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Watering Floodplain Wetlands in the Murray–Darling Basin to Benefit Native Fish
A discussion with managers

Edited by S. Meredith and L. Beesley

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Watering floodplain wetlands in the Murray–Darling Basin to benefit fish
A discussion with managers

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Summary

This report describes the content and outcomes of a workshop entitled 'Watering Floodplain Wetlands of the Murray–Darling Basin for Fish: A Discussion with Managers' held on 5 March 2008 at Wonga Wetlands in Albury (NSW). The workshop was part of a four-year, National Water Commission funded project aimed at optimising wetland environmental watering protocols to maximise benefits to native fish populations.

The workshop had two main objectives:

- to document (with a focus on fish) current management practices associated with the delivery of environmental water into floodplain wetlands in the Murray–Darling Basin
- to begin a meaningful engagement between wetland managers and the project team so that outputs of the project would be appropriately targeted, relevant and useful to managers.

The workshop was attended by 26 people — 18 managers, 7 members of the project team, and a facilitator (Bill Phillips). Managers represented catchment management groups, government agencies and government departments (see List of Participants, page 54). Although managers were invited from throughout the Basin, only staff from New South Wales, Australian Capital Territory, Victorian and South Australian management agencies attended.

Five managers gave presentations outlining management practices and case studies for wetlands within their jurisdiction:

- Dean Ansell gave an overall perspective of wetland management in the Murray–Darling Basin
- Keith Ward focused on the Barmah–Millewa in his discussion of wetland watering issues in the Goulburn–Broken catchment and provided examples using recent watering events
- Tumi Bjornsson outlined wetland management practices and processes in South Australia
- Alan McGufficke explained current wetland management activities and their rationale in the Lachlan Catchment
- Deb Nias described some of the political and bureaucratic barriers to wetland watering in New South Wales.

To gain a more comprehensive, targeted understanding of existing wetland management practices, a four-part survey was sent to a diverse range of wetland managers and agencies throughout the Murray–Darling Basin prior to the workshop. We received responses from 18 agencies representing all states and territories.

Answers from the first section of the survey, entitled 'Allocating Water', revealed that physical and political constraints on the water delivery process were the most significant factors determining which wetlands received water and when they received it. In the current drought, the most commonly listed rationale for delivering water to wetlands was to ensure the survival or maintenance of native communities. The most important biotic group targeted during watering events was the least mobile – native woody vegetation (e.g. red gum, black box); native fish ran a very close fourth behind native wetland vegetation and native birds. Once delivered, the majority of water (76.3%) was left in the wetland to seep, evaporate or dissipate, with only 22.5% returned to the river.

Answers from the second section of the survey, 'Other Wetland Management Activities', indicated that the overwhelming majority (83%) of wetland management activities involve multiple management actions, not just water delivery. Managers identified a suite of 'non-water delivery' actions (e.g. re-vegetation, education and research) that are perceived as either directly or indirectly affecting fish populations in wetlands.

The third section, 'Monitoring the Success or Failure of Wetland Management', revealed that 95% of wetland inundations are accompanied by biological monitoring. The most commonly monitored biota was trees (82% of cases); fish were monitored in 44% of cases.

The final section, 'Managing Wetlands for Fish', asked managers to indicate which fish 'values' they might focus on as part of a wetland management strategy. Most indicated that managing for whole fish communities would take precedence over managing for targeted species, but that this was very case-specific. Murray Cod was listed as the most important native target species, followed by the endangered Murray Hardyhead. Although Common Carp was clearly considered the most important pest species, pest species management was not ranked highly by managers, and the enhancement of native fish communities took clear precedence.

Using key themes developed from the survey responses and manager presentations, targeted group discussions were held on three major themes:

1. **Manipulating wetland hydrology** — this group investigated the extent to which managers consider individual flow components (i.e. timing, frequency, volume, rate and duration of water delivery) during wetland watering events, and discussed the opportunities and the physical and bureaucratic limitations associated with manipulating each component. The group also outlined a range of opportunities and limitations associated with the release of water from wetlands back into adjoining river systems.
2. **Key challenges for putting water into wetlands** — this group investigated the key challenges faced by managers attempting to put environmental water into wetlands. The group identified the availability of water (drought, climate change), the ability to prioritise watering sites appropriately, the ability to manage water quality (particularly with respect to black water and acid sulfate soils), and the need for community approval of wetland watering events as priority issues that need to be addressed.
3. **Adaptive management of fish in wetlands** — the third group addressed individual components of the adaptive management cycle (i.e. assessing condition, setting objectives, designing interventions, monitoring, reviewing and learning, and implementing changes). The relevance of these components to the management of fish in wetlands within their jurisdictions was discussed, and the capacity needed to undertake a truly adaptive management program was documented.

The workshop gave the project team a clearer understanding of the processes underlying current wetland management practices, and provided a context within which the outcomes of the research component of the project must be framed. In particular, it was recognised that although determination of the 'optimum' wetland inundation protocol for native fish may be of considerable scientific interest, such a protocol will seldom be able to be implemented because of the physical and bureaucratic constraints imposed on wetland managers. Instead, and as a direct result of this workshop, a key focus of the research component of the larger National Water Commission project is now to provide tools and advice to managers that will facilitate the optimisation of native fish outcomes in wetlands under sub-optimum conditions.

1 Introduction

Floodplain wetlands are important components of lowland river systems, acting as hot-spots of primary production, nursery habitats and refuges from conditions in the main river channel (Junk et al. 1989, Bayley 1995, Junk and Wantzen 2004). Throughout the world, however, floodplain wetlands and the biota that inhabit them are under threat (Finlayson and Moser 1991, Poff et al. 1997, Tockner and Stanford 2002). Australian wetlands are no exception — human-induced habitat degradation, alien species introductions and, perhaps most significantly, water abstraction have all drastically changed the character and function of an estimated 90% of wetlands within the Murray–Darling Basin (Beeton et al. 2006).

Native fish populations in the Murray–Darling system have also been drastically reduced since European settlement, and it has been estimated that communities are now at approximately 10% of pre-European levels (Murray–Darling Basin Commission 2004). While there is little doubt that impacts within the main channel have contributed to this decline, the degradation of wetland habitats and their linkages to the river channel should not be overlooked.

For this reason the role of floodplain wetlands for the fish of the Murray–Darling is receiving increasing attention. In 2005 the Murray–Darling Basin Commission (MDBC) held a workshop entitled ‘Native fish and wetlands in the Murray–Darling Basin’ (Phillips 2006). The workshop brought together experts in the field for a discussion on the current state of our knowledge and to form an action plan. Knowledge was reviewed by Closs et al. (2006), who concluded that, while some species (most notably the critically endangered Murray Hardyhead) are wetland specialists relying almost exclusively on wetland habitats for their survival (Ellis et al. 2008), most inhabit a continuum between river and floodplain habitats (Gehrke and Harris 2000). Within wetlands, Closs et al. (2006) found that fish community structure and composition is shaped by a number of factors, including wetland bathymetry (Shirley 2002), physical and chemical parameters (McNeil 2004), microhabitat (Balcombe and Closs 2000, Stoffels and Humphries 2003, Balcombe and Closs 2004), food availability (Balcombe 2002) and alien fish species interactions (Shirley 2002, McNeil 2004; see also the review in Wilson 2006). Low-flow areas with complex vegetation, in particular, appear to be targeted by certain species, such as Carp Gudgeons, Southern Pygmy-perch and Flat-headed Galaxias (Balcombe and Closs 2000, McNeil 2004). In addition to many small-bodied adult fish that reside in wetlands, the low-flow or no-flow habitats within wetlands are thought to play an important role in the early life of many larger-bodied fish species because of their ability to produce relatively high densities of micro-prey suitable for fish larvae (King 2004, 2005).

Although the Closs et al. (2006) review represents an adequate reflection of our knowledge, the broadness and generality of this knowledge reflects our poor understanding of the ecological processes that sustain fish communities within Australian floodplain wetlands. Indeed, the report from this MDBC workshop (Phillips 2006) identified 39 targeted ‘knowledge gaps’ relating to the use of wetlands by fish, and suggested that urgent attention and resources be given to developing our knowledge of fish–wetland interactions so that we might better manage the delivery of water to benefit native fish.

In response to these discussions, the Murray–Darling Freshwater Research Centre and the Arthur Rylah Institute for Environmental Research began collaborations on a National Water Commission (NWC) project entitled ‘Optimising Environmental Watering Protocols to Maximise Benefits to Native Fish Populations’. With a focus on managed wetlands, this project targets many of the knowledge gaps identified by Phillips (2006):

- Knowledge gap 5: 'Establish the timing of native fish responses to flooding and recessions (movement cues); including for smaller native species. And, establish if these cues can be managed in 'regulated' wetlands.'
- Knowledge gap 10: 'Assess the process for and ecological value of retaining floodwaters with regulators on floodplains… to suit native fish recruitment and growth.'
- Knowledge gap 11: 'Investigate the benefits of modified regulator operating practices for native fish.'
- Knowledge gap 12: 'Investigate options to maximise the value (for native fish) of environmental flow delivery to wetlands within the existing regulated system.'
- Knowledge gap 13: 'Investigate the impact of watering trials and similar floodplain flow manipulations on native fish species.'
- Knowledge gap 14: 'Investigate whether or not wetlands offer drought refuges for native fish.'
- Knowledge gap 20: 'Develop and apply methods to quantify and maximise the ecosystem outcomes of water delivery to floodplains and floodplain wetlands.'
- Knowledge gap 23: 'Review the impacts of watering regimes on water quality and fish (native and alien) in wetlands.'
- Knowledge gap 27: 'Examine the relationship between imposed wetland water management regimes (e.g. different durations/seasons of wetting and drying) and wetland water quality and native fish.'

More specifically, the research component of the project aims to document ecological processes underpinning relationships between fish productivity within a wetland, the timing, duration, extent of wetland inundation, and the method of water delivery. Ultimately, we envisage that this information will be used by wetland managers to improve outcomes for fish in managed wetlands and the broader river ecosystem.

To achieve this, however, it was recognised that the outputs of our research (e.g. predictive tools, monitoring protocols) need to be relevant and applicable to the political and logistical limitations that wetland managers face. This need was the basis of the first objective of this workshop, which was addressed through presentations at the workshop, a pre-workshop survey, and three targeted small-group discussions:

> **Objective 1**: to document (with a focus on fish) current management practices associated with the delivery of environmental water into floodplain wetlands of the Murray–Darling Basin.

The success of a large-scale project such as this also relies on there being a meaningful and ongoing two-way relationship between researchers and managers. The communication resulting from such a collaborative approach facilitates the awareness of (and timely access to) wetlands being actively managed throughout the Basin. It also fosters the engagement of managers not only in the implementation of project outcomes, but also in the development of tools and protocols that encompass the knowledge gained. As a result, the second objective of the workshop was:

> **Objective 2:** to begin a meaningful engagement between wetland managers and the project team such that outputs of the project are appropriately targeted, relevant and useful to managers.

This report summarises the information exchanged across the three levels of engagement (speaker presentations, pre-workshop survey and small-group discussions) at the workshop. The main outcomes of the workshop are discussed, and we describe how these outcomes will be used to shape the research design and management tools that will be produced as part of the larger NWC 'Optimising Environmental Watering Protocols to Maximise Benefits to Native Fish Populations' project in the future.

Figure 1. Dairy Lagoon (formerly Chinaman's Lagoon), Corowa. A permanent oxbow wetland of the Murray River, which is drying due to the current lack of water. Note the seedbank regeneration in the recently dried wetland soils. Photo L. Beesley.

2 Manager presentations

2.1 Wetland management in the Murray–Darling Basin

Dean Ansell, Murray–Darling Basin Commission

Floodplain wetlands are recognised as an important component of the riverine ecosystem that is the Murray–Darling Basin. Wetlands are receiving attention from the Murray–Darling Basin Commission (MDBC) on a number of fronts, most notably as part of action to protect native fish in the Basin through the Native Fish Strategy, and as part of action to protect the health of the Murray River under The Living Murray Initiative. While these two programs, which are discussed in more detail below, highlight the importance of floodplain wetland habitats in the Basin and advocate for best management practices, the most imminent threat faced by most wetlands in the Basin is drought driven by climate-change. The implications of the drought on wetland management, and measures being taken by the MDBC to address this are also discussed.

Native Fish Strategy

The Native Fish Strategy (NFS) was formulated in 2003 by the Murray–Darling Basin Commission (MDBC) and is scheduled to run until 2013. The primary aim of the NFS is to 'rehabilitate native fish communities in the Basin back to 60 per cent of their estimated pre-European settlement levels after 50 years of implementation' (Murray–Darling Basin Commission 2004). This aim will be achieved by ameliorating key threats to native fish. One objective of the NFS is 'To rehabilitate and protect the natural functioning of wetlands and floodplain habitats for native fish; and revive the links between terrestrial ecosystems, wetlands and rivers' (Murray–Darling Basin Commission 2004). In order to progress this objective the MDBC held a workshop in June 2005 entitled 'Native fish and wetlands in the Murray–Darling Basin' (Phillips 2006). The workshop explored current understanding of the relationships that exist between native fish and wetlands in the MDBC, including 'the significance of floodplain wetlands for Murray–Darling Basin native fish species, the impact of invasive fishes on wetlands in the Basin, and the need to take more integrated approaches'. The workshop created an action plan which highlighted key management actions to be adopted and identified key knowledge gaps.

Priority actions for wetland management, as raised at the NFS workshop include:

- development of policy and program linkages
- identification of wetlands with high conservation value
- improve connectivity among wetlands and between wetlands and the main river channel
- development/modification of operating rules
- strengthening political support for the protection and rehabilitation of wetlands.

Key gaps in knowledge identified at the NFS workshop include:

- identification of priority wetlands
- identification of near-threatened species that rely on wetlands at a Basin and catchment level
- development of a inventory of critical wetland habitat areas for threatened and near-threatened native species and communities
- mapping of barriers to fish movement into and out of wetlands
- identification of cues for fish movement into and out of wetlands
- identification of sources of recruitment of alien fish species (e.g. Common Carp) within the Basin
- assessment of the impact of alien fish exclusion (e.g. carp screens) on fish communities

- the importance of refuges for native fish.

The Living Murray Initiative

The Living Murray (TLM) initiative was established in 2002 and aims to improve the health of the Murray River. In the first instance, this initiative focuses on rehabilitating the health of six sites along the river that are considered to be of high ecological value.[1] These icon or priority sites are: (1) Barmah-Millewa Forest, (2) Gunbower, Koondrook–Pericoota Forests, (3) Hattah Lakes, (4) Chowilla Floodplain (including Lindsay–Wallpolla), (5) the Murray Mouth, Coorong and Lower Lakes, and (6) the River Murray Channel. The majority of these sites are large floodplain wetland systems that are recognised as important habitat for native fish, birds and plants. They are also known to be important sites for waterbird breeding.

Under TLM, water is being recovered for use at the sites. This water is progressively becoming available for use at the sites (the water was due to be recovered by June 2009). The actual volume of water available in any year is dependant on allocation against each entitlement held for use by TLM. The allocation of that water is determined by a prioritisation process — a 'water bid' that takes into account the demand and supply of water. Current criteria for determining priorities among the various bids (2007/08) are intended to avoid the critical loss of threatened fish species, avoid irretrievable damage or catastrophic events, and provide drought refuges that allow recolonisation following drought. The Living Murray allocated 12.8 GL of water during 2007–08. The amount, location and rationale behind watering events are shown in Table 1.

Table 1. Environmental water allocations by the Living Murray initiative in 2007–08.

What	Where	Why
6 GL	Wakool system	Maintain critical fish refuges
≤0.5 GL	Millewa State Forest	Protect Southern Pygmy-perch population
2.6 GL	Chowilla	Critical River Red Gum watering
≤2 GL	Wetlands downstream of Lock 1	Mitigate risk of acidification and protect critical habitat
≤4 GL	Lindsay–Walpolla	Critical River Red Gum watering

Water allocated to the environment can be delivered using a variety of methods, including flow enhancement, weir manipulation, barrage release, via regulated creeks or channels, or pumping or siphoning. Delivering water to a wetland can also carry risks, which need to be taken into consideration and managed. Examples include loss of fish through stranding, damage caused to fish passing through pumps, and potential impacts of poor water quality on receiving waters.

While not a wetland, the River Murray Channel Icon Site is crucial as the principal source of water for the hundreds to thousands of floodplain wetlands in the Murray Valley. One objective for this icon site is to increase the frequency of spring rises in flow, which are important for spawning and recruitment of many native fish species. Another objective is the provision of fish passage.

Monitoring at icon sites will evaluate their progress towards ecological objectives. 'Condition' and 'Intervention' monitoring will be used. Condition monitoring aims to quantify the change in the overall environmental condition at a site that result from water allocations and other works. Consistent methods will be used across icon sites where possible. Intervention monitoring aims to quantify relationships between cause (e.g. watering) and effects (e.g. ecological responses).

Interventions could include pumping, weir manipulation, flow enhancement, retaining floodwater on floodplains, re-snagging, fishways, and dredging (specific to the Murray Mouth).

Climate change and wetlands in the Murray–Darling Basin

The current drought — the worst on record — has resulted in reduced water availability for all users, including the environment. This has meant that current environmental water allocation is based on avoiding environmental damage where possible and protecting threatened species and critical drought refuges. Wetlands that do not receive water face high evaporative losses. increasing the likelihood that fish will be stranded and fringing vegetation damaged. The risks associated with the exposure and oxidation of sulfidic sediments in some wetlands is also the subject of research in the Basin.

The current focus is to identify drought refuges and protect them, so that they will facilitate the recovery of the system. Refuges may be defined in terms of species, populations, or habitat types. To support wetland management, particularly in the face of a severe drought, it will be critical to:

- identify and prioritise wetlands for environmental water
- understand water requirements and optimal delivery strategies
- standardise monitoring to inform outcomes
- engage the community and foster support
- manage trade-offs and better understand the risk involved with different management strategies
- put in place drought recovery strategies.

Figure 2. A wetland with acid sulfate soils. Once soils are exposed to the air (oxygen) they produce sulfuric acid, which when they are wetted again lowers the water's pH[1]. This mobilises heavy metals within the sediments and decreases oxygen levels in the water, creating a hostile environment for aquatic life[1]. Photo courtesy of the Murray Wetlands Working Group.

[1] http://www.mdbc.gov.au/__data/page/915/Acid_Sulphate_Soils_Risks_FactSheet.pdf

2.2 Goulburn Broken Catchment wetland management issues, featuring Barmah–Millewa Forest

Keith Ward, Goulburn Broken Catchment Management Authority

Since European settlement, wetlands in the Goulburn Broken Catchment have experienced marked change, including habitat modification, altered wetting regimes, and the introduction of exotic species. This presentation briefly outlines wetland modification and discusses work being undertaken to restore natural wetting cycles, including the use of environmental water. Barmah–Millewa Forest is used as a case study for environmental watering protocols.

Wetland Modification

Within the Goulburn Broken Catchment, freshwater meadows, shallow freshwater marshes and deep freshwater marshes have been markedly reduced, whereas permanently open freshwater wetlands have increased (Figure 3) (Howell and McLennan 2002). The reduction of meadows and marshes has occurred primarily as a result of agricultural and urban development, including the conversion of natural waterways into irrigation canals and the alteration of flow patterns within river and creek systems. The increased area of open freshwater wetlands is largely a consequence of dam construction to store water for irrigation and domestic consumption, and usually occurred where former wetlands were replaced directly by other wetland types. Unfortunately the environmental values of dams are generally much less than the wetlands types that they replace, and hence a diversity of native wetland flora and fauna is at risk from habitat loss.

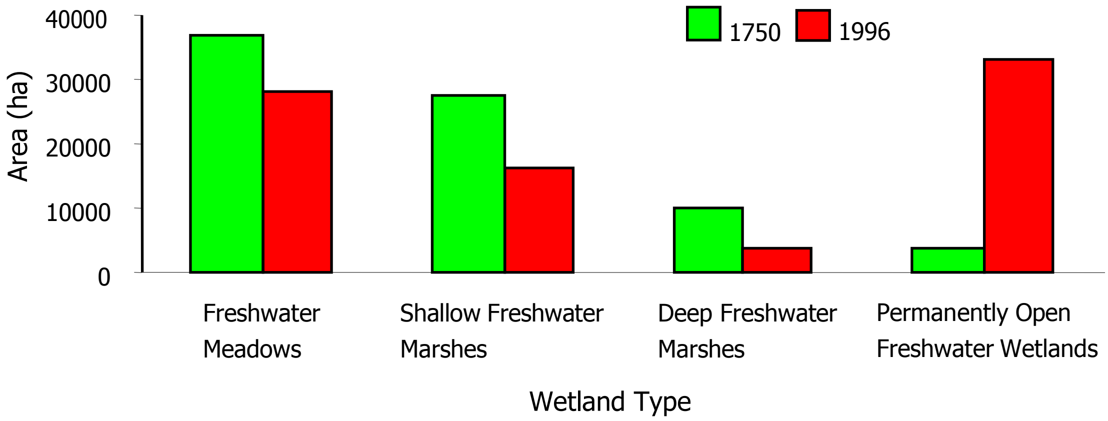

Figure 3. The area occupied by wetlands prior to European settlement (1750) versus a decade ago (1996). Taken from Howell and McLennan (2002).

Restoration of wetland watering cycles

Attempts to reinstate natural wetting cycles to wetlands in the Goulburn Broken Catchment include the modification of connecting channels and the use of environmental water. Earth-moving machinery is being used to lower the height of connecting channels (to commence flow) for wetlands that are high in the landscape, while regulators are being used to block off unnatural summer flows from wetlands that are low in the landscape. Environmental water is being used to recreate components of flood events which occur less frequently due to river regulation. One wetland that receives considerable environmental water is Barmah–Millewa Forest; allocations of water, constraints and limitations to its delivery, water-use protocols, and outcomes of watering are discussed below.

Barmah–Millewa forest environmental water allocations, constraints to delivery, and water-use protocols

Natural flow and flood patterns in Barmah–Millewa Forest have been altered drastically by river regulation (Figure 5). The Forest is an icon site of The Living Murray initiative, and is the largest River Red Gum wetland in the world. Increasing concern over the altered flood regime at the site has led to various environmental water allocations (EWAs) being made available; the first specific allocation was reserved in 1993. This water is maintained by River Murray Water in conjunction with the NSW and Victorian governments. One hundred gigalitres (GL) are allocated each year (50 GL from NSW and 50 GL from Victoria), or a pro-rata share commensurate with irrigator water rights declared in that year, and can be accumulated over seven years to a maximum of 700 GL (Abel et al. 2006)[2]. There is also the capacity for an additional 50 GL of low-security water each year, which is statistically available in about 70% to 80% of years. However, accrued environmental water runs the risk of being spilt from storage in the event of the reservoir filling to capacity, with the exception of 200 ML that is permitted to remain in the account, given that its accrual is in the storage's airspace so as to not affect other water-user entitlements that are set on actual storage volumes.

To put water allocations in perspective, the maximum possible amount (700 GL) is equivalent to 35 days flow of 20 000 ML downstream of Yarrawonga (Abel et al. 2006). Flows of this magnitude are relatively small compared to natural flood events, and any environmental water that falls below the 10 000 ML/day bankfull capacity will not be delivered onto the floodplain.

Many factors constrain or limit the supply and delivery of allocated water to the forest, which affects the capacity to manipulate the timing (within and among years), frequency and magnitude of environmental water allocations. Some of the factors are these:

1. Lending arrangements may mean that water may not be available for use during drought periods. This can occur during drier years when the NSW and Victorian governments may borrow back these allocations for consumptive use, with the water to be paid back into the environmental account during wetter years (Abel et al. 2006, Murray–Darling Basin Commission 2006).
2. High river levels downstream of Yarrawonga Weir are required to maximise the delivery of environmental water onto the forest's floodplain (i.e. piggy-backing of environmental water). Aside from (artificial) irrigation flows, this relies on natural flooding, generally created by the Kiewa or Ovens River that outfall into the Murray River upstream of Barmah–Millewa Forest but downstream of its potential capture locality, in the large Hume Reservoir. The flooding of these systems typically occurs during spring (winter events tend to be captured in Yarrawonga Weir and channels prior to the irrigation season) and hence largely constrains wetting events in the forest to this shortened period.
3. Channel capacity also constrains the volume of environmental water that can be released from storage. To maximise the efficacy of water delivery to the forest, water travelling between Hume Reservoir and Yarrawonga Weir must stay within the 25 000 ML/day capacity of the Murray's channel to avoid water loss and interference to agricultural activities on the lower floodplain terrace (Abel et al. 2006). This effectively caps the size (amplitude) of the environmental flood pulse that can be delivered. The distance that the water travels between source and target also attenuates the amplitude of the flood peak.

[2] States may borrow back, for later repayment, their annual allocation if consumptive water use is low (Murray–Darling Basin Commission 2006a).

4. Rules developed for the EWA release include an ‘automatic’ release in the fifth year of a period in which no flooding has occurred, and hence further modifies managed flood events by potentially reducing the volume of water available for release.

Protocols outlining the release and delivery of water have been designed to facilitate maximal inundation of the floodplain. As this relies on pre-existing high river levels, protocols have been designed around antecedent flow conditions. Rules or triggers governing the release of environmental water, taken from MDBC 2005, are outlined below.

Rule 1 If there is a flood ≥ 500 GL from September through to November, then maintain at 400 GL in December (if sufficient volume in the allocation).

Rule 2 If there is a flood ≥ 500 GL in September or October and kitty is ≥ 400 GL (including overdraw), keep at 500 GL till November and 400 GL in December.

Rule 3 If four years pass with no release, and no flood of ≥ 500 GL in September to November and 400 GL in December, try for 500 GL in October and November and 400 GL in December.

Rule 4 If three years pass with no month from August to November with ≥660 GL, and if a release starts in October or November, the target flow increases to 660 GL at Yarrawonga.

GBCMA also uses significant rainfall as a trigger for water allocation events because rainfall is believed to be an important movement or breeding cue for many species (GBCMA & MCMA 2007).

Figure 4. Barmah–Millewa Forest in Flood, November 2005. Photo K. Ward.

Environmental water allocation at Barmah–Millewa Forest in 2005: a case study

By the 2005–06 financial year 500 GL of water entitlements had been accumulated for Barmah–Millewa Forest. This water was released from Hume Reservoir in mid October 2005, in the wake of natural flooding, ensuring that the forest experienced continued flooding of above 15 000 ML/day for a three month period (Figure 6). Flooding of this magnitude would naturally occur once every two years, but had not occurred during the previous five years.

The bulk of the environmental water release took place for two months (mid October to mid December) and was adaptively managed by a multidisciplinary team of staff from several government agencies (King et al. 2007). The aim of the EWA release was to provide breeding and feeding conditions for frogs, tortoises, waterbirds and native fish in addition to eliciting a response from vegetation and promoting carbon exchange between the floodplain and river (King et al. 2007). To this end it was planned to apply the environmental water in a series of pulses (flood peaks), as it was speculated that changing water depth may be valuable for wetland plants on the fringe of the floodplain and be an important cue for fish and frog reproduction; fortuitously, natural flooding greatly accentuated these pulses (Figure 6).

The water release inundated 57% of the Barmah floodplain and elicited numerous ecological responses in the forest (MDBC 2007). A total of 513 GL was released from the EWA account, facilitated by an overdraw opportunity, to ensure the attainment of all original aims (although over 90% of the EWA release is likely to have returned to the river for further downstream use). Wetland vegetation displayed vigorous new growth, where influenced by the flooding, including expansion of a number of uncommon species (MDBC 2007). Thousands of colonial waterbirds bred, some species for the first time in at least 40 years, and many of these species might have aborted breeding on up to four separate occasions during the flood event were it not for the EWA maintaining elevated river levels to prevent premature wetland draining (MDBC 2007). Fish also responded to the flooding, with spawning activity increasing for Silver Perch and Golden Perch (King et al. 2007). The abundance of young-of-year Murray Cod, Trout Cod and Southern Pygmy-perch also increased after the flood (King et al. 2007). Unfortunately, though not surprisingly, introduced fish species also benefited from the watering event, with an increased abundance of young-of-year Common Carp, Goldfish and Oriental Weatherloach being evident (King et al. 2007). But the system is complex, as an ongoing study of the fish community has since highlighted that some of the species that showed positive responses to the 2005 wetting event also successfully spawned and/or recruiting during the low-flow periods of 2006–07 and 2007–08 (King et al. 2008). Species that did not spawn or recruit during low-flow periods included Golden Perch, Southern Pygmy-perch and Carp Gudgeons (King et al. 2008). Managed flood events are likely to be critical for maintaining populations of all of these species, especially the high-flow specialists, as the frequency of natural flood events decrease further under climate change.

This case study highlights the importance that EWAs can play in replicating a number of critical flood regime attributes that are required for a large range of floodplain flora and fauna species. However, it also highlights that the use of relatively small EWA volumes alone is unlikely to be sufficient to cater for most environmental requirements, and hence natural flooding remains a key factor. Strong investment in research and monitoring programs is required to better inform adaptive management, especially when small EWA volumes are expected to achieve so much in environmental outcomes.

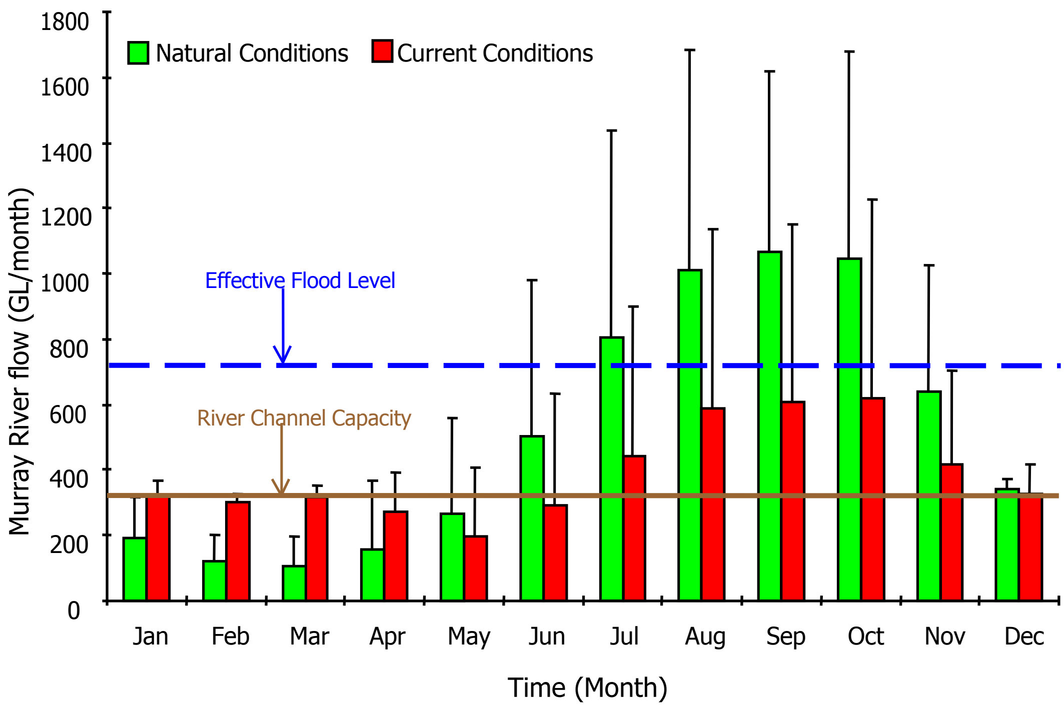

Figure 5. Natural versus current Murray River flows downstream of Yarrawonga. Monthly averages are taken from 100 years of data, + standard error bars are shown. Provided by K. Ward.

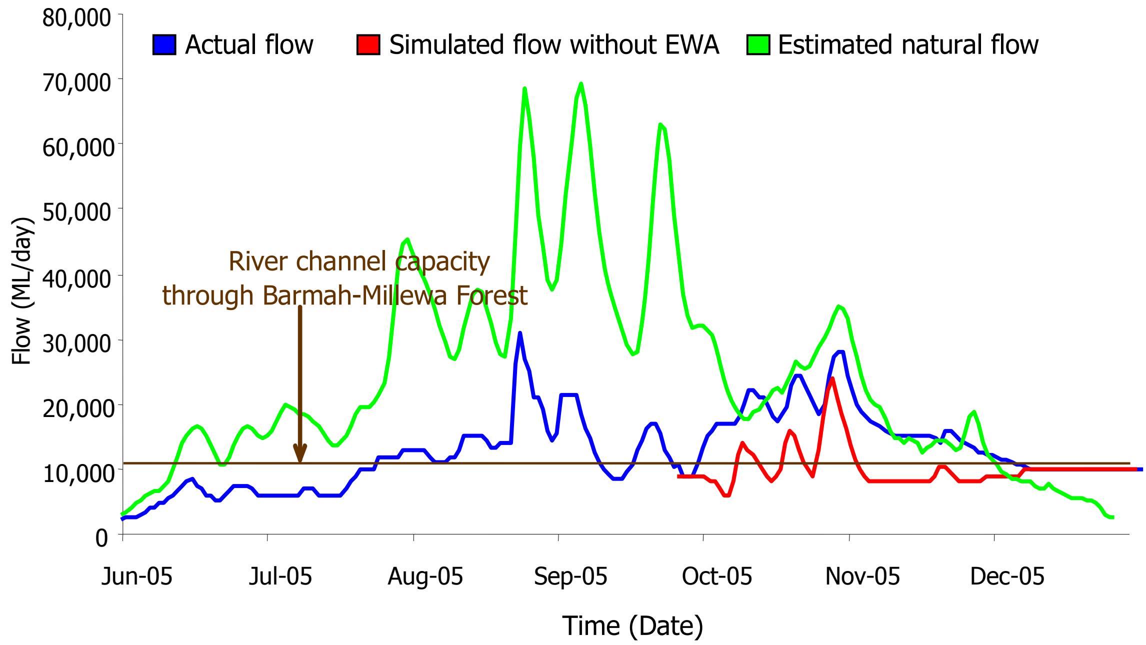

Figure 6. The effect of environmental water release (EWA) on Murray River flow downstream of Yarrawonga in 2005/06. Provided by K. Ward.

2.3 Wetland management processes in South Australia

Tumi Bjornsson, South Australian Local Action Planning Organisations

Wetland management and rehabilitation in South Australia has, in the past couple of decades been community driven. While this approach has been successful for some wetlands, others which may be of notable significance have missed out due to a lack of community interest and/or distance from population centres. Consequently a prioritisation framework for all identified South Australian River Murray wetlands has been developed, the aim of which is to identify unique and significant wetlands for which rehabilitation efforts are expected to deliver a good return on investment.

In the current Water Allocation Plan (WAP) for the River Murray in South Australia, 200 GL has been allocated to wetlands that fill at pool level. Wetlands that fill above 'normal' pool level are not considered at this stage due to limited resources and lack of access to water. The 'managed wetlands' are therefore those that fall within this group of pool-level inundated wetlands. For the managed wetlands to have access to water they have to conform to wetland management plan guidelines, and must also be accredited by the South Australian Wetland Technical Group. Managers can then apply for a licence similar to those given to other users of River Murray water by submitting the plan and application to the South Australian Department of Water, Land and Biodiversity Conservation (DWLBC). The WAP is currently under review.

For a wetland management plan to be accredited it must assess available data, including:

- baseline surveys (fish, frogs, birds, macroinvertebrates, vegetation, groundwater and surface water)
- other data (river records, climate, etc.).

It must also consider:

- ecological objectives (fish, birds, frogs, vegetation threatened or significant in some way)
- threats
- cultural and social importance
- implementation
- hydrology (including a graph of seasonal inundation cycles over the life of the plan and water volume required annually)
- on-ground works (structural)
- revegetation and weed control
- fencing, etc.

Management of wetlands in South Australia is conducted predominantly by community groups with the assistance of Local Action Planning groups and the South Australian Murray–Darling Basin Natural Resources Management Board. Other state government agencies address wetlands on Crown land, and industry makes a minor contribution.

Some examples of managed wetlands include;

- Sweeney's Lagoon (about 2.6 ha; 50 ML), where the objectives are to reinstate temporary water levels (possibly the only remaining functioning temporary wetland prior to the drought), to improve frog and fish breeding conditions (fish may have a restricted possibility of returning to the river), and to improve the health of long-lived vegetation (red gum and lignum).

- Teringie a Ngarrindjeri managed wetland (110 ha; 1760 ML), where the objectives are to stop landwards erosion of the lake shore, protect the lake shore with reeds, get more fresh water into the wetlands, improve fish and bird habitat, and undertake large-scale revegetation.
- Hindmarsh Island, where the objectives are to maintain the pre-drought condition, maintain fish diversity and increase fish abundance, improve freshwater flows into wetlands, and maintain the estuary (and therefore fish) passage.

Most recently, the predominant issue facing wetland management in South Australia, particularly below Lock 1, is long-term low water levels. The majority of managed wetlands have been dry for more than a year. Consequently the salinity has been rising, with one record of 150 000 µS/cm approximately 30 cm below the surface. Acid sulfate threats, such as extremely low pH and the associated mobilisation of aluminum and heavy metals, have become apparent, with many of the wetlands showing low pH. As acidic conditions are brought about by the exposure of wetland sediments (those containing high levels of iron sulfides) to the air (oxidation of sulfides to produce sulfuric acid), a drought response has been to ensure that wetlands do not dry out completely. Water applied to wetlands for this purpose also delivers other environmental benefits, for example, a high diversity and abundance of frogs was detected at one wetland following the addition of water, and the return of numerous birds was observed at another.

Figure 7. The wetlands of Hindmarsh Island. Photo courtesy of the South Australian Murray–Darling Basin Natural Resource Management Board.

2.4 Wetlands of the Lachlan: Lachlan Catchment Management Association actions in brief

Alan McGufficke, Lachlan Catchment Management Authority

Wetlands of the Lachlan

The Lachlan catchment covers 84 000 km^2 and contains up to 400 000 ha of floodplain wetlands within its boundaries. It is unique in the fact that its major wetlands are located relatively high in the catchment, for example Lake Cowel (29 000 ha) which is located on the Bland Creek. Below Forbes the river slows down, forming a number of channels: Bumbuggan/Goobang Creek, Wallamundry/Bogandillon/Wallaroi Creek and the Little Lachlan River. These small channels limit river capacity and form numerous smaller wetlands during high river flows. The river reforms below Condobolin, but when it reaches Willandra Creek it again becomes ‘lazy’ and forms multiple channels and numerous but larger wetlands. The last wetland on the river is the Great Cumbung Swamp (locally known as ‘The Reed Beds’; 54 000 ha); from there the Lachlan reaches the Murrumbidgee River on a regular but infrequent basis.

Wetlands of National Significance include Great Cumbung Swamp (The Reed Beds), Lake Brewster, Lake Cowel/Wilbertroy, Booligal Swamps, Lachlan Swamps, Merrowie Creek, Lake Meerimajeel/Murrumbidgil and,Cuba Dam. Wetlands of Regional Significance are identified in the Lachlan Catchment Action Plan.[3] Regional Significance may relate to drought refuge, cultural heritage, or status of upland wetlands.

River regulation and environmental water allocation

The Australian Natural Resources atlas list more than 45 dams and weirs that regulate the flow of the Lachlan River,[4] which results in an annual surface flow extraction of over 258,000 ML per year. Within this context of water use, the Lachlan River Management Committee (RMC) was established in 1997 to oversee the development of environmental flow practices. The RMC advocated for targeted releases of water from Wyangala Dam to mimic natural flow patterns in the lower Lachlan River, and for an annual high-security environmental contingency allocation (20 GL). These rules took effect in 1998–99, and formed the basis of a statutory water sharing plan which took effect in July 2004. The water sharing plan contains the following environmental water provisions/recommendations:

1. That water stores that exceed extraction entitlements are to be used for the environment. Long-term averages,[5] and current water rights suggest that that 75% of annual flows will be available for the environment.
2. That flows be improved in the lower catchment and natural hydrographs be approximated (winter and spring flood pulses). This will be achieved by allowing some inflows into Wyangala Dam to pass down the river (translucent flow), and by prohibiting the extraction/diversion of water from some tributary inflows. The total volume of translucent and tributary flows per year that can be used for the environment is 350 GL.
3. That water be stored for environmental purposes. That 20 GL of water be stored in dams or lakes ‘whenever the total volume of water available to general security licences exceeds 50% of the access licence share volume at the beginning of a water year or reaches 75% during a water year’. Environmental water is to be used to ‘support waterbird or fish breeding, wetland watering or increase flow variability’.

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[3] Available on the Lachland CMA website (www.lachlan.cma.nsw.gov.au).
[4] www.anra.gov.au/topics/water/overview/nsw/swma-lachlan-river-regulated.html
[5] The suitability of long-term averages in the face of climate change is currently being debated.

4. That water be stored for water quality management purposes. That 20 GL of water be stored each year, and that it be used to reduce salinity or mitigate cyanobacteria (blue-green algae) outbreaks.

Although plans for environmental water allocation are in place, there have been relatively few occasions when the water has been used. In the last 10 years there are three notable examples; water was used in 1998–99 to help approximately 40 000 pairs of Ibis fledge their young; water was released through Wyangala Dam in 1999–2000 on two occasions to fill the Great Cumbung Swamp; and in December 2005 water was released into Merrowie Creek which attracted approximately 8000 to 10 000 pairs of Straw-necked Ibis.[6] The release of water into Merrowie Creek was part of the high-security environmental allocation, and was only used because there had been substantial rain and good flows for irrigators.

Monitoring is under way at 12 wetlands in the Lachlan Catchment. Monitoring evaluates hydrologic regimes, including connectivity to the river, aquatic macroinvertebrates and plants, frogs, birds and water quality. Fish are currently not monitored.

Due to emergency drought conditions the water sharing plan is not active; that is, no water is spare to allocate to the environment. Environmental water will be sought through improved water use efficiency.

Other actions in wetlands

Works are underway to improve the health of wetlands, notable examples include:

- Lake Brewster (a major off-river water storage), where $13 m (contributors: Federal and State governments, landholders and Lachlan CMA) is being used to improve water quality, reduce water loss, protect cultural values, reduce carp impacts and address threatened species
- Great Cumbung Swamp, where works include property planning for wetlands, LIDAR flying and modelling to assess water inflow impacts, carp reduction and landholder connection.

Cultural heritage

Cultural heritage is recognised as a major issue for the wetlands of the Lachlan. The work at Lake Brewster has an Aboriginal work program that employs seven staff. Staff conduct site assessments and relocate any artefacts that will be affected by the works. Lachlan CMA is striving to improve and protected landscape values of the wetlands for Aboriginal communities.

[6] www.naturalresources.nsw.gov.au/mediarelnr/cw200512143272.html

2.5 Nobody knows the troubles

Deborah Nias, Murray Wetlands Working Group

The Murray Wetlands Working Group (MWWG) was formed in 2000 and manages an annual allocation of 32 GL of ‘adaptive’ environmental water on behalf of the New South Wales government. Water is used in the NSW Murray Valley, otherwise known as the Murray and Lower Murray–Darling. To transport environmental water to proposed wetting sites, flows are piggy-back on floods. Creeks and irrigation channels are used as conduits, and pumping is used when necessary.

Getting environmental water to a site is fraught with bureaucratic red-tape. For example, to pump water we are required under the *Water Management Act 2000* (NSW) to gain approval for:

- a water supply works (i.e. to place a pump temporarily on a water course), which entails a fee and public advertisement
- water use (i.e. provision of an environmental flow), which also entails a fee and public advertisement.

In addition, if the construction of temporary earthen banks are required for the delivery and/or containment of environmental water in a wetland area, then a separate application for either a 3A permit under the *Rivers and Foreshores Improvement Act 1948* (NSW) or a licence under Part 2 of the *Water Act 1912* (NSW) may also be required (depending on site location). The application process for permits/licences involve seeking written support form the Department of Primary Industries (Fisheries), a cultural heritage inspection with elders from the appropriate indigenous community (usually with an inspection fee of approximately $500) and consultation with a local shire council to determine whether a development application is required. Once this information has been collated a submission is then forwarded to the Department of Water and Energy for either a 3A permit (no fee has been charged to date) or a licence under Part 2 of the Water Act (this incurs a $117 fee).

One case study that highlights the problems of legislative requirements for the use of environmental water is the wetting of Cliffhouse Station Wetland (Figure 8). This wetland, which covers five hectares, is on private property within the Lock 6 weir pool reach of the Murray River. The wetland normally receives flood waters but had been dry since 1995, and as a consequence fringing River Red Gums were showing signs of water stress. To improve the health and condition of River Red Gums and other wetland flora, 50 ML of water was allocated. Obtaining a Water Supply Works and Water Use Approval, a 3A permit, and a new Water Access Licence took seven months and involved five different government agencies or authorities, the local shire council, and the local Indigenous community. Application fees totalled $578.50. The wetland was originally scheduled to be watered in October 2005. However, due to delays in obtaining the required approvals, the project was postponed and eventually conducted in March 2006. Monitoring vegetative responses to the wetting suggested that watering over autumn–winter does not produce as strong an ecological response as watering during spring–summer (Chatfield 2007, D'Santos 2007), therefore reducing the value of watering.

Why the painfully drawn out process? The *Water Management Act* does not accommodate the adaptive and flexible nature and nuances associated with the use of adaptive environmental water. The Act’s legislative requirements impose restrictions on environmental water that originally had been developed for irrigative and consumptive water use, so that the Act fails to recognise that environmental water has very different needs for its use and application. In this regard, wetlands would benefit greatly if the bureaucracy of delivering environmental water could follow a simple and consistent approach applicable to both governmental agencies and the public alike.

Figure 8. Cliffhouse Station Wetland 128 (A) and 3938 (B) following the application of environmental water. Photos L. Beesley.

3 Survey of current management practices

In order to document recent or current wetland management practices within the Murray–Darling Basin, a survey was sent out to managers from a variety of jurisdictions across the Basin (February 2008). Managers were encouraged to fill in the survey with members of their local management group, and were asked that their responses reflect wetland management practices undertaken over the last five years. The survey was also intended to stimulate thought on wetland management and its associated limitations, as a precursor to discussions during the workshop.

The survey was split into four sections:

- section 1: investigated allocations of environmental water to wetlands, with a focus on determining which wetlands get water, why those wetlands are chosen, and what factors determine how much water they get
- section 2: documented other, 'non-water delivery' management activities that might affect native fish populations within wetlands
- section 3: addressed the extent to which managers monitor the success or failure of their management activities
- section 4: asked managers to indicate which fish 'values' they might focus on as part of a wetland management strategy management for fish.

The survey was completed by 18 managers or manager groups**:** 6 in New South Wales, 6 in Victoria, 4 in South Australia, 1 in Queensland and 1 in the Australian Capital Territory. Organisations that participated in the survey included the Murray–Darling Basin Authority (MDBA), the NSW Department of Environment and Climate Change (DECC), the Murray Wetlands Working Group (MWWG), the Murrumbidgee Catchment Management Authority (CMA), the South Australian Murray–Darling Basin Natural Resource Management Board (SAMDBNRM), NSW Department of Primary Industries (DPI), Goulburn Broken CMA, North East CMA, Mallee CMA, Victorian Department of Sustainability and Environment (DSE), four different South Australian Local Action Planning (LAP) groups, Department of Primary Industries and Resources SA (PIRSA), and the Queensland Department of Natural Resources and Water (DNRW). With two exceptions, the survey was completed before the workshop, so survey responses should be largely an accurate reflection of regional differences and the variability in wetland management approaches across the Basin.

Much of the Basin has been experiencing the worst drought on record during the period that this survey spans, so the recorded wetland management responses reflect actions undertaken when available water resources are critically low. Although some workshop participants felt that this 'drought effect' unfairly biased the results of the survey, it was also noted that such arid conditions are increasingly likely to become 'the norm' as the effects of global climate change are felt. Even so, the survey results should be interpreted in the context of the driest period in the Murray–Darling Basin since the arrival of Europeans in Australia.

3.1 Methodology

Questions ranged from simple ones with 'yes' or 'no' responses, to more complex ones that required ranking or the assignment of approximate percentages to a series of options.

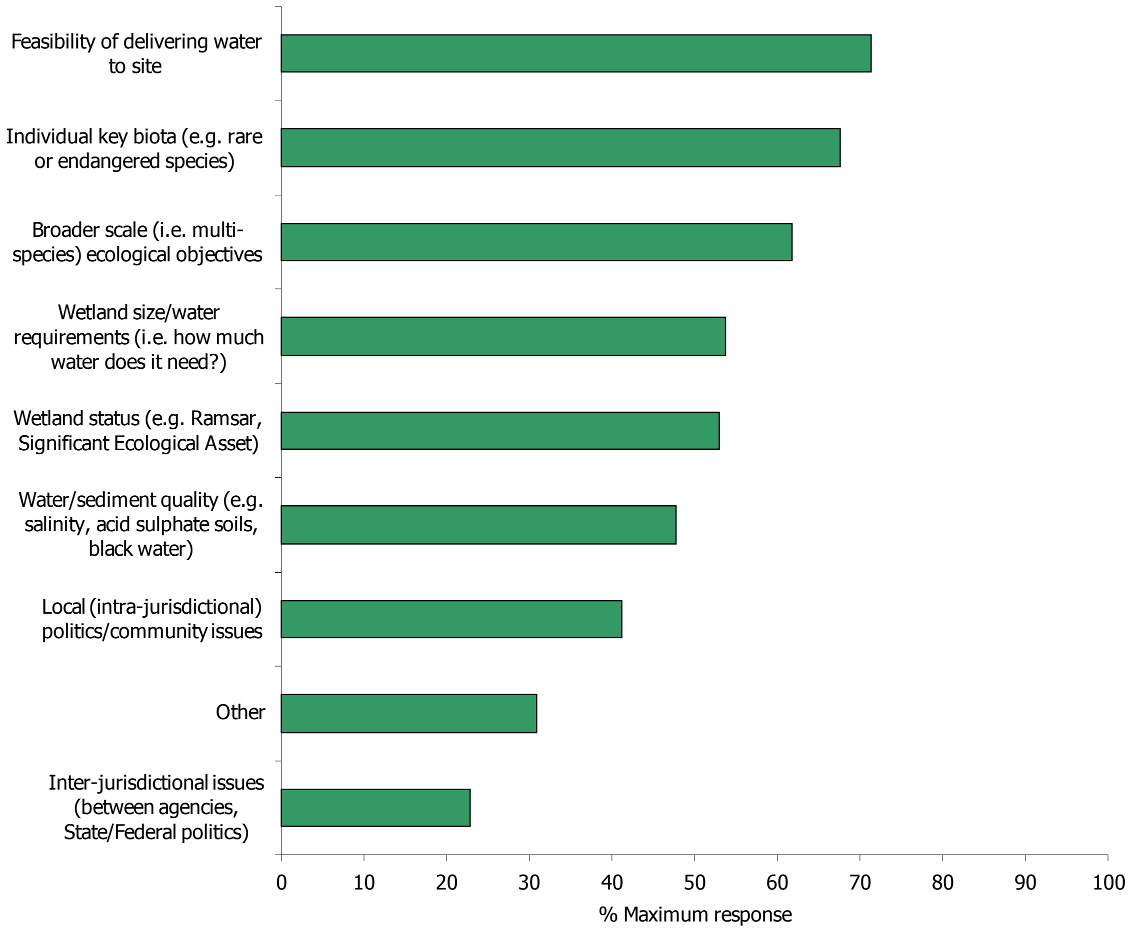
When responses to the rank/percentage questions were in an unexpected form (e.g. equal rankings given, or not ranked), they were interpreted in a way that enabled them to be analysed. Thus when ranks were tied (e.g. 1, 1, 2, 3, 4) the average of the tied positions were used, so that the example given becomes (1.5, 1.5, 3, 4, 5). When ranks were missing (e.g. 1, 2, 3, _ , _, _) the missing positions were treated as though they were tied and the average used, (i.e. 1, 2, 3, 5, 5, 5). Blanks in percentage questions were set at zero, and only responses that summed to 100% were included.

3.2 Results

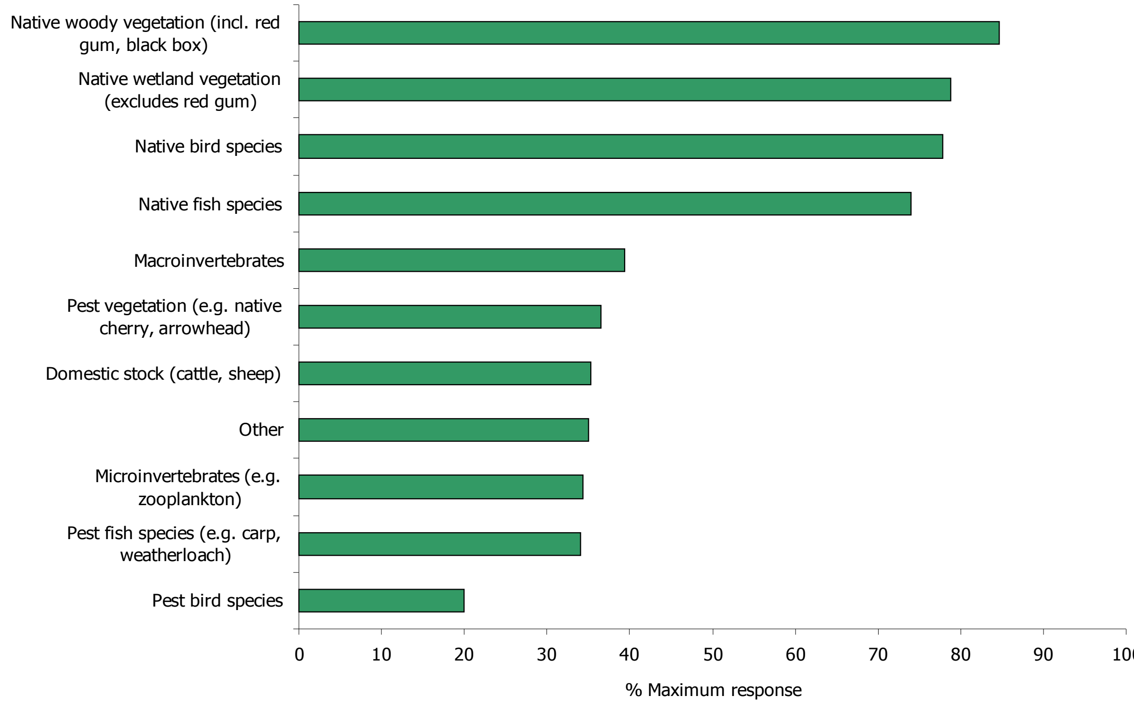
Ranked results are presented as a series of horizontal bar graphs, with '% Maximum Response' along the horizontal axis. A score of 100% Maximum Response can be achieved only if an individual category was ranked no.1 by every survey respondent. Results are presented in this way to demonstrate visually both the overall 'average' ranking of each category, and the relative score each category received when compared to other categories within the same question. Where 'other' results were given, they are recorded below each categorised answer.

3.2.1 Section 1: Allocating water

Q. 1a: What factors have the greatest influence in determining which wetlands receive environmental water allocations?



Q. 1b: Which biota have had the greatest influence determining which wetlands did or did not receive water?

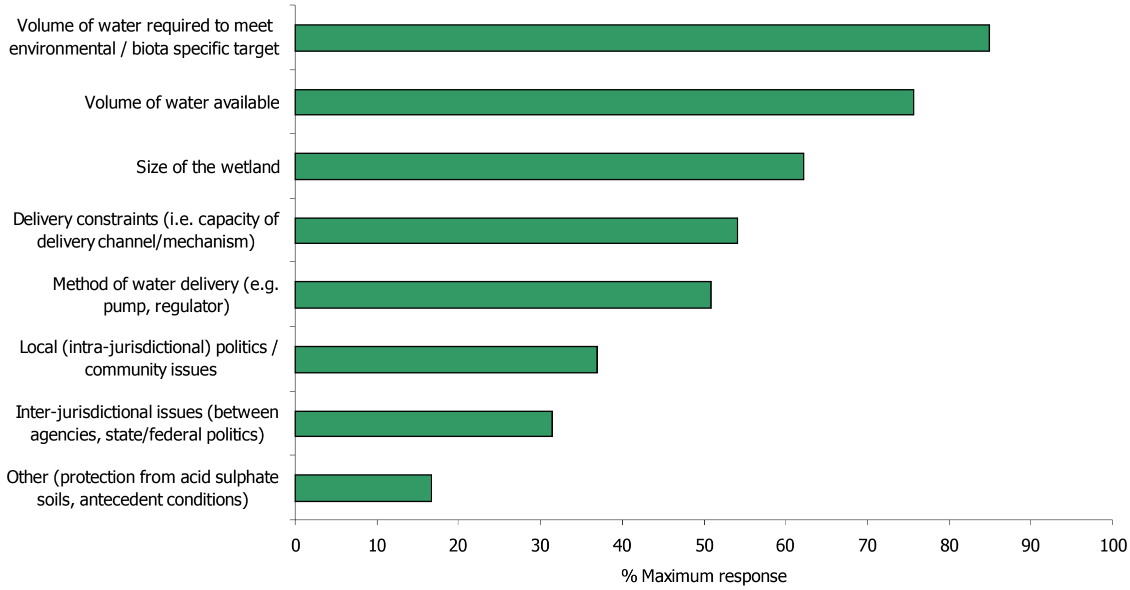


Other biota included: amphibians (frogs) and reptiles.

Q. 1c: What species/community traits do you manage for?

Trait	**Average (%)**
Survival/maintenance of an existing native species/community	61.8
A successful breeding event of one or more native species	29.7
Inducing mortality of pest species	5.8
Interrupting breeding/recruitment events of pest species	4.0
Other	0.0

Q. 1d: What determines how much water a wetland gets?

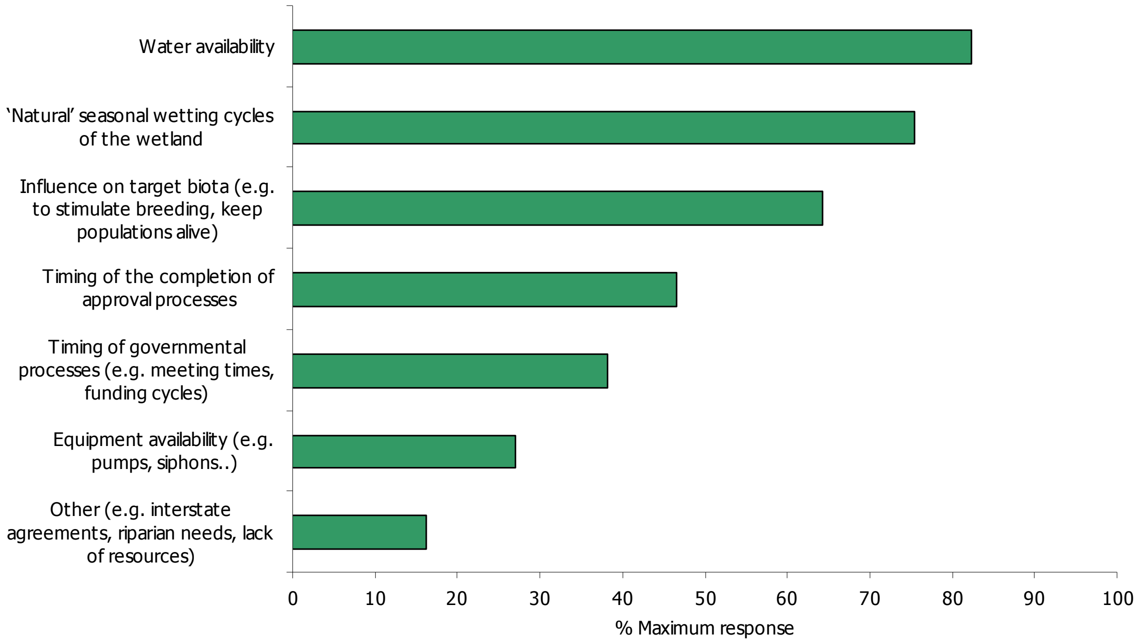


Comments: drought is an important factor that determines the amount of water.

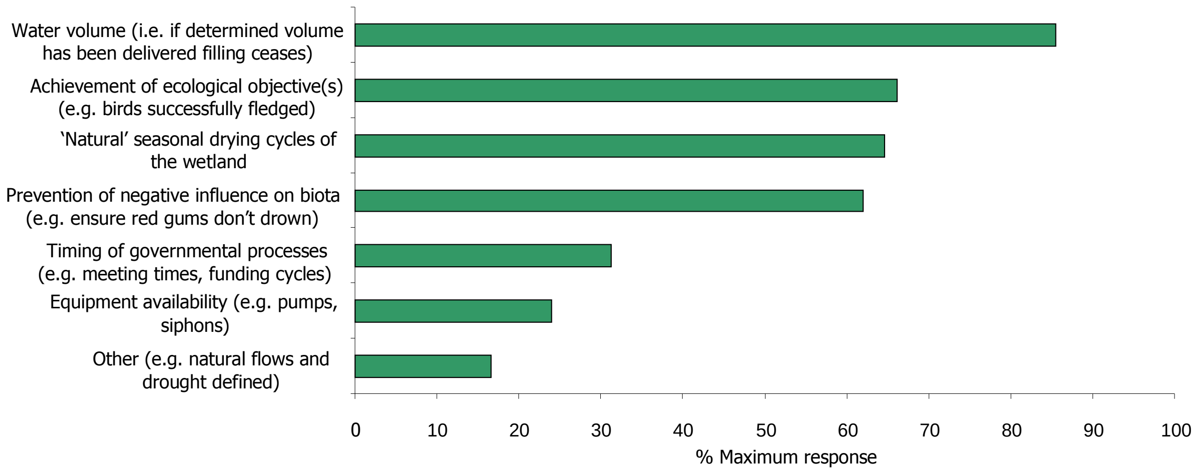
Q. 1e: How do you deliver water to wetlands?

Method of delivery	**Average (%)**
Pumping	26
Opening of an existing regulator (including block banks)	24
Targeted delivery through existing natural river/creek channel	21
Targeted delivery through existing irrigation infrastructure	17
Over-bank flooding of nearby river/creek channel	8
Other (weir raising)	3
Siphons	2

Q. 1f: What determines when you start delivering water to wetlands?



Q. 1g: What determines when you stop delivering water to wetlands?



Q. 1h: What is the ultimate fate of water delivered to wetlands?

Fate of water	**Average (%)**
Left in the wetland to evaporate / seep / dissipate	76.3
Returned to a river / creek	22.5
Removed from the wetland for stock / domestic use	0.7
Removed from the wetland for irrigation use	0.5

3.2.2 Section 2: Other wetland management activities

Q. 2a: Do you undertake direct wetland management activities other than those involving water delivery?

Yes	87%
No	13%

Management activities undertaken include:

- Fencing
- Signage
- Revegetation
- Weed control
- Rubbish removal
- Track rationalization
- Animal and plant pest control (incl. willows)
- Re-snagging
- Educational activities
- Water management options (e.g. structures)
- Research (e.g. into Cumbungi control)
- Monitoring (e.g. sulfidic sediment tests)
- Index of Wetland Condition Assessments
- Fire Suppression
- Dredging

Q. 2b: Is the implementation of these 'non-water delivery' management activities a component of a broader co-ordinated strategy (including water delivery) to achieve specific management outcomes for the wetland?

Yes	78%
No	11%
Not Applicable	11%

Examples of coordinated strategies given by respondents included the Regional River Health Strategy (and sub-ordinate plans), Catchment Management Authority wetland strategy, Landholder–Partner Incentive Strategy, and 'comprehensive' management plans.

Q. 2c: Which, if any, of these activities do you think might have an effect on native fish populations within the wetlands, and if so, how?

Responses were separated into direct versus indirect effects.

Direct

- Vegetation and structure providing habitat and food (e.g. fencing, revegetation, re-snagging)
- Water quality
- Fish passage
- Connectivity

Indirect

- Education
- Research

3.2.3 Section 3: Monitoring the success and failure of wetland management

Q. 3a: Do you undertake monitoring to determine the success or failure of any managed wetland activities (including water delivery)?

Yes	95%
No	5%

Types of monitoring noted:

- Compliance monitoring (the dominant response given).
- Biota monitoring (mostly bird and vegetation, reflects the response to question 1b).
- There was limited monitoring of fish, depending on the ecological objective (see question 3b).
- Water quality monitoring (included groundwater).

Q. 3b: If you do monitor, approximately what percentage of your wetland management projects monitor the following biota?

Biota	Average (%)
Trees	82
Aquatic vegetation	73
Water quality	54
Birds	45
Fish	44
Frogs	37
Macroinvertebrates	25
Sediment quality	21
Zooplankton	14
Algae	7
Reptiles	0

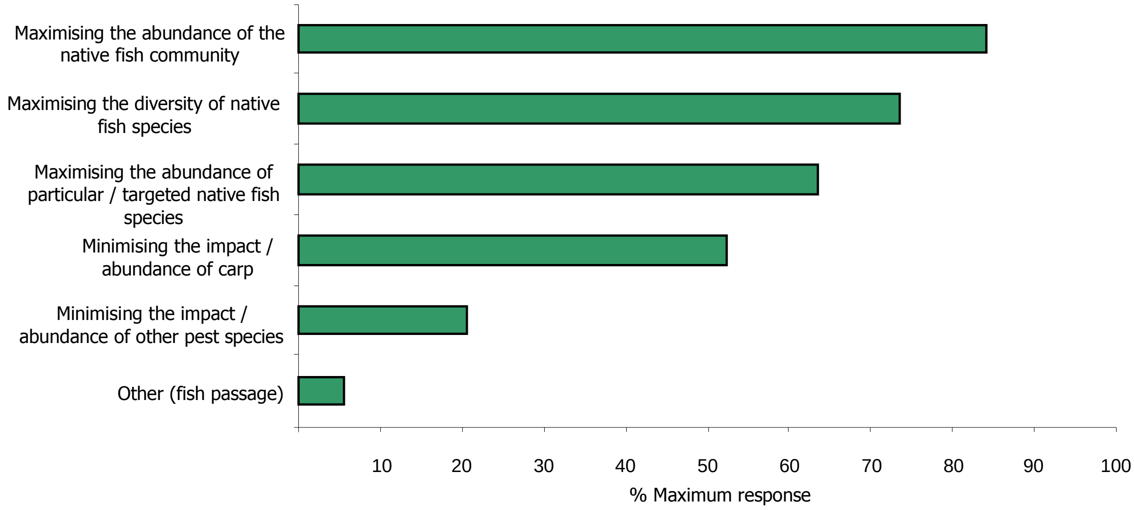
Q. 3c: Is the data gained from monitoring fed back into management models to improve outcomes for the future?

Yes	50%
No	0%
Sometimes	44%
Not Applicable	6%

Different organisations use very different models and inputs, such as decision support systems, general surveillance of wetland condition, index of wetland condition. The link between data collection/interpretation and adaptation of management practices is unclear.

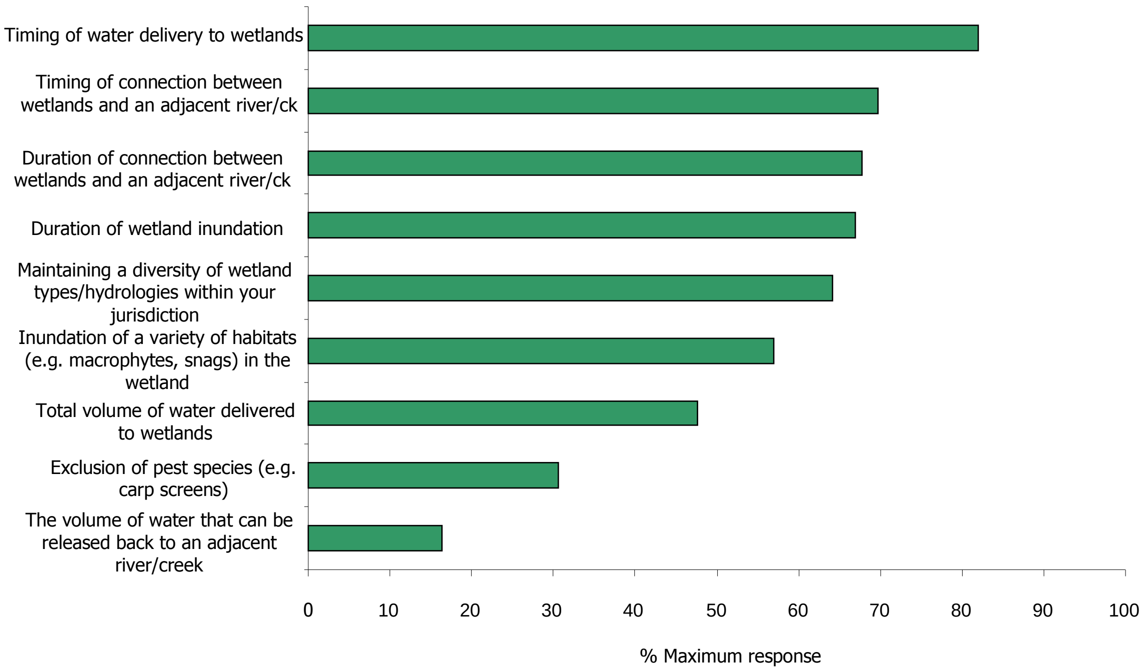
3.2.4 Section 4: Managing wetlands for fish

Q. 4a: What fish objective is most important for your management?



Other: minimising pest species diversity.

Q. 4b: Which of the factors given below is most important to achieving fish objectives?



Note: Many respondents indicated that they found it very difficult to answer this question and expressed only limited confidence in their responses.

Q. 4c: When setting fish-related objectives for managing a wetland/series of wetlands, are you more likely to establish objectives related to (a) individual species, or (b) the broader fish community?

Individual fish species	28%
Fish community	67%
Abstain	5%

Comments: '… more bang for your buck', 'generally, both', 'Focus is largely on threatened/icon species due to legislative requirements and mechanism to gain public support and interest', '…management of a single species may be to the detriment of other species', '…there may be one or two species which may use [sic] as surrogate or indicator species'.

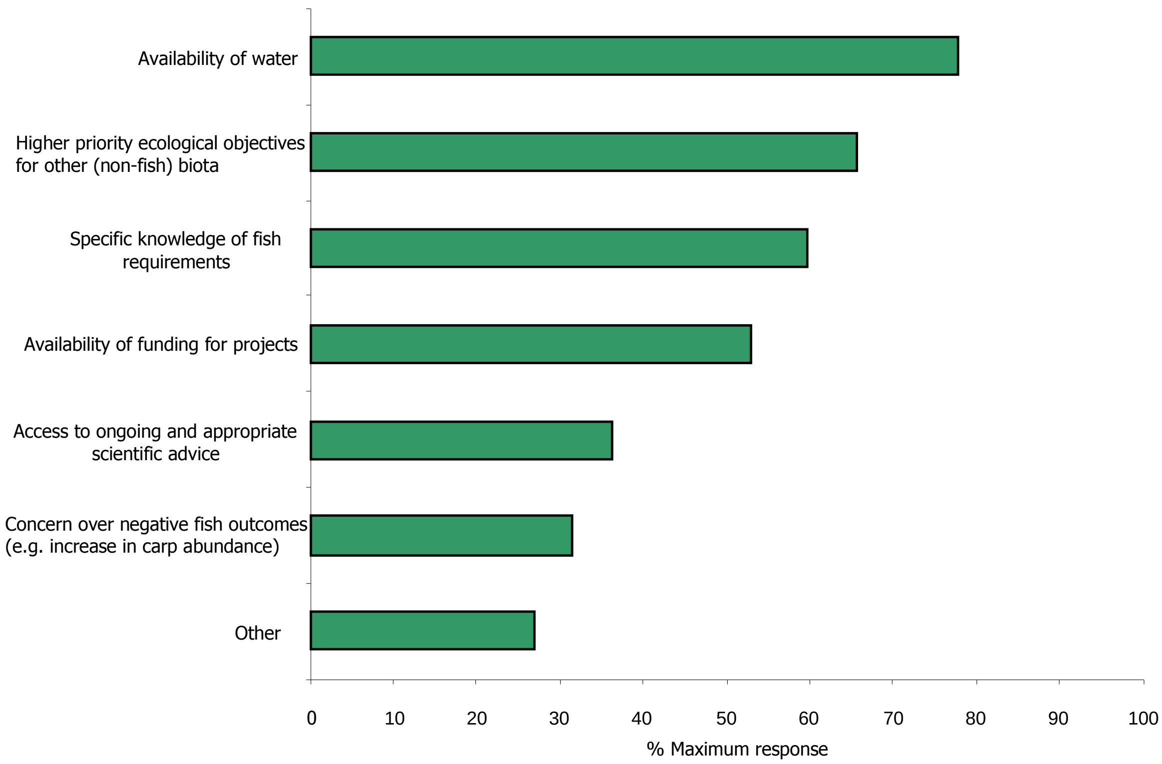
Q. 4d: (i) Considering only individual fish species, please list (in order of influence) the NATIVE fish species that are most influential in determining if and how you manage a wetland.

Species	Number of times ranked (n=14)	Number of times ranked no. 1
Murray Cod	8	3
Murray Hardyhead	6	3
Golden Perch	6	1
Southern Purple-spotted Gudgeon	4	1
Catfish	4	1
Silver Perch	2	0
Trout Cod	2	1
Pygmy-perch	2	1
Dwarf Flat-headed Gudgeon	2	0
Rainbowfish	2	0
'Small bodied fish'	2	1
'Insufficient knowledge'	1	1
Macquarie Perch	1	0
Mountain Galaxias	1	0
'They are all equal'	1	1
Australian Smelt	1	0
'Threatened species'	1	0
Gudgeon spp.	1	0
River Blackfish	1	0

(ii) Considering only individual fish species, please list (in order of influence) the PEST fish species that are most influential in determining if and how you manage a wetland.

Species	Number of times ranked (n=15)	Number of times ranked no.1
Common Carp	14	13
Eastern Gambusia	11	1
Goldfish	6	0
Redfin Perch	4	0
Oriental Weatherloach	2	0
'Insufficient knowledge'	1	1
Trout	1	0

Q. 4e: Which of the items below represent the greatest limitation to your ability to effectively manage wetlands for fish?



Other: politics, legislation, extraction, connecting wetlands to rivers/creeks.

3.3 Summary

The first section of the survey 'Allocating Water' and much of the workshop discussion indicated that logistical constraints (such as the feasibility of delivering water to sites, the volume of water available and the timing of water availability) played the most important role in determining which, if, and when wetlands received environmental water. Thus for the majority (at least) of wetlands, the environmental objectives for watering appear to play a secondary role.

This highlights a major issue in wetland management within the Murray–Darling Basin. Thus although the answers to this survey reflect the drought conditions currently faced across the Basin, it is clear that only a subset of wetlands are being considered as 'manageable'. It is therefore likely that some of our more remote, unique and ecologically important wetlands have slipped completely off the management radar.

Where ecological targets were used to prioritise wetlands receiving water, both native woody and wetland vegetation topped the list of biota that have the greatest influence on decision-making. This is perhaps not surprising during an extended drought, when less mobile and long-lived flora are often targeted for environmental water to sustain them until 'better' times return. Despite their mobility, native birds and fish ranked third and fourth, marginally behind the two vegetation categories but clearly in advance of all other wetland biota. The clear separation the 'percent maximum' ranks of these four categories from all other biota are in line with The Living Murray program's focus on birds, fish and vegetation, and are therefore not surprising in the current environment.

Another interesting result was the low proportion (approx 22.5%) of water allocated to wetlands that was returned to the river, the vast majority (76.3%) being left in the wetland to evaporate, seep or otherwise dissipate. This too is important, because in a less regulated system wetlands may have played an important role in returning high concentrations of prey items and nutrients to the main channel, possibly improving the recruitment success of fish that inhabit the main channel.

Subsequent discussions indicated that there are legal implications for returning water to the main channel, and that these, along with the customary logistical constraints, meant that this option was rarely considered as part of a wetland management strategy. This issue is discussed in more detail in section 4.1.

The second section 'Other Wetland Management Activities' indicated that the overwhelming majority (83%) of wetland management activities involved multiple management actions, not just water delivery. Managers identified a suite of 'non-water delivery' actions (e.g. revegetation, education and research) that are perceived as either directly or indirectly affecting fish populations in wetlands.

The third section 'Monitoring the Success or Failure of Wetland Management' revealed that the vast majority (95%) of wetland inundations are accompanied by biological monitoring. The most commonly monitored biota are trees (82% of cases), and fish are monitored in approximately 45% of cases.

The fourth and final section 'Managing Wetlands for Fish' asked managers to indicate which fish values they might focus on as part of a wetland management strategy. Most indicated that managing for whole fish communities would take precedence over managing for targeted species, but that this was very case-specific. Murray Cod was listed as the most important native target species. Golden Perch, another large-bodied iconic species, came a close third. This is interesting given that there are few records of these fish being found in significant numbers in wetlands, and particularly so in the semi-permanent wetlands that are most often the target of wetland management activities. The endangered Murray Hardyhead ranked second on the list of native species influencing wetland management decision, most likely reflecting the current effort to save the population in north-western Victoria.

The Common Carp is clearly the most important pest species considered by wetland managers. However, pest fish species management was not ranked highly by managers throughout the survey, and the enhancement of native fish communities took clear precedence.

Figure 9. Golden Perch an iconic native species collected in Snake Island Lagoon, Howlong. This species is abundant in large deflation basin wetlands, such as Menindee Lakes and Lake Victoria, and present in anabranch systems in the lower-Murray (e.g. Chowilla and Lindsay-Wallpolla). It is rare in the wetlands of the mid-Murray, but anecdotal evidence suggests it was once present in higher numbers. This decline likely reflects the disruption of their use of floodplain wetlands as nursery grounds. Photo L. Beesley.

4 Management capacity, key challenges and adaptive nature of management

The final task of the workshop involved three small group discussions. In each group, managers were asked to record current management considerations and attitudes, and to list the major limitations to achieving wetland management targets. The three groups were invited to address one of the following key issues identified during earlier discussions:

- **Manipulating wetland hydrology:** This group investigated the extent to which managers consider individual flow components (i.e. timing, frequency, volume, rate and duration of water delivery) during wetland watering events. Group members discussed the opportunities as well as the physical and bureaucratic limitations associated with the manipulation of each component. The group also outlined a range of opportunities and limitations associated with the release of water from wetlands back into adjoining river systems.
- **Key challenges for getting water into wetlands:** This group investigated the key environmental, social and bureaucratic challenges faced by managers attempting to put environmental water into wetlands.
- **Adaptive management of fish in wetlands:** The third and final group addressed individual components of the adaptive management cycle (i.e. assessing condition, setting objectives, designing interventions, monitoring, reviewing and learning, and implementing changes). The relevance of these components to the management of fish in wetlands within their jurisdictions was discussed, and the capacity required to undertake a truly adaptive management program was documented.

Individuals were invited to join the group of their choosing. The results of their discussions are recorded in the following sections.

Figure 10. Water flowing into the connecting channel of Black Swan, Howlong, during summer irrigation flows down the Murray River. Photo L. Beesley.

4.1 Manipulating wetland hydrology

Six wetland inundation 'levers' (i.e. wetland inundation and emptying protocols that managers might be able to affect) were considered by this group:

- timing of wetland inundation (i.e. time of year)
- frequency of individual wetland inundation
- volume of water delivered to wetlands
- duration of wetland inundation
- rate of water rise and fall in wetlands
- returning wetland water to the river

Each lever is discussed individually below.

Timing of wetland inundation

Prior to river regulation in the Murray–Darling Basin, natural wetland wetting and drying events reflected the strongly seasonal cycles of rainfall, snowmelt, and periods of high summertime evaporation. This intra-annual variability, in conjunction with the droughts and floods that characterise temperate Australian river flows over longer timescales, exerted a range of selection pressures on the biota that inhabit wetlands.

In contrast, current river management practices that focus on water delivery during the peak growing season (spring–summer) often result in strongly aseasonal patterns of wetland inundation and drying. The resultant temporal shift in the natural cues for native fauna and flora is widely thought to be a major contributor to the decline in the abundance of native biota using our floodplain wetlands. Thus, for managed wetlands the timing of wetland inundation is important because, to be most effective, it should reflect the natural cycles to which our native biota is adapted.

Despite general agreement on this underlying principle, there appear to be considerable barriers to appropriately timing the delivery of environmental water to wetlands. In an attempt to better understand why this is so, managers were asked:

Question: Is the timing of wetland inundation considered when using environmental water?

Response: Yes, but the opportunistic (often aseasonal) nature of water availability, and both the physical and bureaucratic limitations to delivering it, have been more influential than the ecological requirements of wetland biota in determining timing of water delivery to wetlands.

Limitations to achieving ideal timing of wetland inundation: Limitations to appropriately timed delivery of water to wetlands can be divided into four broad categories:

Physical limitations: For many managers the availability of water for wetlands is driven by irrigation demand, water security (and variable allocations of water of different security), and antecedent rainfall or river flow conditions, all of which can vary on a daily or weekly basis. More permanent physical constraints on water delivery (e.g. dam valve capacity, delivery channel constraints, the availability of water outside the irrigation season) and economic considerations (e.g. cost of pumping, cost of water) also hinder the ability to physically deliver water to targeted wetlands. As a result, the appropriately timed delivery of environmental water to wetlands is often simply not possible.

Figure 11. Water being pumped by the Murray Wetlands Working Group into a wetland near Mildura. Photos L. Beesley.

Bureaucratic limitations: Bureaucratic and political delays in making water available for wetland watering activities often delay the delivery of available water beyond 'natural' temporal boundaries. Managers indicated that the time required to achieve sign-off and gain approvals is often limiting, particularly if the approval process involves more than one jurisdiction. Also, the mid-winter end of financial year often results in unallocated Ministerial and departmental environmental water allocations being made available under the provision that it be delivered by a June 30 deadline. For most parts of the Basin this is not a natural timing for inundation, so it is unlikely to yield the maximum biotic response.

Social limitations: During times of severe drought, the use of significant volumes of environmental water to inundate wetlands has met with significant community resistance. In Mildura, for example, well-publicised community opposition to the inundation of the Cardross wetlands to sustain a population of critically endangered Murray Hardyhead resulted in considerable delay in water delivery to those sites.

Knowledge limitations: Managers indicated that one of the key knowledge gaps was an understanding of the critical timing of key ecological objectives. Although there is a broader understanding that the timing of managed wetland inundations should, where possible, mimic natural wetting or river flow cycles, the impacts of the effects of differently timed inundations on key biota is poorly understood. This is particularly the case for Australian native freshwater fish, for which we still have only a rudimentary understanding of the relationship between flow and fish spawning and recruitment.

Another key knowledge limitation is the effect of different water qualities on fish response. Although the effects of severe blackwater events on large-bodied native fish have been documented (McKinnon 1997), our understanding of the relationship between the timing of inundation, the incoming water quality, and the factors that might lead to a severe blackwater event need to be developed further.

Other limitations: In many systems there are a number of different environmental objectives, often competing for the small volumes of water that are available. Because many of these objectives require different management actions, managers are constantly faced with the need to prioritise water delivery. The timing of wetland inundations often suffers as a result, as managers are forced into a series of suboptimal management actions while attempting to make the best use of environmental water in a complex environment.

Finding solutions: Managers recognised that, because of the diverse political and social conditions across the Murray–Darling Basin, there appears to be no broadly applicable solution to the problem of managing the timing of wetland inundation, and that solutions will often be wetland-specific. Further, when asked what they hoped the broader NWC 'Fish in Wetlands' project might deliver, managers indicated that while the 'ideal' timing of water delivery to wetlands (for individual fish species and the broader fish community) may be an interesting scientific problem, they really needed information on the costs, benefits and risks of putting water into wetlands outside the 'ideal' time window.

Frequency of wetland inundation

Boulton and Lloyd (1992) have shown the frequency of flooding affects the survival of invertebrates in the seed bank of floodplain sediments, and therefore their subsequent emergence during periods of inundation. As these invertebrates are a major food source for the early life stages of all native freshwater fish (and many other biota), we were interested to know if wetland managers considered long-term (i.e. multi-year) wetland watering plans when planning wetland inundations. We asked:

Question: Is the frequency of wetting considered when using environmental water?

Response: Yes, but a variety of physical and knowledge limitations commonly prevent this from occurring.

Limitations to achieving the ideal frequency of wetland inundation: Repeat wetland inundations are often limited by the physical availability of water and a lack of specific knowledge of the benefits of multiple inundations.

Physical limitations: The physical availability of water is the primary factor limiting the ability of managers to undertake repeat inundations of targeted wetlands. Ironically, for many wetland systems that have previously received regular annual inflows in the form of irrigation runoff water (e.g. Cardross Lakes and Lake Hawthorn near Mildura), improved irrigation practices have resulted in less runoff, and hence reduced frequency of wetland inundation. Such wetlands now require managed inflows and water allocations to preserve their environmental values.

Knowledge limitations: The recent drought has highlighted our poor understanding of how factors such as wetland inundation frequency affect the resilience of freshwater systems. From a practical perspective, managers need much better information on resilience at all spatial scales if they are to appropriately prioritise wetland inundations. Managers in this breakout group indicated that, in the absence of good scientific information, this knowledge gap is filled by either the 'gut feel' of the manager themselves, or by a local 'expert', often representing a limited range of wetland biota.

In many cases the ecological benefits of rewetting a previously inundated site have not been demonstrated, and so management decisions often default to maximising the number or area of wetlands inundated using the limited environmental water supply.

Finding Solutions: Managers again stressed the need for the NWC project to work within a context of providing tools and information that not only addresses the 'ideal' frequency of wetland inundation for a variety of taxa, but also provides some understanding of the costs (and possible benefits) associated with suboptimal wetland watering regimes.

Volume of water used to inundate wetlands

Beyond issues of water availability, the volume of water delivered to a wetland is likely to have important implications for the biotic response resulting from a wetland inundation. In many cases, managers may choose whether to inundate the emergent macrophytes commonly found around the edge of a wetland, thereby creating an area of complex habitat that may be advantageous for small-bodied fish and their prey (e.g. Balcombe and Closs 2004; Padial et al. 2009). Similarly, the creation of a diversity of depth habitats within a wetland might also be important in determining fish community response to a wetland inundation. With this in mind, we asked managers the following question:

Question: Is the volume of water considered when using environmental water?

Response: Yes, the minimum amount of water required to meet the environmental objective(s) of the wetland inundation is the primary determinant of how much water an individual wetland gets. For example, some waterbirds require water to be held at an appropriate depth for prolonged periods to successfully fledge. This is, however, bounded by the availability and cost of delivering environmental water.

Limitations to achieving ideal volume of wetland inundation: As indicated in the response, the practical issues associated with the availability and cost of water delivery will eventually determine how much water is available for wetlands. For an individual wetland, an estimate of the volume needed is typically a 'best guess' (often based on previous experience) of biotic requirements and the morphology of the wetland.

*Knowledge limitations***:** There is little fine-scale information that relates the volume of water delivered to a wetland to the ecological response. Furthermore, the amount of water required is likely to vary greatly among biota (e.g. trees, birds or fish) and with local conditions (e.g. soil type, time since last inundation, wetland bathymetry). For some biota, the depth of water within a wetland after watering may be more relevant than the volume delivered or the area inundated.

Finding Solutions: Managers indicated that there was a need for greater clarity linking ecological objectives to specific hydrological conditions within a wetland (e.g. the production of guidelines such as, 'The spawning of Australian Smelt can be maximised if they have access to an unvegetated area > 1 m deep in spring'). Such guidelines will inform the initial estimates of water volume required, and will also inform adaptive management during wetland filling. Similarly, more specific guidelines such as those above may also help inform broader-scale decisions as to which wetlands should get water (e.g. should we inundate one large wetland or several smaller wetlands?).

Duration of wetland inundation

The duration of wetland inundation has two interrelated management components: (1) the *duration of connection* of the wetland to a source river or channel affects the movement of fish between these two habitats, and (2) the total duration that a wetland contains water (i.e. *duration of inundation*) is clearly also important (and particularly so from a fish perspective). Considering both of these components, we asked wetland managers:

Question: Is the duration of 1) wetland connection, and 2) wetland inundation considered when using environmental water?

Response: Yes, although *duration of connection* is intrinsically linked to the volume of water allocated, and to the capacity of the pumps or regulators being used to deliver that water. As a result, there is often limited flexibility to manipulate this.

Duration of inundation is currently considered to maintain suitable habitat for some protected fish species (e.g. Murray Hardyhead) and to maintain water levels thought to be important for some waterbird species. Again, however, the volume and availability of water is the limiting factor in determining inundation duration.

Respondents noted that, at a broader spatial scale, the location of a wetland in the Basin is also important. This is particularly true with regard to wetland desiccation (and hence duration of inundation), which is less of an issue in the subtropical north than in the temperate south because of increased water availability and lower rates of evaporation.

Figure 12. Fyke nets used to quantify fish movement into and out of a wetland. The nets shown above are monitoring movement into the wetland. Photo L. Beesley.

Limitations to achieving ideal duration of wetland inundation: Although evaporation rates have an obvious impact, managers indicated that the total volume of water available represents the primary limitation on a manager's ability to affect a change in both duration of connection and duration of inundation. As such, the limitations around water volume (see above) are also pertinent here.

In addition to these limitations, managers felt that the management of wetland-to-source water connection times was limited by a knowledge of what represents an 'optimum' *duration of connection*. To date there has only been limited work (see Lyon et al in press) in this area for Australian native fish, and this work deals only with open channel river-wetland connections within a limited spatial and temporal scale. Managers also identified a clear knowledge gap with regard to the effects of different water delivery methods (i.e. pumps vs. regulated vs. unregulated channels) on movement of fish between the source water and the wetland. Surprisingly, perhaps, there have been several instances where native fish have successfully moved into wetlands through pumps (Leah Beesley, pers. obs. 2008; see also EPA and MDFRC 2008, McCarthy et al. 2009), thus there may be some value in determining the mortality of fish moving through pumps.

Regarding *duration of inundation*, managers indicated that there is often only a rudimentary knowledge of a wetland's interactions with other determinants of inundation duration (e.g. groundwater interactions, stock access and impact, evaporation rates), necessitating a more *ad hoc* or adaptive management approach to maintaining water in wetlands than can be supported by standard one-off water allocations.

Managers also noted that although there is some consideration of the need to maintain a diversity of wetland types (e.g. permanent, ephemeral) throughout the landscape, often more practical issues of water delivery prohibit such considerations from being acted upon. Further, community and local issues often mean that particular wetlands and/or particular wetland types most commonly receive water allocations irrespective of their contribution to landscape scale diversity.

Finding solutions: Because both *duration of connection* and *duration of inundation* are so closely linked to the volume of water allocated to a wetland, many of the limitations and solutions discussed above (see 'Volume of water used to inundate wetlands') are pertinent here, too.

Further, there may be some scope (where practical) to vary regulator operational rules/ pump intake diameter to alter the rate of water delivery to wetlands in the future such that their effects on fish responses might be better studied and optimised. Clearly the implications of changing the hydraulic and mechanical nature of this connection need to be considered.

Rate of rise and fall

The spawning and movement cues for some Australian native fish have been linked to the rate of rise and fall of water (Mallen-Cooper and Stuart 2003, King et al. in press). Although this relationship remains poorly understood, previous models of fish response to hydrological changes (e.g. Murray Flow Assessment Tool: http://www.mdbc.gov.au/subs/information/mfat/index.htm) have included a rate of water rise and fall component. We were therefore interested to know from managers:

Question: Is the rate of rise and fall of water considered when applying environmental water?

Response: Not specifically for fish, but rate of fall is monitored during waterbird breeding events to prevent birds from abandoning nests. This is particularly the case where environmental water has been used to supplement 'natural' flow events (see Barmah Millewa: section 2.2). Also, in some wetlands where bank slumping is a concern, the rate of rise and fall is considered during managed wetting events. In most cases, however, the rate of rise is determined by logistical and physical constraints of water delivery, and the rate of recession is determined by natural processes (e.g. seepage, evaporation) with little or no management intervention.

Limitations to achieving ideal rate of rise and fall in wetlands: The ability to manage rate of rise and fall is usually limited by both physical and knowledge constraints.

Physical limitations: Logistical constraints around the volume of water available, and the ability to control the means and/or rate of water delivery pose the greatest limitation to a manager's ability to control rate of rise and fall.

Knowledge limitations: As above, the relationship between the rate of rise and fall of water and fish response is only poorly understood, thus without a clear basis for the need to control rise and fall rates, managers will default to the logistically defined rates of water delivery and (usually) the more 'naturally' determined rates of water recession.

Finding solutions: There is broad agreement across both the management and scientific community that there exists only rudimentary data and knowledge of the effects of rates of raising and lowering water levels on fish responses, and as such, this is not a consideration for most managers who often simply need to get as much water delivered to a system by a set date. There is, however, a willingness among managers to, where feasible, alter filling and recession rates as part of a more experimental approach to determine the value (or otherwise) of such an action.

Returning water to the river

The preceding discussion has focused on the benefits of watering at the scale of the individual wetland. These wetlands are, however, a component of the broader river system, and benefits at this larger scale should not be ignored. Such benefits to the river channel include the release of nutrient and food rich wetland water back to the river system (King et al. (in press)) and the transfer of genetic material between populations for wetland/river fish generalists. With this in mind, we asked managers:

Question: Do you ever return water from a managed wetland to the river?

Response: This has been done in the past for those managed wetland inundations that 'piggy back' onto flood events (e.g. Barmah Millewa). In such cases, the return of water is driven by natural processes on shedding floodplain wetlands and is not managed. For smaller, more discrete wetland systems with more targeted water delivery mechanisms, returning wetland water to the river channel is often too problematic to consider.

Figure 13. Two fish species abundant in the floodpain wetlands of the Murray River: (A) Carp Gudgeon and (B) Australian Smelt. Photos L. Beesley.

Limitations to returning water to the river: For the smaller wetland inundations, there exists many limitations to returning wetland water to the river:

Physical limitations: For wetlands filled through unregulated channels, or regulated connections that require simple opening of regulator structures, the ability to move water back out of the wetland will be governed by head difference across the structure/delivery channel. In such cases, releasing wetland water back to the river is likely to be only rarely possible, and if so, for only a short period. Further, for smaller inundations where water is pumped in, moving this water out of the wetland would require additional cost, equipment and approvals, which is unlikely to represent the best cost-benefit outcome in a broader scale wetland management program.

Knowledge limitations: Although there is a sound conceptual understanding of the benefits to riverine fish that might be derived from an appropriately timed inoculation of wetland water (Junk et al. 1989), quantification of this benefit has meet with mixed success. Managers are thus often unable to demonstrate a clear benefit of returning wetland water to the river, and therefore unlikely to endorse the extra resources required to achieve such an action.

At another level, knowledge of the possible detrimental impacts of releasing wetland water back to the river are likely to be wetland specific, requiring further monitoring and analysis and resources. Thus, the threat of negatively impacting riverine water quality (e.g. salt, dissolved oxygen, black-water) and spreading/propagating exotic flora and fauna may also inhibit the release of water.

Social limitations: For some managed wetland inundations, aesthetic, education and public amenity outcomes are at least as important as site-specific ecological outcomes. In such cases, ‘draining’ the wetlands to achieve a less tangible benefit would likely meet with significant public opposition.

Bureaucratic limitations: The NSW Fisheries Act, EPA and ANZECC Guidelines were all listed by managers as likely to require some form of approval, therefore potentially limiting the ability to manage the release of wetland water to the river in a timely manner. Such a bureaucratic limitation is not so important for some wetland management organisations, nor is it limiting for larger scale wetland inundation events that add to existing flood events, but is likely to be the case for many smaller, more discrete managed wetlands.

Finding solutions: Again, where possible and sensible, managers indicated their willingness to assist in designing wetland management protocols to include water releases if they could be monitored in such a way as to demonstrate their benefits/detriments to both the fish community and other flora/fauna.

Summary

Overall, managers considered the timing, duration, frequency, volume of water delivery and the rate of water rise and fall all important when managing wetlands. However, there was a clear message from the managers in this breakout group that managing these attributes is often compromised by the availability of water, the capacity to deliver water, and other institutional, political and social considerations. This was particularly true when contemplating the return of water from wetlands back to the river, which is therefore seldom considered in current management activities.

Of the hydrology levers, managers felt that the timing of water delivery was likely to be the most important for fish, but that there significant knowledge gaps prevent them from making informed decisions about the temporal allocation of water. This represents a key knowledge gap for the larger National Water Commission project.

4.2 Key challenges to putting water into wetlands

The purpose of this breakout group was to investigate the key challenges faced by managers attempting to put environmental water into wetlands. By various means the group identified that future availability of environmental water (i.e. due to drought and climate change), the ability to appropriately prioritise watering sites, the ability to manage water quality (particularly with respect to black water and acid sulphate soils), and the need for community approval of wetland watering events were all key issues that need to be addressed.

These, along with other challenges facing managers, are discussed below. Although it was acknowledged that many of these challenges are inter-related, those considered to be 'priority challenges' requiring further investigation and solutions in the short-term were ranked in order of their perceived importance (a rank of '1' being most important). Note; some challenges could not be separated on the basis of importance, and so shared a rank.

Figure 14. The water crisis: Hume Dam at 24% capacity (January 2009). Photo L. Beesley.

Priority challenges

- ***Water availability (Rank: 1).*** In light of the current drought and impending climate change, managers were concerned that the amount of water made available for wetland management activities will be significantly reduced in coming years. Indeed, managers noted that this is already occurring. For example, water earmarked for the environment has been 'borrowed back' (frozen) by governments and instead allocated for irrigation and/or domestic use. In addition, and where regulators allow, some large wetlands are being disconnected from the river by authorities in an effort to reduce water loss via evaporation. These actions indicate that the use of water for environmental purposes during the current dry period is already an emotionally charged and political issue, and managers voiced their concern that this situation will only be exacerbated as the drought continues.

  From an ecological perspective, reduced water inflow into wetlands via reductions in river connectivity or reduced management activity is likely to result in the reduced distribution and abundance of many wetland fish species/communities. In some severe cases, critically endangered fish communities will be at serious risk of extirpation, possibly extinction. It is possible that managers facing significant and irreversible losses with limited resources will be forced into a state of triage – using water to save species/ecosystems on the verge of collapse. Managers voiced concerns that while likely extirpations/extinctions will necessarily prioritise wetlands, such reactionary management is a poor long-term practise. However, while managers currently deliver water to a range of wetland types with a goal of maintaining landscape scale heterogeneity, in a drought stricken environment it was anticipated that water would be increasingly delivered to a narrowing range of wetland types to protect locally important biota and values.

To achieve the multiple objectives of protecting against extirpations/extinctions and maintaining wetland heterogeneity within an environment of declining water availability, managers indicated that a key priority was to improve the efficiency and efficacy of the water allocation to wetlands. Efficiency may be increased by using a single allocation for the benefit of multiple species (e.g. water birds, river redgums, and fish) and/or less well understood ecosystem benefits (e.g. groundwater recharge). Improved efficacy may be achieved by setting different ecological outcomes (e.g. establishment of appropriately spaced wetland refuges within a catchment landscape), or by more appropriately timed and delivered applications of water. Managers identified key barriers to achieving such changes as a lack of appropriately focused funding, logistical and bureaucratic limitations, and emphasised the increasing need for broad-scale community approval of projects in a drying environment.

- ***Ecological thresholds (Rank: 2).*** Managers were particularly concerned about the lack of knowledge of ecological thresholds for species and/or ecological communities. At a species scale, managers need information about the relationships between physico-chemical parameters (e.g. salinity, dissolved oxygen, pH, water depth) and fish survival. Data is available for some but not all species, and is often difficult to interpret in a 'real world' context. Further, managers often find it difficult to access this knowledge.

  At a local scale, managers would like to establish a series of protocols to determine which, if any, of the wetlands they manage are at risk of exceeding ecological thresholds. For example, knowledge of which wetlands contain acid sulphate soils, receive saline ground water, or are susceptible to blackwater events is of critical importance to the effective management of these systems. Specifically, managers indicated that the development of guidelines that outline triggers for action (e.g. delivery of water) would be helpful.

  At a landscape scale, managers expressed a need for both knowledge and inter-agency co-operation to ensure an appropriate number of refuges are established to allow the continuation of key fish species/communities (and other biota). Again, the funding of appropriate knowledge collection and dispersal activities was listed as the primary constraint limiting our ability to better understand and manage the impact of ecological thresholds into the future.

- ***Climate change (Rank: 3).*** As above, at the individual wetland scale, concern over the effects of climate change relates primarily to water availability and its ecological consequences (e.g. changes to habitat availability and exceedence of water quality threshold). Managers anticipate that risk assessment and site prioritisation will become increasingly important management objectives (see 'Water Availablity' for detailed comments).

  Managers were also concerned about the need to preserve sufficient refuges for aquatic organisms during the current (and impending) drier periods. Although there are a range of climate change based projects examining the role and requirements of freshwater refuges currently being undertaken in the Basin, managers were concerned about the ability of these projects to produce tangible guidelines relevant to the scale at which they operate. It was noted, in relation to refuges, that the river-channel has the potential to act as a refuge for the majority of wetland species. In this context, slow-flow habitats within the main-channel (e.g. backwaters) are important because they provide habitat for wetland species. Managers also recognised that wetlands that lie low in the landscape, and have been kept unnaturally wet by river regulation, are now (in a seeming paradox) important refuges for wetland fish.

- ***Wetland prioritisation (Rank: 3).*** Inter-linked with water availability, the need to determine which wetlands receive water is currently limited by logistical, social and political constraints and in many cases emphasises the preservation of endangered species or wetlands of local importance. A better understanding of the ecological implications of wetland inundation at a variety of spatial and temporal scales is needed to adequately inform the prioritisation process. Further, and in light of the likely reduction in water availability in coming years, the way managers make decisions regarding which, how many and how often wetlands get water may drastically change, with some wetlands being ‘sacrificed’ in order to achieve broader scale benefits. The need for appropriate information and monitoring protocols to both inform and assess such important decisions is a priority issue in need of attention in the short term.
- ***Impacts on water chemistry (Rank: 5).*** At the individual wetland scale, managers indicated they wished to have more certainty around the water quality implications of wetland inundation. Specifically, managers would like to develop some guidelines that would help minimise the likelihood of causing acid-sulfate or black-water events that would limit the success of fish spawning/recruitment events in targeted wetlands.
- ***Knowledge, science, and capacity (Rank: 5).*** The need to combine scientific knowledge with a strong on-ground understanding of managed wetlands is an on-going and important challenge for many management organisations, particularly those with high staff turnover. Establishment of longer-term, meaningful relationships between managers and scientists was recognised as an important step in meeting this challenge.
- ***Community approval (Rank: 7).*** In a farming-based environment where water scarcity is limiting both agricultural production and in many cases farm viability, the use of water for wetland management is being increasingly questioned by the media and members of the public for whom such water could provide economic benefit. Gaining community approval for wetland watering is therefore likely to becoming increasingly difficult. Managers indicated a need to consider public perception as part of any comprehensive wetland management plan into the future, and were keen to explore a broad range of options (e.g. education, site visits) as a means of improving this area.
- ***Trade-offs (advantages vs. disadvantages) associated with managed wetland inundations (Rank: 7).*** In a progressively drying environment, it may be that the water used in previous wetland inundation projects has a more beneficial use elsewhere. Determining where the greater benefit lies represents a major challenge to wetland managers. As above, there exists a key gap in the knowledge required to make such important decisions, and the appropriate monitoring protocols necessary to assess their efficacy.

Additional challenges discussed (in no particular order):

- ***Floods/drought***. What are the implications of management under flood versus drought conditions? If climate predictions of increasing weather extremities are accurate, managers expressed a need for better defined strategies under different climatic scenarios.
- ***Carp***. Managers face the challenge of trading-off optimal outcomes for native fish with the unwanted production of common carp. Although carp screens on wetland inflows may help to alleviate this, managers indicated that other less engineered/less obstructive methods (e.g. timing of water releases to wetlands, altering wetland water levels and rates of rise/fall) need to be further explored and tested.
- ***Connectivity***. Floodplain wetlands receive the majority of their water from the river; however this connectivity has been disrupted by the construction of regulators on connecting channels,

and by the altered stage height of river. Restoring connectivity to these systems is an important challenge for managers and scientists alike.

- ***Infrastructure***. When wetlands are disconnected from the river, delivering water to them by pumping is a time consuming and expensive operation. Having the equipment available at an appropriate time of year is an ongoing challenge for managers.
- ***Cultural heritage***. It is important to ensure that indigenous values are not compromised during water delivery. This has been formally recognised at a number of wetland sites (e.g. Lake Victoria, Lake Wallawalla), and is increasingly likely to play a role in the prioritisation of wetlands, and the logistics required to fill them.
- ***Political and government approval / due legislative process versus flexibility***. All managers expressed the need for a more streamlined bureaucratic process when it comes to water delivery to wetlands. Currently, political will and the sheer volume of bureaucratic red tape can influence whether a water delivery occurs or not. Such limitations can (and do) have strong negative impacts on a manager's capacity to water wetlands within ecologically important timeframes.
- ***Institutional***. As water becomes scarcer and the scale of wetland management extends beyond local issues, there will be an increasing need for management agencies from different jurisdictions to co-operate to achieve common goals. Managers expressed a need to explore the legal and political constraints of this co-operation such that wetland management at the appropriate scale will not be compromised.

Summary

The key challenges for managers in this breakout group focused on the allocation of limited water at both the wetland and landscape scale. These issues include collection of appropriate knowledge for prioritisation, the optimisation of outcomes, and trade-offs among often competing environmental values. Adding to the challenge were uncertainties around adverse outcomes such as water quality. Finally the socio-political dimension complicates the process as decisions are seldom made solely on the basis of environmental outcomes.

Figure 15. Common Carp spawning amongst the macrophytes of a river-wetland connection channel. Photo L. Beesley.

4.3 Adaptive Management for Fish

One of the major goals of the NWC's 'Optimising Environmental Watering Protocols to Maximise Benefits to Native Fish Populations' project is to work with managers to design truly adaptive wetland management plans. Plans address each component of the adaptive management cycle (Holling 1978, Walters 1986), a version of which is presented in Figure 16. To begin this dialogue, this breakout group investigated the extent to which wetlands are currently being adaptively managed for fish. Individual components of the adaptive management cycle were discussed with respect to their current application, limitations to applying them, and whether or not management agencies currently have (with specific regard to fish) the capacity to undertake each component. Individual components are discussed below.

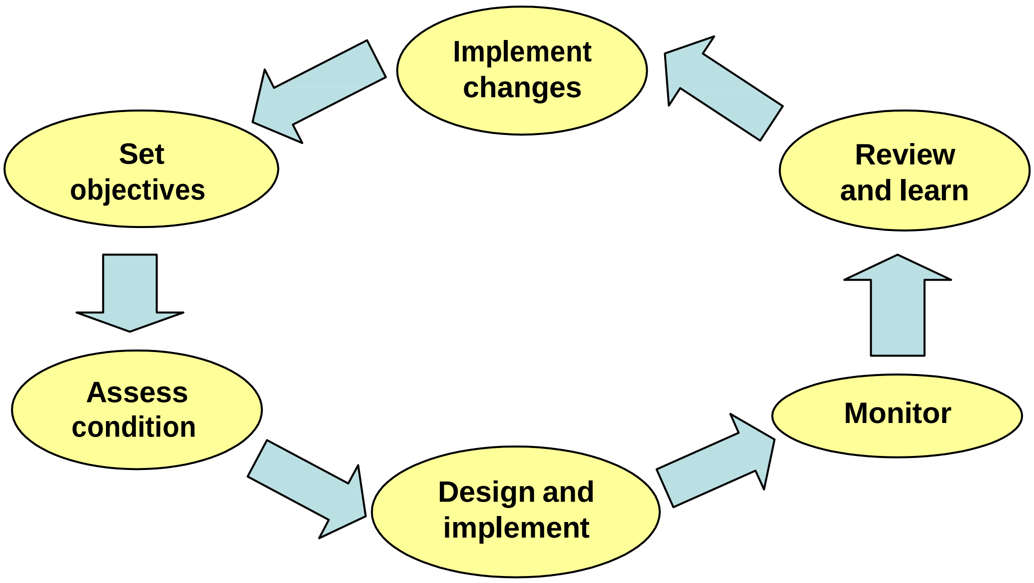


Figure 16: The adaptive management cycle.

1. **Set objectives**: To set objectives (or targets), managers must make unambiguous and quantifiable (i.e. measurable) statements about the desirable future condition of the system they are managing. The suite of objectives for any wetland management exercise should be realistically achievable within the temporal constraints of the proposed management, and should reflect both the positive and negative outcomes resulting from each particular management action.

   Currently, managers set some form of objective(s) for individual wetland management activities. Often these objectives are designed to be readily achievable in the short term (i.e. one year) because of a lack of confidence in the longer-term availability of water or in the water allocation process for multiple-year management activities. Furthermore, many wetland management objectives consider only locally important, site-specific issues and biota. While many management agencies do have broader catchment-scale or landscape-scale objectives (and certainly Catchment Management Authorities as part of their 'Catchment Plans'), the linkages between site-scale wetland management and broader-scale objectives are often not explicit.

   The greatest limitation to the setting of wetland fish objectives identified by managers was a lack of appropriate expertise and knowledge. The setting of measurable goals for fish often requires a biomass or catch per unit effort (CPUE) estimate which is dependent on the relationship between the type of sampling equipment used, and the (often changeable) habitat in which it will be used. Such estimates require considerable experience or rigorous pre-intervention monitoring that can only be sourced from outside the management agency, and is therefore often not undertaken because of the time and cost.

2. **Assess condition:** This requires the manager to measure the condition of the wetland and compare the condition to the objectives (e.g. ratio of native to exotic fish). Where possible, the assessment phase of the cycle should also provide some insight into the cause of changes in wetland condition, although this is rarely the case.

   Managers indicated that some form of assessment is usually undertaken at most wetlands prior to management activities, but both the scale and rigour of these assessments varies widely. A lack of expertise, knowledge and resources (time and money) were listed as key limitations to the appropriate assessment of targeted wetland management activities. In particular, the lack of resources often means that managers are forced to make assessments using data collected *ad hoc* by a range of different agencies using various techniques. This is particularly true for fish data, which most management agencies do not have the resources or expertise to collect effectively on their own.

3. **Design and implement:** This component of the cycle requires managers to design and implement an intervention (or management action) that will, in accordance with their understanding of how that system works, move the system closer to the desired condition (as described during the objective-setting phase).

   While there is an element of design and implementation undertaken for all wetland management activities, managers indicated that it is limited by the availability of water, the ability to deliver that water (both physical and bureaucratic limitations), and a lack of appropriate ecological knowledge or expertise. In particular, wetland inundations often take the form of a one-off pulsed water delivery with little consideration for potentially important ecological factors such as rates of water rise and fall and the passage of fish through the water delivery apparatus. (Notably, there was a key knowledge gap identified here with regard to the movement of fish through pumps.) Also, the often inflexible operating conditions and remote location of some wetlands often prohibit a manager’s ability to affect short-term changes to wetting and drying protocols if unexpected conditions occur.

4. **Monitor:** This stage of the cycle requires the manager to collect information that will be used to asses the effectiveness of the intervention in achieving its objectives. The monitoring may be similar to that undertaken during the ‘Assess condition’ stage, or it may test other attributes thought to be important (e.g. measuring ‘fish food abundance’ to facilitate a more accurate interpretation of ‘fish condition’ data).

   Both the manager’s survey (Section 3) and this breakout group confirmed that some form of site-specific monitoring of wetland management events is undertaken in all but the most exceptional of circumstances, although targeted monitoring of fish occurs much less frequently. It was also noted that in some cases a ‘monitoring committee’ has been established to oversee the monitoring phase, its members being responsible for undertaking the monitoring or procuring external expertise to help them, or both.

   Fish monitoring is, however, often an expensive and time-consuming exercise requiring a high level of expertise that is not available in most management agencies. It is therefore not surprising that managers indicated that in most cases they did not have any in-house capacity to undertake monitoring, instead having to engage external agencies or contractors. As a result, managers indicated there were many inconsistencies in monitoring approaches being undertaken in different wetlands. It was suggested that the application of a more standardised approach to fish monitoring in managed systems would greatly assist agencies to compare wetlands within and beyond their jurisdictions.

Figure 17. Fyke nets used to monitor the fish community in Green Swamp, Gunbower Forest, following a watering event. Photo L. Beesley.

5. **Review and learn:** A properly designed and run monitoring program yields data appropriate for determining whether or not the intervention achieved its objectives, and it is during this 'review and learn' phase that the analysis of this data occurs. Typically, the wetland management will be assessed not only for whether it achieved the objectives set in the initial phase but also for whether the system moved towards the desired future condition.

   Managers indicated that the review and learning phase of the adaptive management cycle is currently undertaken only 'sometimes'. In many cases no particular staff member within the management agency is given this task, and as a result the review of wetland management activities occurs only at the end of the financial year or other reporting cycles. Managers also indicated that this phase requires a high level of expertise that is often not available within the predominantly youthful management agencies, and so is an extra expense not usually built into project budgets. Although it was generally agreed that this phase was currently not done well, managers did indicate that they were very keen to develop the skills required in-house, and would appreciate any assistance in this area.

6. **Adjust:** As a result of the analysis undertaken in the 'review and learn' phase, managers may be required to alter their management practices (e.g. change method of water delivery) or their conceptual understanding of how the system works. Such adjustments should be documented, and the underlying reasons for making them should be clearly explained so that there is a clear logic throughout the current management activity and into the next cycle.

In most cases, managers indicated that the adjustment phase of the project does occur but is rarely formalised. Individual managers gain expertise over multiple wetland management events, and both the management actions and system understanding applied for subsequent wetland projects reflect this knowledge. There is, however, currently no single forum for managers in which they can compare results and make the most use of their collective learnings. This often results in managers receiving different and often competing advice from people with a range of expertise.

Overall, there was clear agreement between managers that considerable deficiencies exist in the application of each step of the Adaptive Management cycle. There were two recurring messages:

1. The application of individual steps was constrained by either the time, money, or technical capacity to undertake the task.
2. Even when undertaken, the procedures applied are often informal, inadequate or inconsistent, and do not result in any adjustment of system understanding or management practices.

A consequence of these limitations is that we are not optimising the environmental outcomes from the limited environmental water we are receiving. We are therefore clearly not making the most of investments in monitoring and assessments due to the lack of integration and synthesis among institutions. As a result, it was a clear recommendation of this breakout group that more frequent formalised interaction between wetland managers and researchers is undertaken to both develop and report on appropriate wetland management activities.

Figure 18. Managers and research scientists in discussion at the workshop. Photo F. Hames.

5 The way forward for the project

This workshop was undertaken as part of the National Water Commission's 'Optimising Environmental Watering Protocols to Maximise Benefits to Native Fish Populations' project, to provide the research team with future direction for the four-year project. Presentations and discussions held at this workshop have provided the research team with a greatly improved understanding of the practical, legal, economic and socio-political limitations facing managers as they plan, enact, and monitor the effects of environmental water delivery to wetlands of the Murray–Darling Basin. And although some of the key messages addressed at this workshop are beyond the scope of the broader project (e.g. the limited volume of water currently available for environmental management of wetlands), many of the concerns raised and suggestions made by managers will be addressed by the research team through the development and application of a predictive tool, and by focusing more on communication between researchers and managers.

Specifically, a key message from managers during the workshop was that they would be unlikely to be able to deliver an 'ideal' water regime (e.g. optimum timing, volume, rate or frequency of water delivery) to wetlands because of the diversity of constraints placed upon them. As a result, the research team was asked to focus on the development of a predictive tool that would allow managers to compare and contrast a range of suboptimal wetland inundation strategies and determine which is most likely to achieve their objectives. Further, discussions and survey results related to the adaptive management of wetland inundations indicated that, although the adaptive management model was broadly agreed as the most appropriate, resource and expertise constraints most commonly limited its application. Here the research team was asked to consider actively participating in data collection, collation, and knowledge transfer between researchers and managers so that future wetland management activities could be undertaken within a consistent framework suitable for comparison across a variety of spatial and temporal scales.

As a result of these discussions, the research team has begun designing and populating a Bayesian belief network suitable for use as a predictive tool. By considering a range of native and exotic fish species, the tool aims to provide managers with a probabilistic assessment of fish population responses to a number of different wetland watering strategies so that they may be compared. It is envisaged that managers will be able to use the tool to ask questions about an individual wetland such as 'What effect might delaying watering by two months have on fish response?', or 'How might the fish response change if we delivered water through a regulator rather than through a pump?'. It is also envisaged that such a tool could be used to help prioritise or determine which sites might receive water by comparing the expected fish population responses in a number of wetlands. Alternatively, where water is being delivered to wetlands for other 'non-fish' objectives, the tool might also be used to assess the effects of altering the mechanism or timing of water delivery so that increased benefits to fish might be achieved.

The Bayesian belief network that forms the basis of such a tool requires a large data set if it is to be effective, and its efficacy is further improved if data is collected in a uniform way. Thus the research team plans to work with managers to trial the use of the network as a basis for an adaptive management program. The strength of such an approach is that it will facilitate much greater interaction between researchers and wetland managers during all stages of the adaptive management cycle. Managers would benefit from greater access to the best available information (including consideration of relevant data collected from outside their jurisdictions), while researchers will gain a more realistic understanding of wetland management issues and an improved ability to sample wetland systems in more meaningful (and comparable) ways.

Such a use of the predictive tool also addresses the need for improved communication between managers and researchers — another key message from both parties during the workshop.

Although this workshop provided a good start, we aim to further enhance the flow of information between managers and researchers through the establishment and use of a wetland demonstration site, and also through more regular communication of project outputs and outcomes to the wetland manager group. Finally, the research team has committed to undertake a similar workshop at the end of the project. This workshop will introduce managers to a working model of the predictive tool, and provide guidance on appropriate monitoring protocols. It will also measure the success (or otherwise) of the project in addressing the issues raised at this workshop, and will outline plans for the ongoing management of Murray–Darling Basin wetlands for the benefit of native fish.

Actions

- The research team will work with managers to develop a predictive tool (Bayesian belief network) that will facilitate the comparison of likely fish response to a range of wetland watering strategies.
- The research team will develop monitoring protocols that demonstrate the ecological benefits of wetland watering.
- Using the above tools and an adaptive management approach, the project team will work with managers to collect and interpret data from current wetland management activities. Data collected will be used to populate and improve the accuracy of the predictive tool.
- A wetland demonstration site will be established and operated as a means of communicating the findings of this project to managers and the broader public.
- Project outputs and outcomes will be communicated to the wetland manager group on a more regular basis.
- A similar workshop will be held at the end of the project to measure the success (or otherwise) of the project in meeting the challenges outlined by this workshop, and to define a way forward for the management of wetland fish in the Murray–Darling basin.

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