Introduction

Sharing water between competing users will be the hallmark challenge of this first decade of the 21st century. We have escalating pressures for water to be made available for productive agriculture, for the growing needs of our cities and for the environment itself.

Not only are the demands on our water resources escalating, but also we will have less water to go around. There are three reasons for this.

- Increasing efficiency of irrigated agriculture means less water finds its way back into rivers from drainage.
- Climate change means we are facing increased evaporation and a likely reduction in rainfall of up to 10% over the next 30 years.
- Over-allocation of groundwater means that stream flows will reduce after a lag time of around 30 years. We appear to be just starting to see this in some rivers.

As our society continues to face this challenge, there are some principles we can observe that may help us get to better and more lasting solutions.

- The whole community needs to be involved in developing and accepting the tradeoffs, not just those benefiting from the extraction of water. It is challenging to involve distant downstream communities and those in our cities who care about our rivers.
- We need to be very clear about what regional wealth is being created by the use of the water, and we need to understand the direct and indirect costs involved.
- We need to understand the factors that determine the health of our waterways and agree on what changes are acceptable.

My talk today will focus on this last point.

Assessments of water quality

Last century we collected a variety of physical and chemical measurements of water. Large data banks were filled with these measurements, which turned out to be of little value in assessing the health of the river, although they were useful as particular diagnostic tests. Part of the problem was measurements varied depending on rainfall, and so gave only a snapshot in time. A quite different set of results could be obtained if one sampled after rain than after a dry spell.

Biological assessments

People are generally concerned with the plants and animals in a waterway, rather than the concentrations of some substances. This realization led to the development of biological assessments of river health. Fish populations have long been a measure of river health, and so have been used as a basis for formal biological assessments.

Assessing river health by measuring the biological populations gets over the problem of spiking of contaminants, since the biota effectively integrates the effect of water quality over the lifetime of the organism. More than this, the biological population we can observe reflects other critical elements such as habitat and flow patterns.
There have been a number of efforts to assess river health using biological tools.

**NSW Rivers Survey, 1997**

The NSW Rivers Survey used fish populations and some 25% of the species expected to occur were not found, indicating the poor condition of many waterways (Harris and Gehrke 1997). Eight freshwater fish species are listed under NSW legislation as threatened, with others pending. Eleven alien species have been recorded in NSW inland waters, most again in the highly regulated Murray-Darling Basin.

**Australian State of the Environment Report, 2001**

This Report identifies that we have already lost. Of 208 frog species in Australia, 20 are considered endangered and seven are vulnerable. Of over 200 freshwater fish species in Australia, 11 are considered endangered and 10 are listed as vulnerable under the Environment Protection and Biodiversity Conservation Act. Thirty-five exotic fish species have become established in inland waters, with eight identified as having a significant adverse effect on biodiversity. Fifty-seven species of freshwater Crustacea are regarded as threatened. Some of the larger freshwater crayfish species are under considerable pressure from habitat loss and overfishing, and appear to have been lost in the Lower Murray.

**Australian Catchment, River and Estuary Assessment, 2002**

This assessment was undertaken as part of the National Land and Water Resources Audit. It examined 14,606 river reaches throughout the agricultural regions of Australia and reported an aquatic biota index (invertebrates) and a physical environment index. Each was reported separately in four bands (un-impacted reference condition and three bands of increasing level of impairment. On the biological assessment, one third of the river length assessed (21,909 km) was to some degree impaired, meaning it has lost between 20% and 100% on the invertebrates that would have been expected to be found in similar un-impacted reaches. Almost one-quarter of these rivers have lost at least 20% of the different kinds of aquatic invertebrates that would be expected to occur under natural conditions.

The environmental assessment considered catchment disturbance, flow disturbance, nutrients/suspended solids and aquatic habitat, and indicated that 85% of reaches had been modified, largely by catchment activity. Nutrients and suspended solids are higher than natural in some 90% of river reaches. More than 50% of river reaches had impaired habitat, largely due to loss of riparian vegetation.

**Health of terminal wetlands**

A number of Australian rivers end in terminal wetlands, some of which have been designated as internationally important under the RAMSAR convention. In NSW, the Macquarie Marshes and the Narran Lakes are both designated and both seem to have been adversely impacted by reduction in inflow waters through irrigation development.

Irrigation development does little to change the impact of the infrequent large flood, but it does reduce the frequency and duration of small to medium floods. This can lead to a shrinking of the overall wetland area, a reduction in bird breeding events and a change in the botanical composition away from wetland plants.

An Index of Wetland condition has been developed by the Victorians in an attempt to develop a standardized tool for assessing wetland health (Anon 2005).

**The Sustainable Rivers Audit**

In 2000, the Murray-Darling Basin Ministerial Council decided to initiate the development of a Sustainable Rivers Audit (SRA) that would assess river health using five themes: macroinvertebrates, fish, water quality, hydrology and physical habitat. The aim of the SRA was to provide consistent Basin-wide information on the health of rivers (through a rigorous systematic monitoring program) to drive high level, sustainable land and water management decisions. In 2004 the MDBC released a series of reports that trialled the methods proposed for the Audit. The MDBC is implementing the Audit across the Basin, and results can be expected over the next year or so.
What makes for a healthy aquatic ecosystem?

What sort of biological populations do humans value in our aquatic ecosystems? There are some populations we clearly seek to avoid:

- Algal blooms are unsightly and odorous, and can at time be toxic to humans and stock. They are commonly a consequence of low flows and excessive nutrients.
- Bacterial communities that are excessive can run the system out of oxygen leading to fish kills and unpleasant smells. They are a consequence of organic pollution.
- Introduced plants or animals that dominate a system at the expense of native organisms – examples include water hyacinth and other aquatic weeds, carp and other pest fish such as tilapia.

So what do we value in an aquatic ecosystem?

- The presence of iconic fish species such as Murray cod and native organisms like platypus,
- Native fish – healthy populations with good numbers and mix of species,
- Wetlands and their associated water bird populations,
- Some will value the presence of introduced sporting fish such as trout, although others will regard these as feral fish.

The Victorian River Health Strategy (2002) defined an ecologically healthy river as one with flow regimes, water quality and channel characteristics such that:

- the majority of plants and animal species in the river and riparian zones are native, and the presence of exotic species is not a significant threat to the ecological integrity of the system;
- natural ecosystem processes are maintained;
- major natural habitat features are represented and are maintained over time;
- native riparian vegetation communities exist sustainably for the majority of the river’s length;
- native fish and other fauna can move and migrate up and down the river;
- linkages between river and floodplain and associated wetlands are able to maintain ecological processes;
- natural linkages with the sea or terminal lakes are maintained; and
- associated estuaries and terminal lakes systems are productive ecosystems.

The drivers of river health

We impact on the health of rivers in a number of ways. The most common are listed here,

Habitat degradation

Alterations to flow regime

Water is stored in dams in wet periods so it can be released for human uses in dry periods. This can lead to flow reversal, where rivers run low in winter and run bankfull in summer. The extraction of water can greatly reduce overall flow affecting instream habitat, terminal wetlands and water quality.

Loss of connectivity

Large dams fragment the essential connectivity of rivers and prevent the pulses of small to medium floods that stimulate fish and bird breeding and ensure wetting of riparian wetlands.
The dams block fish movement, leading to fragmented populations vulnerable to disturbance. Dams also commonly lead to cold water plumes downstream if deep bottom water is released, and these plumes can impact the biota for hundreds of kilometers downstream. The dams trap sediment, nutrients and detritus that previously flowed to downstream sections.

Weirs
Weirs are placed across rivers to raise water levels to assist in extracting it by gravity, or for other purposes, but weirs block fish movements. Of the 53 native freshwater species in NSW, 28 undertake large-scale migrations and 16 migrate on local scales. There are over 4,300 physical barriers to fish migration on NSW waterways, and some 26 effective fishways. Weir pools provide ideal habitat for algal blooms and carp. They often maintain adjacent wetlands in a permanently wet condition, which can damage ecosystems adapted to wetting and drying.

Desnagging
Large woody debris (snags) were removed to aid navigation and flood control and to provide recreational benefits, but snags provide critical habitat for a variety of organisms. Desnagging is rarely practiced nowadays, but the legacy of the past remains. Destruction of riverside (riparian) vegetation has removed the supply of woody material to many streams.

Levee banks
Levees have been constructed to protect areas from flooding, but have served to disconnect the river from its floodplain with significant wetland loss and impacts on fish and bird breeding. We know that during floods fish move out onto the flooded floodplain for feeding and that floods stimulate high levels of production of plants and animals.

Destruction of the riparian zone
Riverbank vegetation is a critical part of the river habitat, influencing light and temperature in the water, and providing organic matter as leaves fall. It also provides a filter for nutrients and sediment that might enter the stream from adjacent farmland of logged forestry areas. In many areas we have allowed grazing to destroy this vegetation altering the stream conditions and leaving banks exposed to erosion during high flow events.

Loss of riverine wetlands
Terminal wetlands are lost when too much water is removed. In other cases, water level manipulations mean that wetlands no longer experience the wetting and drying cycles under which the organisms present have been selected. In other cases, grazing of the wetland by stock leads to a loss of aquatic plants that are replaced by algae, which might then seed blooms in the river downstream.

Exotic species
Australia has a long history of introduction of exotic species that have displaced native species. We are still stocking trout to provide a recreational fishery. There is strong evidence that these exotics have had significant impacts. Similarly plants like water hyacinth, willows and blackberries have had major impacts and are being removed in some catchments. Carp have been a very successful invader and are favoured by constant water levels. They impact on native species and dominate the biomass in the highly regulated Murray-Darling system. They make water more turbid by stirring up sediment as they feed, and uproot aquatic plants.

Over-exploitation
Commercial and recreational fishing provide a major pressure on certain species, and are one factor thought to have led to the marked reduction in Murray cod, yabbies and River Murray crayfish and possibly silver perch. Restocking of mostly native fish is undertaken in all eastern states and territories although with varying success. The loss of genetic diversity and introduction of diseases into wild fish populations have occurred as a result of restocking in some areas.
Pollution

The current challenge for pollution control is the non-point pollution of materials washing off farmland, and the pollutants carried in irrigation drainage waters. While most farmers are keen to use sustainable land use practices, some still dump massive amounts of nutrients, organic matter, agricultural chemicals, sediment and salt into waterways. These pollutants are a major cause of algal blooms, stream degradation and the loss of biodiversity. Salinisation has now been recognized as a major national problem and will lead to a loss of aquatic plants with significant flow on to many organisms that depend on wetlands.

Going forward

We have already developed some useful tools for assessing the health of our rivers, and better tools will emerge as we learn more about how our rivers function.

The large scale assessments already done in Australia indicate significant change has occurred in rivers in our settled areas due to catchment activities and water management itself. These changes have been the price our community pays for the agricultural development that has created wealth and supported the populations in rural Australia, and to support our cities with the food and fibre they need.

There are three imperatives as we go forward:

• Significant examples of the remaining undamaged aquatic systems need to be protected and managed to ensure they are retained,
• If we seek to develop any of these rivers in the future we need to do so on the basis of good understanding of how they function, and ensure we do not repeat the mistakes of the past,
• In developed parts of Australia we need to decide what level of change in our aquatic ecosystems is acceptable and to seek to reduce the impacts of catchment activities to ensure these rivers are maintained as healthy working rivers.

Protecting undamaged rivers

There are four main reasons why we need to maintain undamaged aquatic ecosystems (Cullen 2002).

• To provide “seeding” sources to help re-colonise areas that have been damaged.
• To provide benchmark reference areas so we can assess how much our managed rivers have departed from the natural condition.
• To protect the aquatic species that live in these rivers. These organisms are of value in themselves, and the aquatic communities provide essential and often irreplaceable genetic material and ecosystem services.
• To meet our international biodiversity obligations.

The independent report to the Prime Minister’s Science, Engineering and Innovation Council (Morton, et al, 2002) called for the establishment of a Heritage River system to protect the remaining undamaged rivers. The Australian States have identified some rivers that are presently relatively undamaged, and recognised the importance of protecting them from development.

The Paroo River and Coopers Creek are examples in Queensland; the Ovens and Mitchell in Victoria. Other important and relatively undamaged rivers worthy of attention include the East Alligator in Northern Territory, the Clarence in New South Wales and the Fitzroy in Western Australia. The Barmah-Millawa wetlands are also recognised as priority conservation areas.

There is a case for a National Heritage River System, and this requires leadership from the Federal Government.
New water resource developments

Australia has large amounts of water in the North, although we have few success stories of developing economic agriculture in this region. We need to invest in a decade of knowledge acquisition to start understanding our northern rivers before we go building more uneconomic and environmentally damaging dams. Streamflow measurement and river health assessments are required, as well as an understanding of how the flood pulses of these rivers drive the prawn and other fisheries.

Deciding the limits of acceptable change for river health

Many irrigators, whose wealth is dependant on irrigation water, often believe that that their river is in good health, and that there is no need to take water back from irrigation for the environment. However, in assessing the health of the river, we need to look at the whole river, since commonly the deleterious impacts are observed downstream.

In our settled landscapes we have no chance of restoring rivers to any pristine condition. This is just not a possibility when we have changed the catchment vegetation and hence flow patterns. We can however seek to have a healthy working river which will have similar characteristics outlined above from the Victorian River Health Strategy. The key to this is ensuring ecological processes are maintained and that systems retain the capacity to adapt to changing conditions.

This is a difficult area, and there is little doubt that our predictive and planning tools will improve with more knowledge. The challenge is to identify the relationship between the damaging function (flow reduction, pollution and so on), and the health of the river. These are not simple linear relationships, and are often stepped functions where little change is observed initially, but once some threshold is reached change can be sudden and at may be very hard to reverse. Examples include waterbodies able to tolerate nutrient pollution for some time, but then suddenly switching from being dominated by aquatic plants to being dominated by algal growth, and being very hard to switch back.

Rivers can be degraded by a number of factors as outlined above, and it is important to understand what are the various factors causing an impact on any particular river. If a river is flow stressed, it is not likely that significant investment in riparian revegetation will lead to an improvement in river health. If the health of a river is unacceptable, it is necessary to be clear as to what is the factor causing the damage, and to intervene to a sufficient extent that an improvement in river health can be expected.

The challenge of environmental flows

We have gone through three stages in the development of our thinking about river flow and river health.

- Firstly, we decided that each managed river should have at least some minimum flow all the time to maintain its ecology.
- Secondly, we moved to trying to mimic natural flow patterns by releasing a certain proportion of the inflow water to a dam.
- The present approach is based on identifying the important ecological assets that must be maintained, and then deciding what are the appropriate flow regimes needed to protect them.

The Murray Flow Assessment Tool (MFAT) has been developed to identify the ecological impacts of various flow regimes for the Murray River, and considers effects of flow on native fish, floodplain vegetation, wetland vegetation, waterbirds and algal growth. It is available on the MDBC Website.
References


