Water for the environment

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Key messages

- Aquatic and water-dependent ecosystems require surface water flows or access to ground water to survive. They include Australia's highly valued rivers, lakes, floodplains, wetlands, and estuaries.
- Regulation of rivers with dams and weirs and the extraction of water from rivers and groundwater threatens the viability of these ecosystems, many of which are now degraded.
- To function properly, these ecosystems and the species in them require not just adequate volumes of water but the right seasonal pattern and variety of conditions.
- Providing water for consumption while providing for ecosystems often involves trade-offs or compromises. A good understanding of the condition of ecosystems under different regimes of water use, can help make these trade-offs transparent and identify ways to reduce them.

Rivers, wetlands, lakes, and estuaries have become degraded from water extraction and the regulation of river flow using dams and weirs. Water-dependent ecosystems have specific water requirements to keep them viable, and Australian governments have committed to deal with the environmentally unsustainable levels of water use – termed over allocation.[1] Water can be provided for the environment by limiting its use and by other regulations built into water plans and the operation of dams and rivers. Alternatively, water entitlements are bought and managed specifically for the purpose of improving environmental outcomes. By reducing levels of extraction, environmental water provision is often in conflict with other uses, most acutely in the heavily used, but highly valued, rivers of the Murray–Darling Basin. Environmental water management is becoming more formalised, with ambitious goals and involving significant trade-offs with other uses, so it is important to understand the water needs of these ecosystems and how they can be met. A key element of this is transparency on the ecological outcomes or targets that will be achieved by returning or keeping specific allocations of water for the environment.

Aquatic and water-dependent ecosystems include rivers, lakes, floodplains, wetlands, and estuaries that depend on surface water flows or ground water to sustain their characteristic biota. As described in Chapter 2, these water ecosystems are of great value to many Australians. They provide important aesthetic, recreational, and cultural benefits that are part of our national identity. Water environments provide valuable services such as good water quality and habitat for plants and wildlife, and they provide direct economic support for tourism and fishing industries. For Indigenous people, water environments have a strong religious value that is intertwined with environmental and livelihood values.

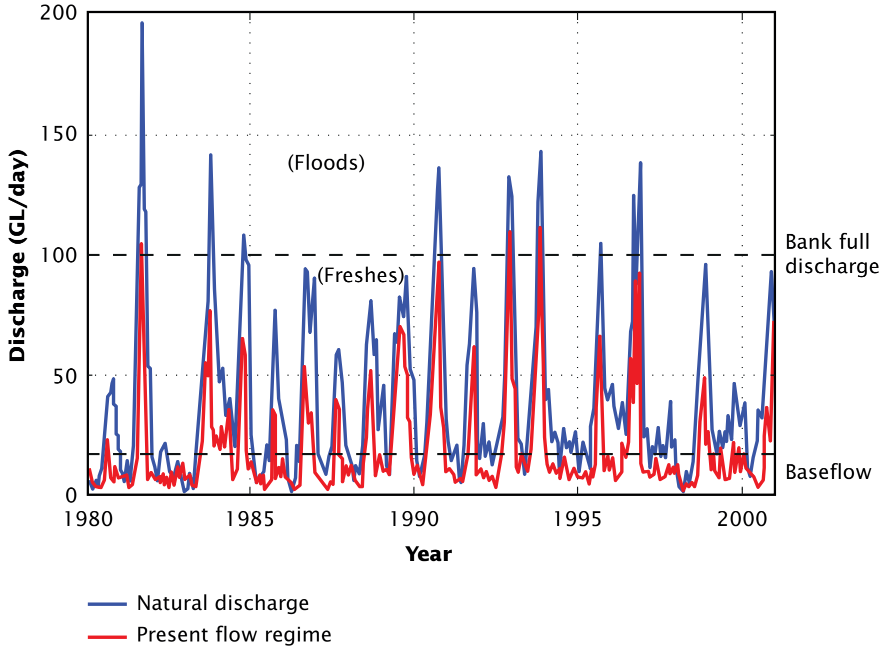
There are several threats to water-dependent ecosystems, including direct habitat destruction to make way for other land uses, decline in water quality, and the proliferation of pest species of water plants and animals (such as carp and cane toads). One of the largest threats is the impact of water use and water resource development on the flow regimes of rivers. Water supply infrastructure – such as dams and weirs – removes water from rivers, and regulates discharge downstream, altering the patterns of floods and seasonal flows that the ecosystems need. Ecosystems naturally survive droughts and floods, but the changes in flow regime resulting from water use and flow regulation artificially extend or intensify the droughts that some ecosystems, such as floodplain ecosystems, experience, putting them under increased stress (Figure 9.1). Even in rivers unregulated by dams, and in groundwater aquifers, high rates of water use can reduce the amount of water available to support ecosystems and threaten the benefits they provide. Levee banks and other structures on floodplains can isolate wetlands and forests from the floodwaters they require.

The challenge in managing water resources for multiple uses is to provide sufficient water to the environment to sustain ecosystems and maintain water quality while ensuring efficient and effective use of extracted water.

The condition of aquatic ecosystems

Despite their high value, water-dependent ecosystems are under threat across the world.[2] Over half of the world's largest river systems are moderately or strongly modified by dam construction, flow regulation, and water use, and half of the world's wetlands have been lost, but unevenly across countries.[3] Freshwater populations of vertebrate species were reduced by half between 1970 and 2005, which is a sharper decline than observed in marine or terrestrial ecosystems.[4]

Australia does not have a comprehensive inventory of the distribution or condition of freshwater ecosystems, despite this deficiency having been previously noted.[5,6] Major loss of habitat has been observed, but the exact loss of ecosystem values and species cannot be determined. It is important for conservation to know the status of the remaining ecosystems. Across the 40% of the continent that is most intensively used, over 85% of the rivers have been



▲ ***Figure 9.1**: Flows in the Murray River at the South Australian border with Victoria illustrating how the present flow regime compares with natural flows. River regulation and extraction of water upstream have reduced the frequency and size of floods that exceed the bank full discharge and spill into wetlands and floodplain forests. For the 21-year period shown, flows would have exceeded bank full discharge and wetted floodplain in eight years under natural conditions but under water regulation the floodplain only received water in three years. Volumes of water spilling to the floodplain were also far less than would have occurred naturally. The longest gap between floodplain watering events in this period would have been six years under natural flows, but it was eleven years under the present regime. The character of base flows has also changed, with the summer season of low flows now being longer and with a lower discharge than under natural conditions because of upstream extractions.*

degraded by human activity to some extent.[7] In the Murray–Darling Basin, 20 of the 23 rivers were rated in 2008 to be in poor or very poor ecological condition.[8] Populations of native fish in the Basin have declined significantly over the past 50 years, with fish communities currently reduced to about 10% of their pre-European levels.[9] Now more than half of the 35 native fish species in the Basin are considered threatened or rare under state, territory, or Commonwealth listings and exotic species make up 56% of the total fish biomass in the lower catchment.[10] Approximately 50% of Australia's wetlands have been lost to other uses, including 90% of floodplain wetlands in the Murray–Darling Basin, 50% of coastal wetlands in New South Wales and 75% of wetlands on the Swan Coastal Plain in the South West of Western Australia[11] and many remaining wetlands are experiencing significant long-term declines in river flows. Associated with the wetland loss is the decline in annual average waterbird numbers across Australia from 1.1 million in 1983 to 0.2 million in 2004.[12] Other important aquatic species, such as many macro-invertebrates and amphibians, have also significantly declined in numbers and distribution.[13]

The flow–ecology link for sustainability

Environmental sustainability requires that populations of plants and animals are self-sustaining. This means providing suitable habitat to ensure that populations can be supported at all stages of their life cycle. Provision of habitat includes food sources for each species, conditions for a species to live, to survive competition with other species, and to breed. Food webs (Figure 9.2) show that species are dependent upon each other through predator and prey relationships. To maintain a viable ecosystems, a relatively stable mix of different types of species is required.

Changes to water flow can change the populations of water plants and algae (primary producers) resulting in complex population changes in higher level organisms that consume them. Higher level predators also exercise top-down control on the unsustainable explosion of populations of lower level organisms, so flows need to be sufficient to cater for all types of organisms in an ecosystem. Natural disturbances, including floods and droughts, help sustain a resilient and diverse community of species where none completely dominate.

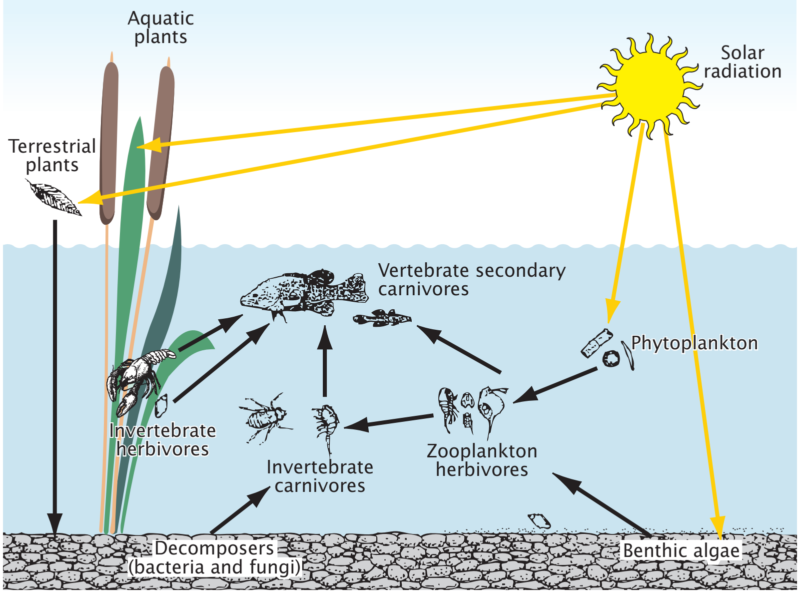


Figure 9.2: Example of some of the food sources in an aquatic food web. Benthic algae, phytoplankton, aquatic plants, and terrestrial plants are primary producers that grow using nutrients and sunlight. They are consumed by herbivorous zooplankton and invertebrates, which in turn are consumed by invertebrate carnivores and fish.

Populations of each plant and animal also need to be large enough and sufficiently dispersed and inter-connected to ensure that localised extinction does not put the whole population at risk. Where populations are isolated, or environmental assets cover a small area, their viability as ecosystems is reduced. The Australian lungfish, part of an ancient group of fish, is only found in the Burnett and Mary Rivers of South East Queensland, for example, and is vulnerable to exposure of breeding habitat as a result of river regulation.

To provide sufficient water for environments, it helps to know how ecosystems of rivers, floodplains, wetlands, and estuaries depend on variations in river flows or discharge of groundwater. The amount of water is important, but so are the patterns of flow, which change with river regulation. Often it is the seasonality of flows, the size of floods, or their duration that triggers organisms to respond or that determines the suitability of habitats. Many Australian waterbirds do not have a seasonal breeding cycle, but are opportunistic, reflecting Australia's unreliable river flows, and only breed when wetlands are inundated for several months.

Water requirements of rivers

Rivers have distinctive flow patterns that create and define a variety of habitats: 'base flows' are slow and steady; 'freshes' are rises of water level with faster currents, but flows are contained within the channel; while flood peaks spread beyond the river banks to recharge floodplains and wetlands and connect them with the river (Figure 9.3). Each flow level supports a diversity of organisms.

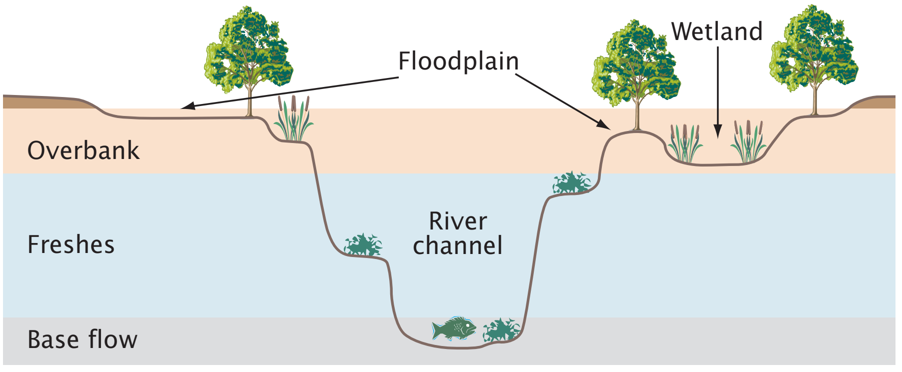


Figure 9.3*: Different river features are inundated at different levels of flow. Overbank flows inundate floodplains and wetlands, and freshes fill much of the river channel with fast flowing water.*

It is important to maintain base flows in rivers, which could dry out or stagnate from upstream extractions. Some flow is required to keep habitats inundated, to supply nutrients and dissolved oxygen, and to prevent smothering from deposition of fine sediment and algae. Flow is also important to maintain adequate water quality. Freshwater flow from upstream is often required in Australian rivers to dilute salt discharges from groundwater. As explained in Chapter 5, although toxic algal blooms are associated with eutrophication, it is the maintenance of flow in a river that can be used to prevent their occurrence.[14] The construction of weirs to increase the depth of water for pumping reduces the velocity of base flows and removes their benefits. It is the interplay of flow, turbulence, and light penetration that is often critical to river food webs as microalgae are a major source of food.[15]


Burtundy Fishway, Darling River, New South Wales. Photo: Kris Kleeman, © MDBA.

Freshes and floods provide signals for some fish to commence breeding. The connection of habitats along a river is also important because it ensures access to different habitats at each stage of the life cycle and allows cross breeding between populations. One of the main impacts of weirs, dams, and other structures has been to prevent fish passage. Fish ladders can overcome this by bypassing these structures, illustrating that flow management should be complemented with other measures. However, many of Australia's smaller fish are unable to pass through fish ladders.

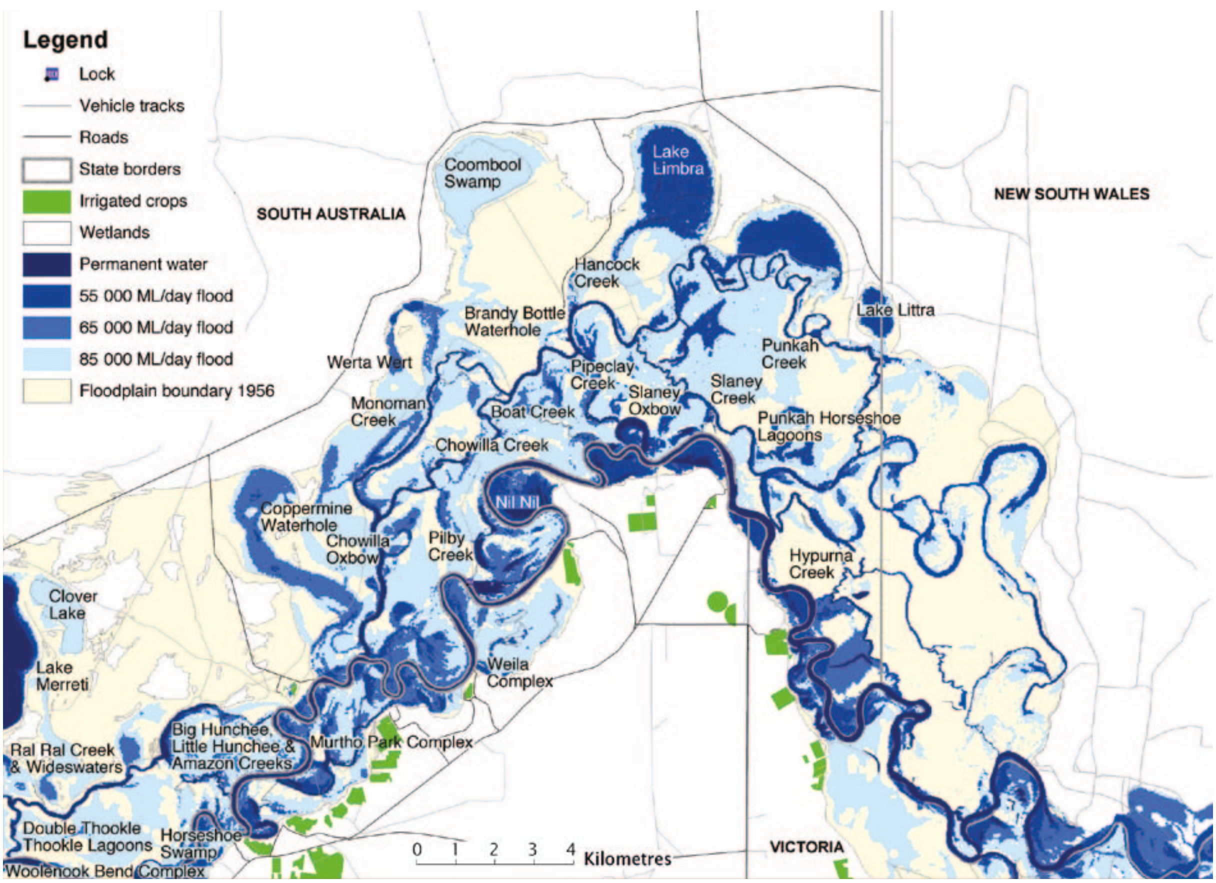
The natural destruction created by floods can renew a river and maintain a diverse range of habitats. High flows are important to shape and clear a river of accumulated sediment, plant matter, and debris. For example, the dam on Lake Jindabyne has been modified in recent years to allow flow to be released down the Snowy River in an effort to reduce the amount of sand that had accumulated over several decades of impounding floods. Floods in the Daly River (Northern Territory) scour out sand from the pools that provide deep, slow-flow habitat for animals and plants that live there during the dry season.

Water requirements of floodplains and wetlands

Floods that overtop river banks inundate floodplains and wetlands, replenishing soils and recharging shallow groundwater aquifers. They provide important connections between the river and floodplain, enabling exchange of sediments, nutrients, algae, fish, and other organisms.

Although floodplains appear flat, subtle variations in topography create habitats of varying frequency and depth of inundation that suit different plants and animals. Only the largest floods inundate the whole floodplain, perhaps once every few decades. At lower elevations, and closer to the river, the floodplain may be inundated perhaps once every year (Figure 9.4). Different species are adapted to different flooding frequencies and depths. In the Murray–Darling Basin, river red gum forests are found where floods occur typically every 1 to 5 years, while other species such as black box tends to occur higher on the floodplain where flooding is less frequent. Trees rely on groundwater between floods but evaporation accumulates salt in the floodplain soils. Periodic flooding is required to both recharge the groundwater supplies and flush salt from the soils. A floodplain ecosystem can be reduced greatly in extent when flow regulation reduces the frequency and area of inundation.

In places, the floodplain can cover tens of thousands of hectares and support vast wetlands, such as the Kakadu wetlands adjacent to the South Alligator River in the Northern Territory. Some wetlands have groundwater connections and remain full with water while these connections persist. Others dry out as floodwaters evaporate. Wetlands often have a channel or 'flood runner' connecting them to the river and to each other so they flood as soon as the river height is sufficient to fill the channel, rather than relying on flooding across the whole floodplain. Wetlands are scattered across floodplains, forming mosaics that inundate consecutively at increasing flow heights and have varying frequency, timing, and duration of connections (e.g. in January 2011,



▲ ***Figure 9.4****: Extent of flooding on the Chowilla floodplain for different discharges of the Murray River, as determined from remote sensing and river gauging. A 55 000 ML/day flood inundates small areas of wetland near the river while an 85 000 ML/day flood inundates extensive areas of floodplain forest as well.*


Black winged stilt, Werribee, Victoria. Photo: John Manger, CSIRO.

Lake Albacutya at the very downstream end of the Wimmera River filled for the first time since 1974). Wetlands are critical habitats for aquatic plants and insects, waterbirds, frogs, turtles, and fish because they retain water for extended periods. Defining the conditions needed by these species locally, regionally, and nationally is complex but continuing research is increasing our understanding of the ecology of floodplain ecosystems.

Connections between river and floodplain in lowland rivers can last for several weeks and stimulate growth of large populations of algae. Some animals such as zooplankton have dormant stages – they reside in floodplain soils and emerge on re-wetting to take advantage of the food resources. Some of this soup of aquatic organisms mixed with terrestrial plant and animal detritus is carried by return-water back into the river, thereby providing food for organisms in the river. These types of rivers are known as 'flood-pulse' rivers because their ecosystems depend more on periodic flooding than on the supply of material from upstream catchments. The connection between river and floodplain in regulated rivers is frequently reduced, depriving them of food. Measurements in the Murray River during the millennium drought suggest the floodplain provided little food to the river and the food webs relied instead on in-stream production by microalgae, leading to an overall depletion of food resources.[15]

Many waterbirds rely on floods to fill large expanses of wetland making them suitable for breeding with appropriate nesting sites and abundant food resources. Some of the most important breeding areas are large shallow expanses that occur towards the ends of inland rivers (e.g. the Macquarie Marshes on the Macquarie River, the Lowbidgee Floodplain on the Murrumbidgee River, and the Coongie Lakes on Cooper Creek). Such extensive wetlands are sometimes drained or protected from inundation by levee banks to convert them to agricultural land; for example, three quarters of the Lowbidgee wetlands have been lost to agriculture.

Water requirements of estuaries

Estuaries are a transitional habitat between rivers and the sea, where variations in salinity are critical to maintaining diverse habitat. Typically, salinity increases from near zero where a river enters an estuary to that of the sea towards the mouth. Under flood conditions, an estuary might be flushed with freshwater all the way to the mouth, but in periods of no river flow the whole estuary may become saline.

Rivers transport sediment, nutrients, and other materials into estuaries stimulating growth of algae and aquatic plants (primary production) and making estuaries highly productive. Because they can support both freshwater and marine species, they also tend to be zones of high biodiversity, and coastal fish use estuaries as nurseries, especially during high river flows. For example, barramundi and banana prawn recruitment in the Fitzroy River (Queensland) estuary is stimulated by high river flows,[16] probably as a result of increased access to refuges and food on an inundated floodplain and increased availability of organic detritus that is used as food for juveniles.

Reductions in river flows, due to upstream water use, can have detrimental effects on estuaries by changing the salinity and mixing conditions. Most of the fish, invertebrates, and plants living in estuaries have optimal salinity ranges and varying salinity imposes a physiological stress on them. Without river flows to mix the waters in an estuary, they can become stratified leading to depleted oxygen concentrations in bottom waters, killing crustaceans, and fish. Such events have occurred in the Swan Estuary, Perth and the Gippsland Lakes in recent years, associated with reduced river inflows. Significant river flows are also required to periodically scour an estuary mouth, keeping it open to the sea and enabling fish and crustaceans to migrate in, as well as flushing salt and nutrients out. Occasional flushing by floods reinvigorates and renews estuaries, ensuring they continue to support a diversity of species.

Managing environmental water

There is a logical sequence of considerations to ensure that adequate water is provided for the environment through water plans and river operations. The details of how environmental water decisions are made vary from jurisdiction to jurisdiction[17,18] but good, transparent plans involve the following steps:

- Identify the sites or environmental assets that are to be protected or restored.
- Describe the desired range, size, and connection of habitats needed to support the ecosystems and set target conditions for them and the biota that they support.
- Assess the volume of water and the patterns of water delivery that are required to support the different habitats and the diversity of dependent biota.
- Ensure the required water is provided for in water plans and operations under foreseeable conditions of climate, water storage levels, and patterns of water use.
- Balance and optimise provision of water for the environment against other uses and values, modifying target conditions and assets protected accordingly.
- Complement environmental water management with other measures such as structural works, catchment management, and control of invasive species.
- Monitor and evaluate the provision of water to the environment and assess the ecosystem response against the targets from the species level up to the integrated ecosystem to adapt management to unforeseen or uncertain outcomes.

Because of the need to maintain regulation and water use, not all features of the flow can be reproduced at their natural frequency, so it is important to know how ecosystems will respond to each flow characteristic. At times there will be inevitable competing demands between water for human use and that for ecosystems so there will be a trade-off, or compromise, of ecological condition to allow use of water while protecting or restoring some ecosystems or some ecosystem values. Many ecosystems are not in a pristine state as a result of loss of habitat from land use, or species numbers have been reduced by other threats such as water quality and pests, so the outcomes of flow will differ strongly from just requiring a natural flow regime to reproduce the natural state of ecosystems. This makes it important to know the likely ecosystem condition for a range of flow regimes so that the trade-offs between environmental condition and levels of use are shown transparently. One of the criticisms of many water plans is that, although they provide water for the environment, the ecosystem assets or values that are to be protected are not clear, so there is little accountability of whether the environmental flows actually meet ecological needs.[17,18]

To undertake these planning processes requires good ecological understanding of the water needs of ecosystems, but it also requires that understanding to be integrated and applied to the practical considerations of water plans, and there are a range of formal techniques to do that. Better use of those techniques can overcome the problems of lack of transparency in the ecological outcomes of water plans.

First, there are a range of techniques to characterise the important features of flow in undeveloped rivers and to identify the missing features in rivers where water is extracted or regulated so that these can be reproduced.[19] For floodplains and wetlands, the flow levels in the river need to be converted to the extent and duration of inundation of flooding. This can be done using aerial photography or satellite remote sensing[20] (Figure 9.4 is an example). Accurate elevation data from laser altimetry and satellite remote sensing is critical to detect the subtle topographic differences that lead to different communities of plants and animals.

Knowing how flow creates habitats is a critical first step, but those habitat conditions then produce a response in the ecosystem, which is the ultimate aim. Understanding the response should consider not just that of individual species (especially indicator or target species), but also the overall ecosystem through food webs and competition between species as determined from experiments and monitoring of ecosystems.[21] Ecological research is producing increasingly good information about the response of species and ecosystems. Although it has been known for a while that waterbirds require wetlands to be inundated for months for successful breeding, there is now evidence that breeding by some species in the northern Murray–Darling Basin can be triggered by 25–30 days of high flow, shorter than the 50 day threshold used elsewhere. The quicker response could be because food is generated more quickly in the northern Basin.[22]

Individual results need to be extrapolated to the broader situations that occur in nature, through a conceptual understanding of how ecosystems function as a whole (such as the flood-pulse behaviour of lowland floodplains described above). Conceptual models are used to group

The Coorong and mouth of the Murray River. Photo: Michael Bell, © MDBA.

similar classes of organisms and describe the various ecosystem functions that can be related to physical features of flow and water quality to provide a basis for extrapolation.

Numerical models of ecosystems can be built if better information is available. They describe the physical environment of ecosystems and ecosystem responses to a changed environment to reveal their condition under different management scenarios. An early example was the Murray Flows Assessment Tool used to underpin the return of water for the Living Murray Program.[23] The study of the Coorong at the mouth of the Murray River, outlined below, is a recent example. Model predictions can be checked over time against observed changes to an ecosystem. They provide a testable hypothesis on how an ecosystem will respond to environmental flow management. When the actual ecosystem response differs to that hypothesised, experiments can be undertaken to refine the concepts behind the model, lead to better ecosystem understanding, and improve targeting of environmental flows. This is the essence of adaptive management and increasingly ecology is being applied through ecosystem models.

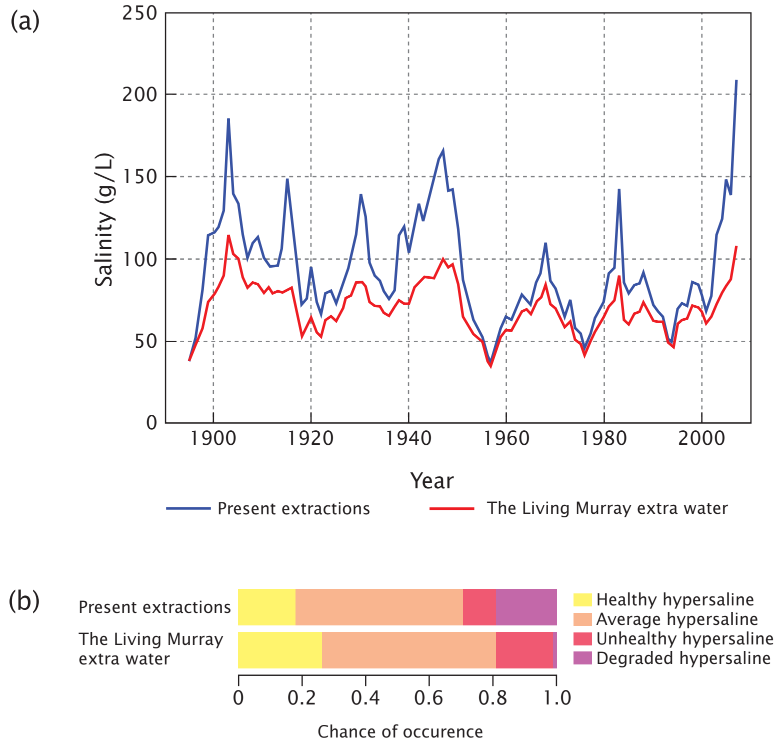
Engineering measures and broader catchment management can be used to enhance the outcomes of environmental water. Regulators, weirs, and embankments are used to direct water to priority ecosystems, reduce losses, and protect ecosystems from water at undesirable times. The Barmah Millewa forest on the Murray River, for example, has a network of regulators to control flow to different parts of the forest. Water can also be pumped and piped to provide critical supplies to a wetland. In 2009, 122 ML/day were pumped into the Hattah Lakes wetlands for a

Figure 9.5: Map of the Coorong and surrounding region.[25] During moderate to high river flows, water discharges through the barrages near the Murray Mouth and into the Coorong, diluting its salinity. The salinity naturally increases towards the south-east as freshwater gradually evaporates leaving saline water behind. Extended periods of low flow increase salinity throughout the Coorong.

period of 50 days. This was an emergency measure to provide relief to highly stressed wetlands while long-term solutions were sought. The water supported the regeneration of river red gums and breeding of waterbirds such as Australasian shovelers, hardhead ducks and great egrets, but it did not create the nutrient exchange processes of natural flooding.

The Coorong – applying ecological understanding

The Coorong, at the mouth of the Murray River (Figure 9.5), provides an example of how ecological understanding can be used to design efficient planning of environmental water. The Coorong is valued particularly for the numbers and varieties of waterbirds that nest and feed there. Most of the freshwater input to the Coorong occurs nears it mouth, through the Murray River barrages, so, contrary to most estuaries, salinity increases away from its sea connection, driven by evaporation from the lagoon. Four broad habitat conditions were identified in each of the North and South Lagoons, related to particular water levels and salinity conditions. Each supports distinctive groups of bird, fish, invertebrate and plant species.[24] During the millennium drought there



▸ ***Figure 9.6**: Figure 9.6: (a) Simulated yearly averaged salinity in the South Lagoon of the Coorong for inflows from the Murray River under the present water extraction regime in the Murray-Darling Basin and under enhanced environmental flows provided by the Living Murray initiative. (b) The frequency of occurrence of the four ecosystem states for each simulation, showing that environmental flows are able to almost completely avoid the degraded hypersaline state that would otherwise be experienced 20% of the time.[27]*

was virtually no flow through the barrages, which increased salinity in the South Lagoon of the Coorong to over four times that of sea water and caused the 'unhealthy' and 'degraded hypersaline' states to dominate there. These are states of reduced diversity of species. In the 'degraded hypersaline' state, only one fish and one bird species are common.

A hydrodynamic model of the Coorong was developed to predict salinity and water levels in the lagoon in response to freshwater flows through the barrages.[26] The model assesses the relationship between flow releases in the Murray River and the occurrence of the four ecosystem states in each lagoon. Under present extraction levels in the Murray–Darling Basin and the historical climate, the degraded hypersaline state occurs for 20% of the time in the South Lagoon (Figure 9.6). Providing a minimum flow of 1500 ML/day through the Murray mouth, as the Living Murray scenario portends, reduces the peaks in salinity and avoids the degraded hypersaline state for 99% of the time. It would only take 4% higher discharge on average than the current regime to achieve the 1500 ML/day minimum flow target. This suggests that significant improvement in ecological condition of the Coorong could be achieved with a relatively modest increase in flow, but that flow is needed at the critical times of greatest salt stress.

Environmental water operations

Water for the environment used to be provided by regulating water use through water sharing plans. Operating rules for dams (in regulated rivers) ensured water was released downstream to maintain a base flow, transmit floods of desired timing, duration and peak, or to minimise damage from continuous supply of water downstream for extraction.

These measures are now being complemented by water being provided to the environment through water access entitlements in the same way that irrigation and urban water users have entitlements to use water. An allocation of water is made against these entitlements each year and environmental water managers (like other users) can use those allocations at their discretion to achieve the best outcome – in this case to meet environmental targets. An early example of environmental entitlements was the return of up to 500 GL/year of extracted water to the Living Murray Initiative to provide water to six ecologically significant sites along the Murray River. State governments hold similar entitlements to provide environmental water and the *Water Act 2007* (Commonwealth) established the Commonwealth Environmental Water Holder to manage water to protect and restore the environmental assets of the Murray–Darling Basin. The Australian

Pig nosed turtle, Northern Territory. Photo: John Cann.

Government is purchasing water entitlements from irrigators in the Murray–Darling Basin to be managed by the Commonwealth Environmental Water Holder.

The benefits of actively managing environmental water through entitlements are potentially high, but they pose additional challenges to obtain the best ecological outcomes. Environmental managers will hold well in excess of 1000 GL of entitlement in the Murray–Darling Basin. Although this is a large volume of water, it still falls short of the several thousand gigalitres of water involved in large floods, so environmental allocations will not produce floods purely from dam releases. They are more suited to supplementing or 'piggybacking' on natural floods in rivers to extend the duration or area inundated by the flood in ways that increases their environmental benefit. Alternatively, the water may be used to maintain river flows, or supply to wetlands, in dry periods to provide habitat and prevent poor water quality. Ecological knowledge can be used to match the use of water against the greatest needs at the time.

Annual allocations against the environmental entitlements could be traded to increase the environmental outcomes or to minimise the conflict between consumptive and environmental uses. Demand for consumptive water use is highest in dry years, while some ecological outcomes can best be achieved in wet years, so trading allocations between the two classes of users in wet and dry years may benefit both. These are just a couple of examples of how managing water entitlements for the environment will become quite sophisticated. It is a complex problem of optimising outcomes from a limited resource, where precise ecosystem understanding is fundamental to achieving the best outcomes.

Conclusions

The policies and legislation that provide water for the environment have strengthened in recent years, but implementing those principles in water plans has been slow.[18] In many water plans, there is limited description of ecological conditions, the desired environmental outcomes are often inadequately specified, and they lack detailed monitoring, evaluation, and reporting linked to the environmental outcomes. To develop robust plans for environmental water requires good ecological knowledge, much of which can be applied now, with excellent prospects to link aquatic ecology with environmental management to find better ways to work with nature to restore and protect key environmental assets.

As competition for water use becomes more intense, environmental water management will come under the same pressure as other uses to increase efficiency and maximise outcomes from the water used. The ecological outcomes achieved and their value to society will need to be demonstrated, requiring strong application of ecological knowledge.

Further reading

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