑	☑	☑	☑				
Hollands Creek	☑		☒		☑			☑
Ovens River	☑	☒	☒	☑				
Upper Murrumbidgee	☑	☑	☑	☑	☑			☑
Katfish Reach		☒	☒	☒			☑	

*Including alteration to hydraulics and geomorphology using direct bank for bed alteration or indirectly using flow deflection devices, such as rock groynes, log deflectors, riffle construction.

found on Golden Perch and Murray Cod abundance, or the 'nativeness' metric (Boys *et al.* 2013b). Native fish did aggregate at reintroduced snags, but across a suite of replicated resnagging sites, there was no consistent measurable response relative to natural background or interannual variability evident at control and reference sites. Similarly, hydraulic and geomorphic indicators did not respond to resnagging, suggesting that wood placement had little effect on increasing hydraulic variability or channel scouring (Southwell *et al.* 2009). These two features of fish habitat creation have in the past been attributed to resnagging elsewhere (Lester & Boulton 2008).

Fish passage

Many fish species move between habitats for the purposes of feeding and recolonisation (Mallen-Cooper 1996), and barriers that impede these movements have the capacity to impact on population dynamics in the MDB (Baumgartner 2006). Mitigating barriers through fishway construction or barrier removal can result in large increases in fish production when compared to other habitat rehabilitation activities (Roni *et al.* 2005), and its success has been well-documented under the NFS (see Baumgartner *et al.* 2014 in this volume).

Fish passage improvements have been attempted in five demonstration reaches and have been monitored in three. Whilst some reaches report that fishways are functional (fish have been observed using the fishways), none have evaluated passage efficiency (i.e. ascent success relative to failure) to any great extent. In the Ovens River reach, Trout Cod (*Maccullochella macquariensis*) have been observed utilising a rock ramp fishway during low flows (Raymond *et al.* 2013a). Monitoring of fish assemblages immediately upstream and downstream of the Loudoun Weir fishway (Dewfish Reach) has revealed no consistent changes, although large numbers of fish have been observed moving through the fishway at times (including Bony Bream, Carp Gudgeon (*Hypseleotris spp*.), Golden Perch, Murray Cod and Carp (*Cyprinus carpio*)) (Berguis 2013, Andrew Norris, pers. obs., 2013).

Riparian rehabilitation

Riparian zones provide structural habitat for fish (e.g. snags) and terrestrial input of sediments and nutrients to streams, thus influencing habitat quality and availability, water chemistry and trophic dynamics (Pusey & Arthington 2003). These factors in turn influence the fitness of individuals, species diversity and the composition of fish assemblages (Pusey & Arthington 2003). Demonstration reaches offer great potential as experiments examining the linkages between riparian rehabilitation and fish population dynamics under a broad range of rehabilitation scenarios.

Riparian interventions such as stock exclusion, native tree planting and exotic weed removal were the most frequently reported rehabilitation activity across the demonstration reaches (Table 2), but we could only find evidence of monitoring and evaluation of this activity in the Dewfish reach and plans to do so in the Upper Murrumbidgee reach. In these cases, riparian condition was being evaluated, but no attempt was being made to link riparian condition to fish responses. The opportunity has not yet been taken in demonstration reaches to address ecological questions such as how rehabilitated riparian zones compare in form and function to degraded and more pristine areas, or at what spatial and temporal scales works need to be undertaken to improve local fish populations. Such questions have been identified as being important if the practice of riparian rehabilitation is to be progressed (Rutherfurd *et al.* 2004; Brooks & Lake 2007).

Control of alien species

Alien fish were targeted at six of the seven demonstration reaches, with all but one citing Carp musters as the activity undertaken. Carp musters are community run angling competitions where Carp are the target species and are considered more of an engagement tool to educate the community about threats to native fish in the reach, rather than an attempt to reduce Carp numbers. Three Carp musters run in the Bourke to Brewarrina reach removed close to a tonne of fish (David Cordina, NSW DPI pers. comm., 2013). Whilst this would have an insignificant impact on the biomass of Carp in the reach, approximately 170 anglers participated in the Brewarrina muster and approximately 70 and 170 anglers participated in the two Bourke musters, making the musters a community engagement success.

The Dewfish reach has demonstrated how a more integrated approach to alien fish control can have positive results. In this reach, targeted Carp removal (traps and electrofishing) was conducted at tributaries and within the main river channel above Loudoun weir. Mark recapture estimates of the proportion of Carp removed ranged upwards of 42% of the total population (Butcher & Norris 2010). Additional on-going Carp removal was conducted using Carp musters, local anglers and electrofishing during twice-yearly surveys. Although Carp numbers quickly re-established at the river channel site, they remained low in some tributary sites until a major flow event in 2011 triggered an increase in abundance. Following initial Carp suppression, Hyrtl's tandan (*Neosilurus hyrtlii*) re-established in Myall Creek (Raymond *et al.* 2013a). Prior to this, their population has been in decline coinciding with an increase in Carp numbers and the deterioration of a number of other environmental factors such as water quality. It appears that integrated Carp management will need to involve sustained and repeated efforts if Carp numbers are to be controlled in a reach.

Fish screening at water diversions

There are concerns over the significant loss of native fish at water infrastructure in the MDB, especially at unscreened water diversions (Baumgartner & Boys 2012; Baumgartner *et al.* 2014). A pilot trial of fish screens was undertaken at an experimental pumping station in the Namoi demonstration reach in an attempt to develop 'fish-friendly' screen design criteria for application throughout the MDB (Boys *et al.* 2012a). Smaller fish (<150 mm) were significantly more susceptible to entrainment and screen contact than larger fish, and whilst screen mesh size had little impact on fish entrainment, even modest reductions in the approach velocity in front of the screen (from 0.5 to 0.1 m/s) afforded significantly greater protection for fish (Boys *et al.* 2013a). The pilot was a temporary trial, and other demonstration reaches could now test the preliminary screen design criteria outlined in Boys *et al.* (2012a) at more permanent installations in a controlled manner (e.g. taking a BACI approach) to test hypotheses relating to improvements to fish populations.

Future Directions and Challenges

Demonstration reaches were always intended to be treated over a sufficiently long timeframe (e.g. 7–10 years) to ensure lag-effects, successional changes and inter-annual variability could be interpreted appropriately (Barrett 2004). Given that no reach has yet been operating long enough to achieve this, there is a strong need to continue these long-term rehabilitation experiments. Although the results being relayed from reaches may still be preliminary, these projects are exercises in adaptive management and it is therefore prudent to reflect on some of the successes and barriers to success. Doing so may help ensure demonstration reaches continue to foster a rigorous and evidence-based approach to the rehabilitation of native fish and their habitats in the MDB.

Testing targets of the NFS

To return native fish populations to 60% of their pre-European levels, it has been proposed in the NFS that the following targets (among others) need to be met: (i) reinstating migratory pathways in 50% of habitats currently impacted by barriers; (ii) reducing the abundance and distribution of alien fish by 30%; and (iii) re-establishing 80% of river–wetland connections through environmental watering (MDBC 2004). These targets are yet to be assessed, and demonstration reaches may provide an opportunity to test the practices required to reach such targets, across manageable scales. But for this to occur, it is likely that the monitoring programmes of demonstration reaches will need to be re-examined. Currently, a qualitative approach to goal setting has been adopted (e.g. an increase in native fish abundance or improvements proportion of native fish to alien fish). A greater emphasis may need to be placed on quantifying the magnitude of these improvements so that the contribution of demonstration reaches towards the targets of the NFS can be better determined.

Dealing with the issue of scale

The scale at which reaches are implemented and assessed may need to be revisited. It has been suggested that the Bourke to Brewarrina reach may be too large (~200 km) to effectively manage rehabilitation activities and create a measurable response for the given level of investment (Boys *et al.* 2013b). It may also be that the large home range of some fish species means that populations will respond to habitat changes at scales well beyond the demonstration reach. For instance, Golden Perch tagged in the Bourke to Brewarrina demonstration reach were found to undertake upstream migrations of up to 1000 km, being recaptured by anglers at St George Weir on the Bokhara River (southeastern Queensland) within 12 months of tagging (Boys *et al.* 2013b). The fact that these large-scale movements into and out of demonstration reaches could confound results should be carefully considered as the monitoring programmes of demonstration reaches progress.

Increasing public availability and peer review of the science

Demonstrating to the community, the benefits of a coordinated and multifaceted approach to fish habitat rehabilitation is a cornerstone of the demonstration reach approach. This requires making research findings publically available. Some demonstration reaches have made scientific outputs accessible online, but most results remain in technical or interim reports (97%), with a large proportion not publically available (47%; see Table S1). Technical reports are a critical part of adaptively managed demonstration reaches as they ensure results are rapidly relayed back to rehabilitation managers. But a greater rate of conversion of technical reports to peer-reviewed papers would also increase public confidence in rehabilitation investment and ensure the approach has greater potential to be utilised beyond the MDB. At time of publication, only a small proportion of outputs appeared in the peer-reviewed literature (3%), possibly reflecting the fact that rehabilitation projects are long-term experiments requiring years of investment to deliver rigorous, publishable results.

Making the most of unanticipated results

Having research agencies actively involved in regular survey work has sometimes produced additional results that were not originally anticipated in the monitoring programmes, but nevertheless have the capacity to contribute to the goals of the NFS and to the adaptive management of reaches. Examples of this include the information gathered on fish migrations in the northern basin (mentioned earlier) and reports of the first confirmed case of epizootic ulcerative syndrome (EUS or red-spot disease) in wild-caught native fish in the MDB (Boys *et al.* 2012 b). Considering that the NFS has set a zero introduction of native fish diseases or parasites as one of its targets (MDBC 2004), such information can make an important contribution to formulating future river management plans.

Rehabilitation cost-benefit analysis

River rehabilitation should be optimised by implementing a combination of works, applied at appropriate scales, to provide the greatest ecological return for a given level of expenditure. Currently, it is hard to determine from demonstration reach activities the relative cost and contribution of different interventions to native fish recovery. Although hard to determine, the answer will ultimately require an integration of ecological response and economic data as part of a cost-benefit analysis. Financial information on demonstration reaches costs was difficult to obtain or inconsistently reported across reaches (Inovact 2012). A standardised approach to reporting expenditure on different activities could improve the ability to 'unpack' the relative costs of rehabilitation. Such standardised rehabilitation databases are becoming more prevalent in some parts of Australia (Brooks & Lake 2007).

Evaluating community uptake

Stakeholder adoption and ownerships of demonstration reaches will assist with the continuation of the NFS and support future fish habitat rehabilitation activities in the MDB (see also Hames *et al.* 2014). It is therefore important that demonstration reaches evaluate whether the community is supportive of the activities undertaken, generally satisfied with rehabilitation outcomes, and whether advocacy has been built to enable ongoing behavioural change. Social monitoring was not within the scope of the original monitoring framework for demonstration reaches (Boys *et al.* 2009), and to date, social analysis has only been attempted in the Hollands Creek reach (Bartley Consulting Pty Ltd 2010). In this case, the analysis suggests that there was an improvement in community knowledge about water quality, river health and native fish over a 3-year period (Fern Hames, pers. comm., 2013).

Conclusion

A recent review of river rehabilitation projects in southeastern Australia found as little as 14% were scientifically evaluated, with low rates of data retention due to poor archiving and institutional restructuring (Brooks & Lake 2007). Demonstration reaches can play a role in addressing these past failings through the implementation of a coordinated, basin-wide network of rehabilitation projects with mandatory reporting based on a standardised evaluation framework.

Demonstration reaches also have the potential to be a powerful vehicle for engaging the community in fish habitat rehabilitation beyond the NFS and the MDB, but this will be dependent on the quality of the science they produce and the level of ongoing funding they receive. It will be essential to ensure that research outcomes are made available to support management in a timely fashion. Greater attention should be given to reporting in the peer-reviewed literature; ensuring closer links between rehabilitation goals and the targets of the NFS; improving financial transparency; and evaluating community acceptance.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Compendium of research outputs of Native Fish Strategy demonstration reaches.