Inland waters

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Key messages

- ✻ Australia has unusual inland water ecosystems, particularly within arid and semi-arid parts of the continent, which are characterised by boom-and-bust extremes in water availability.
- ✻ Inland water ecosystems and groundwater-dependent ecosystems are vulnerable to change in water availability, caused by extraction of water for human uses.
- ✻ Solutions to declining freshwater biodiversity include a more sustainable balance between water allocated to the environment versus other uses, habitat restoration in rivers and streams, and management strategies to control invasive species.
- ✻ Australia is a world leader in policies for water resource management, including environmental flows.

AUSTRALIA'S INLAND WATERS

In one of the world's most arid continents, Australia's inland waters support a rich diversity of life. Biodiversity is enhanced by the gradual change in the climate from the northern tropics, through a dry interior, to temperate zones in the south. Australia's inland waters are further characterised by variability, which has shaped ecosystems over millennia and, more recently, driven human development to manage water resources. Significant numbers of plants and animals are dependent on inland water ecosystems, either fully or periodically, during at least part of their life-cycles. These species include fishes that live in rivers or lakes, waterbirds that forage and breed in wetlands, and floodplain eucalyptus trees that require periodic inundation by floodwaters.

Australia receives an overall average of 417 mm of rainfall per year; however, the wide variation in rainfall across regions governs the nature and character of inland waters and their biodiversity.[1] Inland water ecosystems include lakes, rivers, floodplains and wetlands, as well as waterbodies in rock cavities deep below the Earth's surface. Some inland waters, especially the waterbodies in rock cavities, depend on groundwater (i.e. water held beneath the Earth's surface in soil-pore spaces and in the fractures of rock formations) to maintain their ecosystems. Inland waters may be fresh or saline. Some water bodies have natural salt concentrations with salinities greater than that of sea water (described as 'hyper-saline'). For example, Victoria's largest natural lake, Lake Corangamite, is naturally hyper-saline.

This chapter looks at this wide range of ecosystems and the management challenges that they present.

Australia's inland water ecosystems, such as this billabong in Kakadu National Park, Northern Territory, support a rich array of biodiversity. Photo: John Coppi, CSIRO.

Dynamics of change: boom and bust

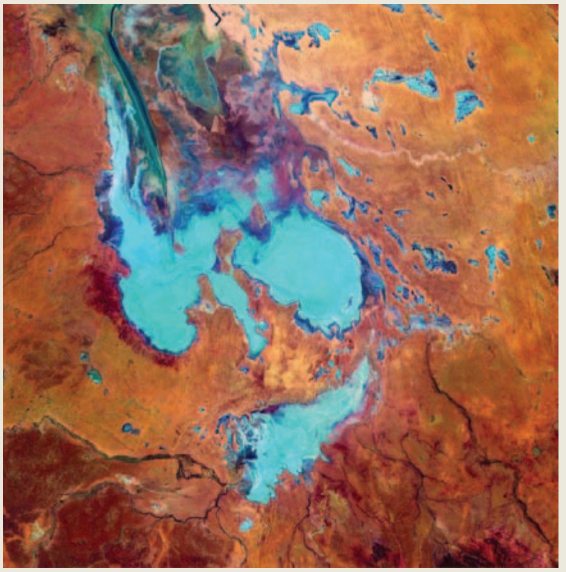
As we have seen earlier (Chapter 2), Australia's climate is inherently variable. Hence, inland rivers are freshwater systems of low water-yield but of high variability. For example, in dry periods the Paroo River of New South Wales contracts to a series of waterholes and lakes, but large floods can inundate approximately 800 000 ha. In boom periods, thousands of small creeks feed large wetlands or lakes and vast floodplains fill. The watercourses formed during these periods eventually dry out into meandering braided channels, billabongs and waterholes, exchanging nutrients through the landscape and creating a series of habitats for plants and animals while doing so. The extent of this variability is extreme compared to most of the world's river systems (Box 10.1).

Our aquatic ecosystems have adapted to the dynamics of 'boom and bust', of extreme dries and wets. Most of the habitat that the floods create is fleeting. Some species use these areas and the resources that they offer opportunistically, whereas others rely on the persistence of freshwater refuges for their entire life-cycle. Many fishes use the floodplain as nursery areas for their young; species of frogs that have persisted in burrows during the dry engage in a frenzy of reproduction; and waterbirds migrate long distances to collect in colonies. The inevitable busts follow, extending much longer than the flush and reducing the rivers to disconnected waterholes.

Box 10.1: Kati Thanda–Lake Eyre – epitome of boom and bust

Kati Thanda–Lake Eyre is the fifth-largest terminal lake in the world. It occurs in a region where evaporation far outweighs precipitation. and covers 9690 km^2 of mainly dry salt-pan until the rivers and creeks flood its surface. The boom and bust nature of the region drives the ecology of Kati Thanda–Lake Eyre. Few animals or plants tolerate the extreme salinity of Kati Thanda–Lake Eyre but, given enough fresh water, an explosion of life is triggered. Warm water and the growth of phytoplankton provide ideal conditions for millions of invertebrates to proliferate, and soon the fish and waterbirds arrive.

In 2009 Kati Thanda–Lake Eyre flooded. The lake system provides an end point for channel flows, food web processes and primary production, supporting fish populations and, finally, more than a million waterbirds. Human use of some resources is also ephemeral, with graziers using the surrounding areas for cattle in the boom times, moving them out during the downturns. By 2012 the lake dried to form a series of creeks and pools.



Satellite image of Kati Thanda–Lake Eyre filling. Photo: Goddard Space Flight Center's Landsat Team and the Australian ground receiving station teams.[2]

Floodplains: productive systems

Inland river ecosystems are much more than just the main river channel. They are made up of extensive floodplains, formed when the river breaks its banks and flows over low-lying land, including channels, lakes, billabongs, wetlands and waterholes. Floodplains can comprise over 90% of the riverine ecosystem and are fundamental to its functioning. The flow in an inland river creates a diversity of habitats, first as it expands and then as it contracts and breaks up into fragments of differing sizes and durations.

Carbon is supplied into floodplains during wet phases, and because it provides an energy source it supports the biodiversity of soil and, in turn, the working of the entire ecosystem. Flooding must occur sufficiently often to replenish the soil carbon in floodplains, and subsequently to carry it along rivers to other places. Dams on inland rivers have interrupted this cycle, however, as they 'capture' floods and restrict inundation. When the irregular but reliable flood regime is lost, many floodplain plants are gradually replaced by more dry-tolerant species. As a result, the floodplain shrinks, biodiversity declines and floodplain productivity is reduced. These impacts can have surprisingly widespread ripple effects, such as those felt by woodland birds (Box 10.2).

Box 10.2: Woodland birds and their sensitivity to altered flows

Flooding affects woodland birds through primary productivity, habitat quality, or open water for drinking.[3] Declines among woodland birds are due to habitat loss, fragmentation and degradation, and they are further influenced by changing flood regimes and subsequent loss of floodplain productivity. Richness, diversity, abundance, density and breeding numbers of woodland birds are significantly greater in floodplains and riparian zones compared to 'dry' non-floodplain and agricultural environments.

For example, a study in the Murrumbidgee Catchment of New South Wales found that floodplains support greater abundances of birds. Regions irrigated at low to medium intensity may also provide significant habitats for woodland birds, particularly during drought periods. These benefits are probably mediated by positive vegetation responses to greater water availability from higher groundwater tables. However, in areas of high-intensity irrigation there were negative effects on woodland birds, including an increase in the abundance of feral species such as starlings, *Sturnus vulgaris*, and competitive natives such as noisy miners, *Manorina melanocephala*.

Apostlebirds, Struthidea cinerea, *at Yanga National Park, New South Wales. Photo: Heather McGinness, CSIRO.*

Groundwater: the hidden resource

Groundwater is often overlooked despite being important in the water cycle. Groundwater-dependent ecosystems are geographically small, yet they are an important part of Australian biodiversity. Groundwater-dependent ecosystems are frequently connected to surface waters. In perennial rivers, such as the Daly and Roper rivers of the Northern Territory, permanent base-flows are maintained by groundwater inputs during the dry season. Base-flows allow fishes to persist through the dry season, and are important areas of production for aquatic invertebrate animals.[4]

Groundwater-dependent ecosystems may also be isolated from surface waters, occurring instead as subterranean water-filled cavities in limestone or fractured rock. Here they are often inhabited by mysterious animals found in no other ecosystem, known as stygofauna (see Chapter 2).[5]

Although groundwater-dependent ecosystems may be out of sight they contribute to economic, cultural and scientific values. All Australian governments now require water plans to recognise the ecological value of water, including groundwater.[6] Groundwater may be heavily relied upon for water extraction but the impacts of this may not be manifested until too late to undo any harm. Characterising these impacts represents a gap in knowledge, one important contribution to which is the *Atlas of Groundwater Dependent Ecosystems* released by the Bureau of Meteorology.[7]

Australia's endemic biodiversity of inland waters

A notable characteristic of inland water biodiversity is the high proportion of endemic species – those species restricted in their geographic ranges such that they are only found in certain catchments. Endemic species are often the focus of conservation because their loss in one region cannot be replaced from populations living elsewhere. Endemism is characteristic of many groups, including crayfish, mussels, stygofauna and frogs. For example, 94% of our frog species are found only in certain inland ecosystems – the highest rate of endemism among Australia's vertebrate species.[8]

The New Holland water-holding frog, Cyclorana novaehollandiae. *Photo: Danial Stratford, CSIRO.*

The number of native Australian inland fishes is relatively small (about 280) in comparison to other continents (South America 2000, North America 600, and Africa 1400).[9] However, approximately 70% of Australian inland fish species are endemic; further, they show unusual adaptations to highly varying environmental conditions. The highest endemism is found among the central, southern and western basins that are characterised by aridity and long-term isolation.

WATER RESOURCE DEVELOPMENT: ADAPTING TO A VARIABLE ENVIRONMENT

Aridity and variability in rainfall had a profound influence on the last two centuries of Australian history, resulting in efforts to secure water supplies by manipulating flows. Water remains today among the natural resources most highly sought after by humans. Irrigated agriculture is reliant on both surface water and groundwater resources, using storages, canals, pipes and channels to offset climatic unpredictability. Consequently, throughout Australia there are now multitudes of water-control devices including locks, floodplain levee banks, and dams. Many lakes, rivers, wetlands, and groundwater ecosystems have been altered as a result of water development. Many rivers are now 'working rivers', in which natural flows have been reduced and which have been turned into delivery systems for human use of water (Box 10.3).

On average, across the continent only 6% of water resources are consumed each year.[1] However, the highly uneven distribution of these resources and their use by people results in some inland waters being fully or over-allocated, while others remain undeveloped. Most irrigated agriculture occurs in the south in areas where run-off happens naturally to be lower (Figure 10.1). The highest use of surface water occurs in smaller water supply catchments around cities. In the Murray–Darling Basin, on average, 48% of surface water is extracted each year, whereas consumptive water use in coastal basins draining northern Australia is frequently less than 5%.

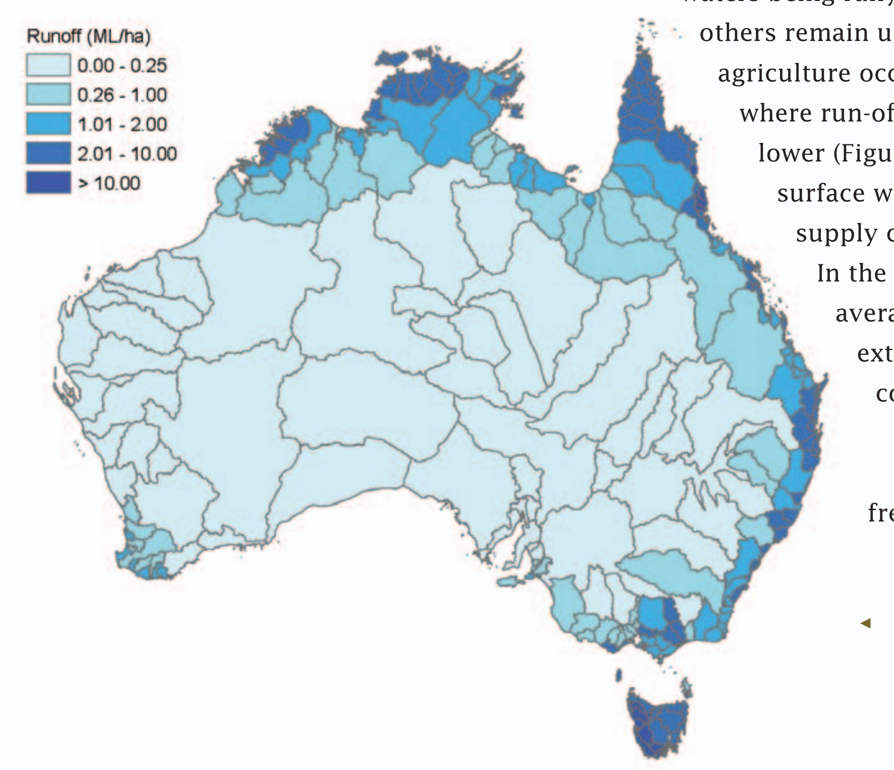


Figure 10.1: *Annual average distribution of run-off from each drainage division in 2004–05, with lines indicating catchment boundaries.*[1]

Box 10.3: The Murray–Darling Basin – a history of development

Dams were built on the Goulburn, Murray and Murrumbidgee rivers early in the 20th century to meet the needs of irrigation. Dam-building then moved to more northern and inland rivers, and finally into upper catchments after the 1950s (the last in 1995). Dams in the Murray–Darling Basin have the capacity to hold around 25 000 gigalitres, which is about one year's run-off, and consequently flow regimes are highly modified. Today, irrigation in the Basin contributes to 60% of Australia's agricultural production.

The storages are designed to smooth the year-to-year variability of flows in the system and provide more consistent delivery to water users. Combined with water extractions, smoothing has reduced the total volume of flows, thereby reducing the seasonality, frequency and duration of wet and dry cycles. These changes have profoundly affected the ecology of the Basin, including loss or alteration of wetlands; decline in extent and condition of vegetation on floodplains; decline in the abundance and diversity of native fishes, invertebrates and waterbirds; reduction in water quality; and invasions of non-native species.

In response, policies aimed at re-balancing over-allocation of water and in rehabilitating ecosystems have led to significant investments in the purchase of land and water entitlements and in infrastructure to deliver environmental water. The *Water Act 2007* states that the Murray–Darling Basin Plan must 'promote sustainable use of the Basin water resources to protect and restore the ecosystems, natural habitats and species that are reliant on the Basin water resources and to conserve biodiversity'. One of the challenges in water resource planning has been the paucity of scientific knowledge to establish ecological requirements for and to predict consequences of environmental flows.[10]

Cataract Dam and Reservoir, New South Wales. Photo: Gregory Heath, CSIRO.

Unlike the Murray–Darling Basin, water resources in northern Australia are relatively lightly exploited. Northern Australia contains more than 50 major rivers and many hundreds of smaller streams. Freshwater ecosystems are diverse, supporting at least 170 fish species, 150 waterbirds, 30 aquatic to semi-aquatic reptiles, over 60 amphibians and over 100 macro-invertebrate families.

Planning for water resource developments is underway, although many gaps remain in scientific knowledge.[11]

Aboriginal ecological knowledge

Use of Australia's inland water extends back tens of thousands of years. Aboriginal lives often centred around waterholes or wetlands, which provided resources of food and shelter. A rare example of Aboriginal use of inland water resources remaining in irrigated catchments is the Brewarrina Aboriginal fish traps (*Baiame's ngunnhu*), a complex arrangement of stone traps, channels and rock walls covering 400 m of the river bed. The fish traps are believed to be as much as 40 000 years old, and they demonstrate an intimate knowledge of the behaviour of fish. Inquiry into Aboriginal water values and traditional knowledge of the ecosystem is increasingly important in managing water.[12]

A section of the Brewarrina Aboriginal fish traps. Photo: Bradley Moggridge, CSIRO.

Challenges to biodiversity of water resource development

The most important variable to explain challenges to inland water biodiversity is water movement – hydrology.[13]

Changes to water flows

Many of Australia's rivers are affected by activities that disrupt hydrologic regimes and the ecological processes stemming from natural wetting and drying cycles. Changes in flow that exceed the environmental bounds – and consequently the reproductive requirements of many species – ultimately lead to changes in biodiversity. River floodplains are particularly vulnerable to change, especially in arid regions.[14]

Habitat loss, degradation and fragmentation

The timing, amount and quality of water are the principal factors influencing persistence of habitats essential to water-dependent species. Habitat fragmentation occurs when weirs, dams, pipes, regulators and irrigation diversions prevent dispersal or access to breeding habitats. For example, an estimated 10 000 dams and weirs are located on main channels in the Murray–Darling Basin, hindering the passage of fish to feeding, spawning, or sheltering habitats and diminishing their ability to recolonise after droughts or high flows.

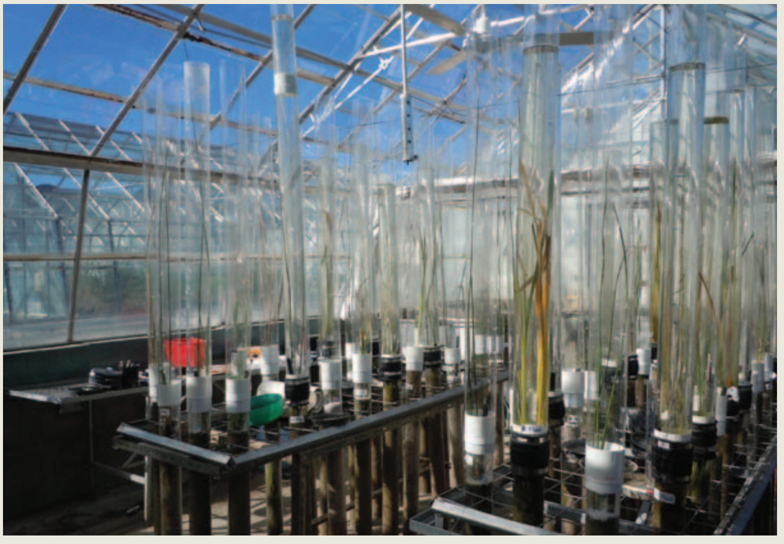
Invasive species

The best-documented example of non-native invasive species in inland waters is the fishes of the Murray–Darling Basin. Populations of the 46 species of native fish are now at about 10% of the numbers present before European settlement.[15] Twelve non-native invasive fishes now inhabit the Basin, with European carp, *Cyprinus carpio*, and red-fin perch, *Perca fluviatilis*, predominating. Carp alter habitats and productivity by destroying aquatic plants, increasing water turbidity and disrupting the feeding of native species, while red-fin perch eat the smaller native fish. Other invasive species are native, where one species dominates another due to changes in habitat (Box 10.4).

Box 10.4: Invasive species, changes in flow and habitat loss

The Barmah–Millewa Forest is a floodplain located on the Murray River. A dam has substantially altered the natural flood regime, resulting in changes to the flora and fauna of the forest. One major change is the loss of semi-aquatic grasslands dominated by moira grass, *Pseudoraphis spinescens*, a significant habitat for colonially-nesting waterbirds. Moira grass has been replaced by the native invasive giant rush, *Juncus ingens*, which forms dense monocultures. Even after recent prolonged floods, the invasive rush still dominates, suggesting a possible permanent transition in vegetation.

The strategy for management is to use environmental flows to restore the degraded floodplains. However, the flood requirements of these two key species are little known, so research is being undertaken to determine them and to explore whether the transition to giant rush is permanent.



Determining water requirements of giant rush using glasshouse experiments. Photo: Lyndsey Vivien, CSIRO.

Measuring water properties during a blue-green algal bloom in Chaffey Reservoir, New South Wales. Photo: Brad Sherman, CSIRO.

Climate change

Southern Australia is likely to experience more frequent and intense droughts in future, whereas northern Australia is predicted not to be so affected. The rate and magnitude of climate change are likely to outpace adaptation by inland water species and ecosystems, but there is comparatively little known about the consequences for biodiversity.[16]

Use of natural resources

Inland waters are embedded within ecosystems subject to varying uses and, as a result, management can profoundly influence the quantity and quality of their waters. Erosion of soils in agricultural catchments can cause sediment run-off into streams, changing turbidity and habitat for aquatic organisms (see Chapter 7). Nutrient run-off can lead to blooms of nuisance algae, causing fish kills and rendering water unsuitable for human use. These are also affecting the Great Barrier Reef (Chapter 3). Land clearing and infilling of wetlands are all past legacies with lasting impacts on the biodiversity of inland waters.

MANAGEMENT OF INLAND WATER BIODIVERSITY

Three advances in water management are notable for their successes and future potential.

Environmental water management in over-allocated catchments

Competing demands for water make it necessary to provide a share of water for the environment in order to halt decline. The National Water Initiative is the blueprint for water reform in Australia. It was signed by the Council of Australian Governments in 2004, and confirmed in legislation by the *Water Act 2007*. Environmental water holdings are now in place for many water-stressed catchments, and environmental flows are used to mimic components of natural variability in magnitude, frequency, seasonality, duration and sequencing of flows. Many environmental objectives can thereby be met:

- Providing breeding opportunities for water-dependent plants and animals
- Creating or prolonging connection of rivers, floodplains and wetlands to promote migration of flora and fauna, ecosystem diversity and ecological functions
- Maintaining refuges during extreme drought.

Adaptive management is essential for complex and inherently variable ecosystems, where change and outcomes are difficult to predict. Field-studies of environmental watering are necessary for management actions to be adjusted over time, via testing against the best available knowledge through sound scientific monitoring, and then iterative review and refinement. The Paika Lake example demonstrates adaptive management in practice (Box 10.5).

Box 10.5: Adaptive management of environmental flows

Paika Lake is located in the Murrumbidgee Catchment of New South Wales. Paika Lake and surrounding local wetlands had been isolated from flooding for over 100 years, being disconnected from the Lowbidgee floodplain by levee banks and roads. Restoration of water to Paika Lake and surrounding wetlands began in 2011. Opening up the historical flows has resulted in the arrival of 20 000–40 000 waterbirds of over 35 species, including three threatened species, the blue-billed duck, *Oxyura australis*, freckled duck, *Stictonetta naevosa*, and Australian painted snipe, *Rostratula australis*. Environmental water has also benefited river red-gum forest, and adjacent to the wetlands seedling regeneration is abundant. The wetland responses are now being used to inform continuing land and water management, demonstrating adaptive management in action.[17]

Automatic time-lapse images showing the same view two weeks apart at Paika Lake, New South Wales. Time-lapsed images enable monitoring of changes in inundation and resultant responses by vegetation and birds. Photos: Heather McGinness, CSIRO.

Adaptive management requires monitoring to understand the outcomes of decisions, to improve the state of knowledge and to inform the next step in decision-making (see Chapter 4). Monitoring can be expensive and limited in scope. Advanced genetic techniques, termed 'metagenomics', can help us explore the diversity of organisms in complex environments and improve understanding of the effects of management. Bacteria and animals living in the sediment leave behind traces of their DNA and metagenomics can be used to read the sequences of the DNA to identify thousands of organisms. Bacteria are the worker bees of the soil: they cycle carbon and nutrients, and so any disruption to these processes can affect the functioning of ecosystems. A study of soils in a river red-gum forest of the Murrumbidgee River found a rich diversity of animals and plants, with over 2500 different organisms identified.[18] Many of them had been subjected to 10 years of drought, and at some sites this had been followed by inundation for a year. Survival through the extremes of drought and flooding demonstrates resilience of these largely invisible components of biodiversity.

Habitat restoration for floodplains and wetlands

Some land management practices in agriculture have left a legacy of erosion, altered water quality, changes to riparian plant communities, and loss of native aquatic plants and animals. Now, multi-million dollar investments are being made to improve aquatic ecosystems and to ensure their sustainable use. One of the most significant environmental problems in irrigated catchments is salinisation. Salt is naturally present in many landscapes, and dissolved salts are brought to the surface by rising groundwater levels that result from the removal of the native vegetation that originally kept the water table low, and also as a consequence of some farming practices. Management strategies include the use of salt-tolerant plants; planting of deep-rooted crops and pastures; revegetating with native plants; engineering to divert saline waters (Box 10.6); and prevention of further clearing in vulnerable areas such as groundwater recharge zones.

Fenceposts on an expanse of salinised land in the Western Australian wheatbelt, near Meckering. Photo: Willem van Aken, CSIRO.

Box 10.6: Managing salinised floodplains

The Bookpurnong floodplain of about 1800 ha lies next to the River Murray in South Australia. Irrigation has led to greater salinity at the soil surface and in the aquifer, and to manage this problem a salt interception scheme was built in 2007 to protect and rehabilitate the river and floodplain. Field trials were conducted to explore the effectiveness of different options for managing the salinised floodplain. The study demonstrated that the benefits of the interception scheme were localised, and that a long-term systems-based approach to management is needed.[19]

Management of vegetation on the floodplain needs to consider both surface waters and groundwater, such that inundation can replenish and freshen soil and the saline aquifer. Single inundations result only in a temporary improvement in vegetation condition; consecutive inundation is needed for sustained groundwater freshening and for continual removal of salt from the root zone. Groundwater management can improve tree health by increasing recharge to maintain the low-salinity water that floodplain trees rely on between floods.

Dead trees on Bookpurnong floodplain. Photo: Arthur Mostead, Murray-Darling Basin Authority.

Management of riparian zones is an effective way of restoring biodiversity in the broader landscape. Through such management, sediment and nutrient run-off can be reduced, channel erosion prevented, shade provided to a stream for temperature control, and wildlife corridors re-established in fragmented landscapes. Riparian zones are highly productive, and act as refuges during droughts and as protection from fires. Restoration of riparian zones is becoming a collective effort involving farmers, landholders, community groups, regional natural resource management organisations, government agencies and industry bodies.[20]

Managing invasive species

Invasive species – mostly non-native – compete for or destroy habitat and food resources. In Australia, there are at least 65 non-native aquatic plants. Tropical rivers are vulnerable to invasions of mimosa, *Mimosa pigra*; rubber vine, *Cryptostegia grandiflora*; and *Parkinsonia aculeata*. River systems have been affected by weeds, including water hyacinth, *Eichhornia crassipes*; lippia, *Phyla canescens*; willows, *Salix* species (Box 10.7); and alligator weed, *Alternanthera philoxeroides*.[21] Hydrologically disturbed wetlands are more likely to have fewer species of native plants and higher incidences of invaders.[22]

There are at least 20 species of introduced fishes in Australia inland waterways.[20] In a recent audit of river health in the Murray–Darling Basin, the European carp, *Cyprinus carpio*, made up 60% of the total biomass.[23] Other vertebrate pests in Australian river systems include the cane toad, *Rhinella marina*; feral pigs, *Sus scrofa*; water buffalo, *Bubalus bubalis*; and banteng cattle, *Bos javanicus*.

Although many invasive species are introduced, native species such as the giant rush (Box 10.4) can be also opportunistic invaders. Another example is cumbungi, *Typha orientalis*, which is an invasive in Western Australia, but is native to eastern Australia.

Box 10.7: Weeds and water savings

Willows are non-native invasive trees of many waterways and wetlands in south-eastern Australia, including Tasmania. They form large, dense, shallow root masses that invade riparian ecosystems, out-competing native vegetation and occupying stream beds. Willows slow stream flow, increase flooding, and consume large volumes of water. They propagate vegetatively, twigs being able to grow into new trees at new sites. Programs of removal have been undertaken over decades with varying success. Experience shows that without revegetation of a recently cleared area and ongoing rehabilitation, willows may re-invade.

Water use by willows is large: studies show that more than five and a half megalitres of water could be saved annually for every hectare of willow canopy removed (for trees in-stream with permanent water). The evaporative loss of 1 ha of willows is enough for about 17 households each year. A comparative study on the same watercourse showed that replacement of willows by native vegetation could lead to maintenance of the annual water savings, with water use by eucalypts being approximately one-third that of the willows.

The public company Water for Rivers (an initiative of the Commonwealth, New South Wales and Victorian governments) recently removed 170 ha of willows in north-eastern Victoria and 50 ha in the Yanco Creek, Murrumbidgee, Yass and Murray rivers. This removal has returned 1200 megalitres of water a year to these river systems. At a market price for high-security water of $2000 per megalitre, the five and a half megalitres per hectare per year used by willows is worth about $2.4 million.[24]

Riparian area invaded by willows. Photo: Tanya Doody, CSIRO.

NEXT STEPS

Australia is one of few countries in the world with a strong policy framework for the effective management of river systems. There is growing community understanding of the link between water use and declining ecological health of inland rivers and their floodplains. Extensive areas of suitable land and ample water resources will remain under high demand and have been identified for expanding irrigated agriculture and mining activities, particularly in northern Australia.

Experience teaches us that water reform in over-allocated catchments is contentious, costly, and dependent for success on informed debate. Science helps here by underpinning rehabilitation and restoration, drawing upon knowledge of climate, flow regimes, genetics, movement patterns, water requirements and ecological processes. Despite significant investments, there remains limited information on inland water ecosystems and even less regarding groundwater-dependent ecosystems.[25] Research is underway to improve knowledge of drivers of ecosystem change, in monitoring technologies, and in development of predictive tools to assist decision-makers.

Whether considering a freshwater system already altered or one that is planned for development, decision-makers should have access to information and knowledge of water availability and biodiversity. Enhancing and promoting individual and community participation in decision-making for water resource management is among the most effective ways of achieving conservation, rehabilitation and sustainable management of inland waters.

FURTHER READING

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