

Myth & the Murray

Measuring the real state of the river environment

by Jennifer Marohasy



We have all heard about the declining health of the Murray River, including poor water quality, dying red gums and threats to the continued survival of the Murray cod—this is the popular view in urban Australia. Along the river, communities believe that the end of commercial fishing, a substantial restocking effort, improvements in on-farm practices and the construction of salt-interception schemes have resulted in a healthier river. The available evidence supports the local view and suggests that, with the possible exception of native fish stocks, the river environment is healthy.

Many of the scientific reports that have led to the perception that the Murray River is in poor health make their comparisons with a natural river, which is one without dams and locks, one that gushes and then runs dry. Such comparisons are misplaced. If the ultimate objective of the conservation movement is a natural river, then we must reject the cultural heritage and economic wealth created by the engineering works, including the Snowy Mountains Scheme. In its natural state, the Murray River could not provide for Adelaide's water needs and it could not support the irrigation industries that have made the region the food bowl of Australia.

2. INTRODUCTION

'Myths embody popular ideas on natural and social phenomena.'

Oxford English Dictionary

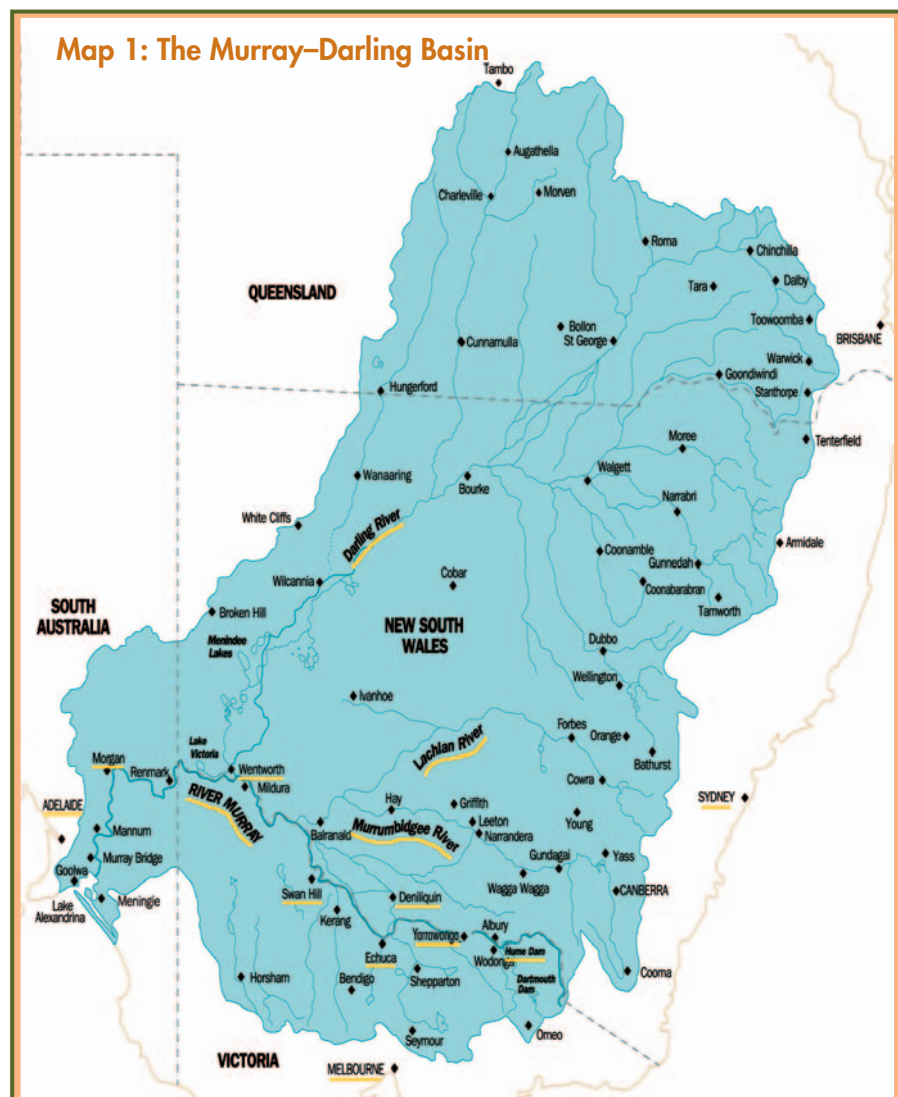
In Australian cities, a popular idea about the Murray River has emerged. The image is of a once great river that is now dying: 'Over the past 100 years, the flow of water through the River Murray system has changed. Most of this is due to dams, locks, and levies which were constructed to provide water for irrigation, drinking and industry. The alteration to the system's water flow has caused changes to the environment. Water quality has dropped, some wetlands have become dry, native fish are struggling to survive and some areas of land have become salt-affected. If things are left as they are, the River Murray system could die.'¹

The Australian Conservation Foundation (ACF) has specialized in saving rivers. According to their Website, 'saving rivers is in our blood' and 'we've worked to save the Franklin, Fitzroy and Snowy Rivers. Right now the Murray River's need is urgent.'² The ACF, and others, have initiated a campaign to return 1,500 gigalitres per annum (about 3 Sydney Harbours full of water, 1 gigalitre equals 1 billion litres) of irrigation water to the river as environmental flow to help fix the problem of the 'dying Murray'.³ A group of Australian scientists sponsored by the World Wide Fund for Nature (WWF) suggested this target be achieved by irrigators voluntarily giving back 10 per cent of their current water allocation, with the remainder to be bought by government.⁴ At current market prices of approximately \$1,200 per megalitre (1 megalitre equals 1 million litres) it would cost approximately \$1.8 billion to

buy the total amount of water proposed (1,500 gigalitres).

While spending money on the environment may seem like a worthy cause in itself, what would actually be achieved if this quantity of water were released? The Murray River environment is highly modified as a consequence of the many dams and locks constructed over the last 100 years to 'drought proof' the region.

Many local communities believe a vocal environmental lobby has formed a partnership with scientists pursuing funding. They regard this partnership as having hijacked the debate and, through exploiting an ill-informed media,⁵ given city-dwellers the wrong impression that the Murray is facing a crisis. Local communities generally reject the idea that the river is dying and many reject the various proposals to take additional water from irrigators.⁶ Nevertheless, they recognize that there are environmental issues to deal with, are embracing more environmentally friendly farming technologies and have already



made significant contributions by way of environmental flow, including to flood red gum forests.⁷

Irrigated agriculture has been a feature of the Murray River since the early 1900s when the first dams and irrigation channels were constructed. Wheat, cotton and wine-grapes are amongst the many crops now grown on land that was once covered in salt bush.

In 1974, the Snowy Mountains Hydroelectric Scheme was completed and 1,100 gegalitres per annum was diverted west from the Snowy River to the Murray and Murrumbidgee Rivers. The additional water was diverted with the aim of generating hydroelectricity, drought-proofing the region and providing additional water for irrigation.

The Murrumbidgee and Darling River systems flow into the Murray River most years, while the Lachlan River flows into the Murray approximately once in every 20 years, Map 1. This entire catchment area is often referred to as the Murray–Darling Basin and covers an area of 1,061,469 square kilometres, equivalent to 14 per cent of Australia's total area.

The Murray–Darling Basin is now home to approximately two million people and supports one quarter of the cattle herd, half of the sheep flock, half of the crop land and almost three-quarters of the irrigated agriculture in Australia. The value of the Basin's agricultural production exceeds \$8.5 billion per annum, which represents 41 per cent of the national output from rural industries. Manufacturing industries in the Basin rely on this agricultural output for 70 per cent of their \$10 billion per annum production.⁸ Adelaide is not in the Murray–Darling Basin, but water piped from the Murray River typically supplies about half of Adelaide's water needs. In dry years, the reliance upon Murray water can increase to as much as 90 per cent of needs. Adelaide is thereby able to present itself as an English-style city of roses and churches; despite being the capital of the driest state in the world's second-driest continent.

A dying river with deteriorating water quality cannot sustain the environment, agriculture or Adelaide—at least not in the longer term. How is it that the river appears to be healthy to the local communities, whereas the overwhelming advice from eminent Australian scientists and research organizations suggests that the River is an ecological disaster? It is this issue that I shall explore through a consideration of the available evidence.

3. MEASURING THE STATE OF THE RIVER ENVIRONMENT

If we are to understand the real state of the world, we need to focus on the fundamentals and we need to look at realities, not myths.

Bjørn Lomborg, 2001

3.1 Received Messages about the Murray's Health

The simple message that the Murray River is dying has been repeated over and over in the Australian media. But what do the actual data look like? How many red gums are dying relative to the total population of red gums? At what rate are Murray cod numbers declining? How do salinity levels compare now with what they were before the salt-interception schemes were built?

Basic environmental statistics can give us an indication of the magnitude of the problems we face and the extent to which current programmes are successfully addressing environmental issues.

The focus of this *Backgrounder* is on those indicators that have influenced current public perceptions of the River's health because key organizations have promoted them as the most important. These indicators are: salinity, fish (in particular the Murray cod), sediment and nutrient loads and river red gums. Also considered is the issue of 'water diversions', because this measure was identified by the Australian Bureau of Statistics as an important indicator in their 2002 report *Measuring Australia's Progress*.

Macroinvertebrates (bugs) are also included. While they have received little if any media attention in the context of the Murray River, they are relatively easily sampled and normally considered an important measure of the overall health of a waterway.

3.2 The River's Mouth

While a dry Murray mouth is generally perceived to be a symptom of a dying river, a dry river bed and dry river mouth are natural parts of the Australian landscape during drought. The historic photographic record shows that the River ran dry well upstream of South Australia before the construction of the Hume Dam (completed in 1936), including at Swan Hill in 1914–15 and 1923.

Of more ecological significance from the perspective of river health is the issue of the barrages

that restrict tidal flow and movement of fish at the river mouth.

At Wellington, the Murray River flows into a 85,000 hectare lake complex which, under natural conditions, would be estuarine, Map 2. Under natural conditions the level of the lakes and mouth of the river would change constantly because of the variations in water flow, tide and wind action. By 1940, barrages had been constructed across each of the five channels connecting the lakes with the Coorong and the ocean, Map 2. These engineering works restrict tidal flow into Lakes Alexandrina and Albert and stop freshwater flowing out to the River's mouth. An intended consequence of the barrages was the creation of artificial fresh water lakes with more constant water-levels. Hence, while we now complain about salt in the lakes from river water, under a natural situation they would be estuarine—very salty from the sea.



A dry river bed is a natural part of the Australian landscape during drought—the Murray River at Riversdale, New Year's Day, 1914, 50 kms upstream of Swan Hill

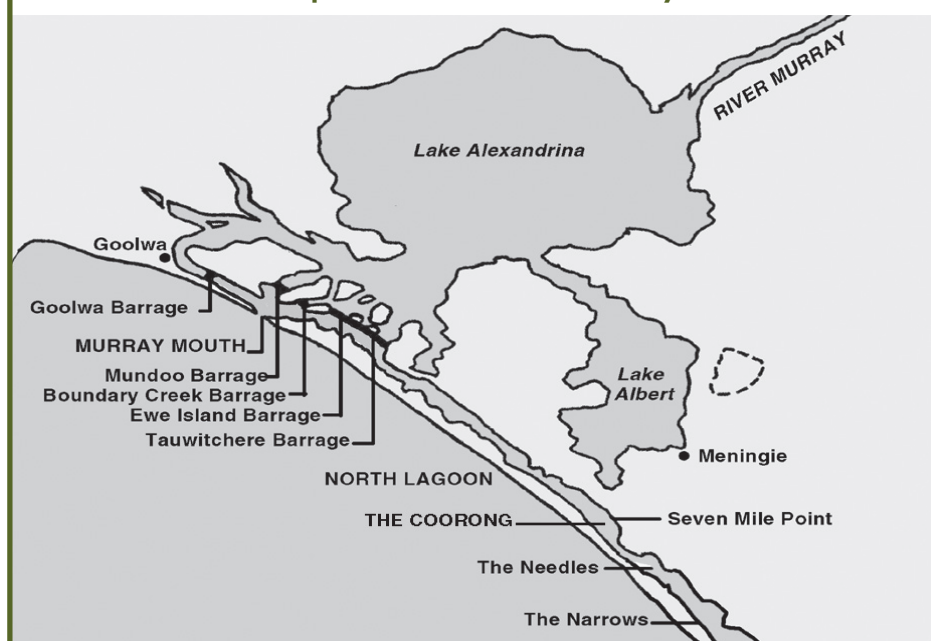
3.3 The Official Institutions

Four institutions have shaped our current perception of the health of the Murray River:

1. The Australian Bureau of Statistics (ABS) is Australia's official statistical organization, with a mission to assist and encourage informed decision-making, research and discussion within governments and the community, by providing a high quality, objective and responsive national statistical service.⁹

2. The Commonwealth Scientific and Industrial Research Organization (CSIRO) is one of the largest and most diverse scientific institutions in the world with over 6,600 staff located at 60 sites throughout Australia. The CSIRO Division of Land and Water has more than 500 staff and a budget of approximately \$50 million. This Division has several Research

Map2: The Mouth of the Murray



Directorates focusing on Murray–Darling Basin issues, including the Rivers and Estuaries, Salinity and Sustainable Irrigation Systems Directorates.

3. The Murray–Darling Basin Commission (MDBC) is an autonomous organization responsible to the governments of New South Wales, Victoria, South Australia, Queensland and the Commonwealth with annual revenue from these governments exceeding \$60 million. The Commission's key responsibilities include managing the Murray River and advising government on matters related to the use of water, land and other environmental resources of the Murray–Darling Basin.

4. The Cooperative Research Centre for Freshwater Ecology (CRCFE) is a joint venture between 19 partner organizations including all the major State and Federal government departments and research organizations involved in Murray River research. This organization has been responsible for the production of key reports to government on the state of the Murray River and, in particular, an influential survey of fish.

As research funding becomes increasingly targeted towards government-nominated problems, particular areas of research risk becoming veritable industries, within which scientists chase funding by investigating subsidiary fields and special cases within the overall area.¹⁰ As more researchers become attached to the particular issue, and dependent upon the funding it provides, the field of research involved thereby achieves a degree of independence and even defines its own reality—as long as no serious external or internal challenge is mounted to the status quo.

The federal government policy of funding 'collaborative research' through Cooperative Research Centres works strongly to increase the potential advantage of researchers who corroborate the status quo, rather than those who constructively and competitively challenge it.

3.4 Water Diversions (Irrigation)

3.4.1 The Murray–Darling Basin

In 2002, the ABS published a report titled *Measuring Australia's Progress* which identified six 'headline indicators' for the environment including 'Inland Waters'. The Inland Waters section concluded, 'increasing extraction of both surface and groundwater, particularly for agriculture, are leading to a continuing deterioration of the health of water bodies.'

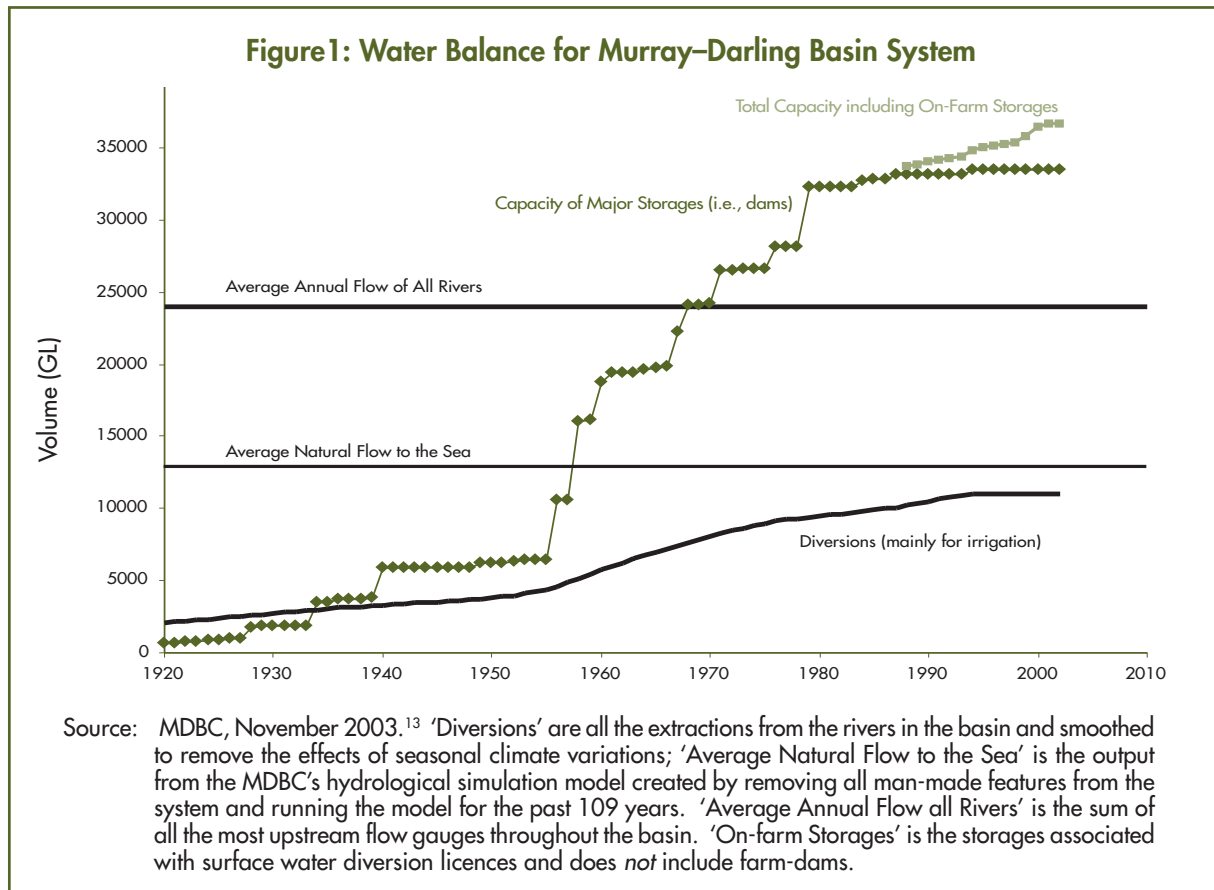
A supporting graph, titled *Water diversions, Murray–Darling Basin—1930 to 2000*, shows that water diversions have increased steadily from the 1930s to 1994 when a cap on extractions was imposed by the MDBC. Over 95 per cent of diversions are for irrigation.¹¹ The report concluded, 'In the 1990s, in response to the environmental problems caused by water diversions and to ensure continued supply for those who use water, a cap was placed on the volume of water that could be taken from the river systems in the basin. While increases in diversions have slowed, the MDBC notes that it is too early to decide whether and to what level the cap needs to be changed to avoid further degradation.'

The quantity of water extracted from the system (diversion) is the only trend data provided for the Murray–Darling Basin in this important ABS report. It is important to note that, in the report, a causal link between water diversions and degradation is assumed. However, no data are provided to establish an actual link between diversions and river health, and no other measured statistics are provided to give an indication of actual river health.

The ABS report does not provide a total water balance. It is thus unclear how much water is being extracted relative to the system's total storage capacity and average annual inflow.

The average annual inflow for the Murray–Darling Basin has been calculated as the sum of all the most upstream flow gauges throughout the basin at 24,000 ggalitres.¹² In the 1920s, the amount of water being diverted for irrigation and other uses from the system exceeded the system's storage capacity (i.e., dam capacity), Figure 1. In the late 1930s, diversions and storage capacity were about equal, at approximately 3,500 ggalitres. However, storage capacity increased rapidly from the mid-1950s through to the early 1980s, while diversions increased at a much lower rate, Figure 1. The Snowy Mountains scheme was built including the major storages of Lakes Eucumbene and Jindabyne which are in the Snowy Catchment but supply water to the Murray–Darling Basin Catchments. The capacity of major storages is now 33,438 ggalitres; with on-farm storages the total capacity is 36,645 ggalitres. The amount of water now diverted annually (mostly for irrigation) is approximately 11,041 ggalitres, Figure 1.

The Murray–Darling Basin's large storage capacity relative to average inflows and diversions provides a capacity to store water in very wet years for use during



drought. The system's storage capacity is approximately 53 per cent more than annual average inflow.¹⁴

The average amount of water *potentially* available will equal the average annual inflow *plus* the storage capacity. Although diversions have increased, because storage capacity has increased much more, the actual percentage of the potential total capacity used by irrigators now (approximately 18 per cent) is only marginally greater than the percentage used in 1950 (approximately 13 per cent). The storages, however, are rarely full. When the last *Water Audit Monitoring Report 2000/01*¹⁵ was undertaken, storages greater than 10 gegalitres in capacity were at 61 per cent (no values were given for smaller storages or the total system). At 60 per cent storage, irrigation use as a percentage of total capacity was 8 per cent in 1920, 22 per cent in 1950 and 24 per cent in 2002.

While the ABS report gives the impression that the 'degradation' to the Murray River by way of 'salinity, loss of fish species and algal blooms' is caused by water diversions leaving too little water in the river, a total water balance is not provided to enable a comparison of the amount of water extraction with the amount of water stored by the dams. In reality, as a consequence of the increase in government storage

capacity (i.e., dams) over the last 50 years, the water level in the main stem of the river is unnaturally high for much of the length of the river, most of the time.¹⁶

The information presented in Figure 1 is not easily accessible. It is remarkable that general information on storage capacity and total inflows relative to diversions for irrigation is absent from key MDBC documents published over the last 10 years, including the *Audit of Water Use in the Murray–Darling Basin*¹⁷ and *Review of the Operation of the Cap*¹⁸ which, like the ABS report, emphasize the amount of water currently used by irrigators, emphasize differences in monthly flow now relative to natural conditions, but do not place this information in any context relative to total storage capacity.

3.4.2 The Murray River

The Murray River is a component of the larger Murray–Darling Basin system, Map 1. Not all water flowing into the Murray–Darling Basin reaches the Murray River. For example, the Lachlan River is approximately 1,480 kilometers long with an average annual flow of 1,270 gegalitres,¹⁹ but in most years contributes no water to the Murray River. The Lachlan

is a terminal river system with most of the inflow feeding the Great Cumbung Swamp.²⁰

Inflow into the Murray River varies from 2,500 gegalitres to 40,000 gegalitres each year; a reflection of the highly variable nature of the basin's climate.²¹ A computer model has been developed by the Murray–Darling Basin Commission (MDBC) that estimates the total water balance for the Murray River based on a hypothetical average year under natural conditions (i.e., without any dams), and also under current conditions (i.e., with dams, locks and levy banks), Table 1. In an average year, under current conditions, total inflow is 12,607 gegalitres. About 24 per cent of this water is lost from the system through evaporation and transmission, 34 per cent is diverted, mostly for irrigation, and 41 per cent flows out to sea, Table 1.

The information is rarely presented in this form. Instead, the impression generally given is that diversions for irrigation account for up to 80 per cent of the river's natural flow, leaving only a small percentage of the water to flow through to the Murray River mouth.²² The 80 per cent figure appears to be calculated by variously combining losses and diversions and calculating medians rather than averages, giving the impression that the basin has been 'drained to death'.²³ The reality is that diversions for irrigation average approximately 34 per cent of total inflow and approximately 41 per cent of inflows flow to the sea in an average year.

3.5 Salinity

Until September 2003, the CSIRO Land and Water Website included the statement:

...[a] look at Australia's largest and most developed river system, the Murray–Darling Basin, shows the nature of the problem we face. Salt levels are rising in almost all of the Basin's rivers and now exceed WHO guidelines for drinking water in many areas. Business as usual is not an option. If we do nothing, the salinity of the Lower River Murray—where Adelaide

pumps out its drinking water—will eventually rise to exceed WHO guidelines.

However, no data were provided to accompany this very powerful statement on the Website and requests to the CSIRO for data to support this assertion brought referrals to the Murray–Darling Basin Commission (MDBC).

Daily readings for salinity from 1938 are available on request from the MDBC for Morgan, South Australia. Morgan is the key indicator locality for water quality in the Murray–Darling Basin. Morgan is just upstream of the pipeline off-takes for Adelaide's water supply. Its use as an indicator site emphasizes the relative importance of river salinity impacts on all water users in the system.²⁴ The yearly averages for salinity measured through electrical conductivity (EC $\mu\text{sec/cm}$) show current salinity levels at Morgan are equivalent to pre-World War II levels, Figure 2. The peak in 1982 is attributed to the drought at this time, with low flow conditions normally associated with higher salt levels.

A plot of yearly average salinity levels for the last 20 years indicates that salinity levels have dropped since the drought of 1982, Figure 3. Concentrations did not return to the 1982 levels despite the recent drought. Water quality has, in effect, improved. Upstream at Swan Hill and Yarrawonga salinity levels are stable, Figure 3. Contrary to information that was posted on the CSIRO Website, salinity levels are *not* increasing at key sites in NSW, Victoria and South Australia.

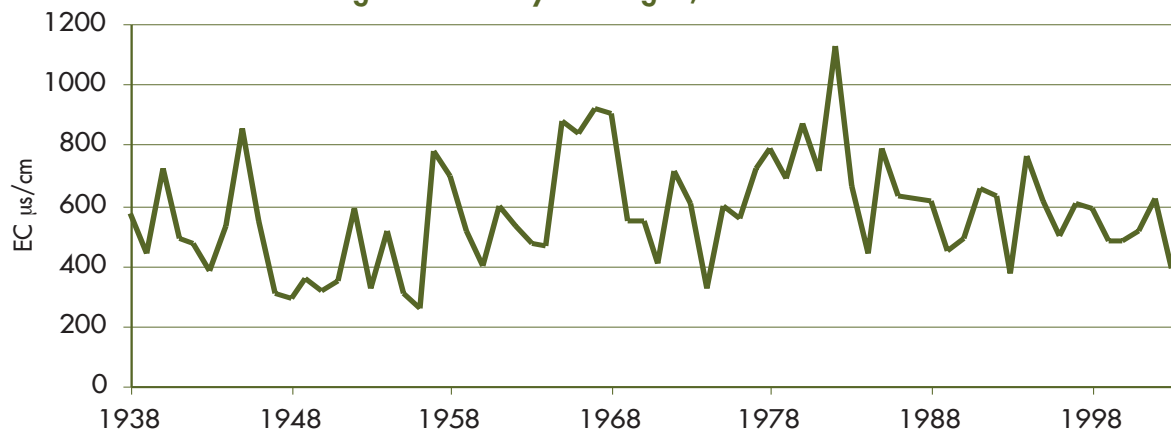
Table 1: Water balance for an average year in the Murray River

	Current*			Natural*	
	GL/year	%		GL/year	%
Total					
Inflow	12607	100		17052	100
Losses	3044	24		3458	20
Diversions	4328	34		0	0
Flow to Sea	5235	41		13594	80

*'Natural' assumes the river is in a state unmodified by human intervention while 'Current' is post-development with dams, locks and levy banks. Under natural conditions, the inflow is shown as greater than under current conditions as on-farm dams and levies will prevent water that under natural conditions may have flowed into the Murray River from reaching the River.

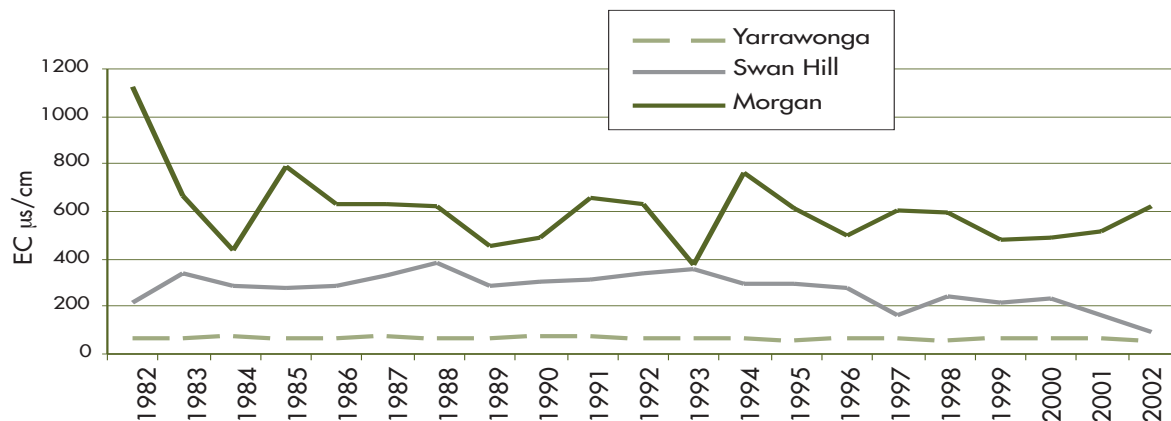
Data Source: Murray–Darling Basin Commission, 1998. GL = gegalitres (10⁹ litres). Murray River includes Lower Darling. Mean inflows, losses and diversions are for the period 1891–1992.

Figure 2: Salinity at Morgan, 1938–2003



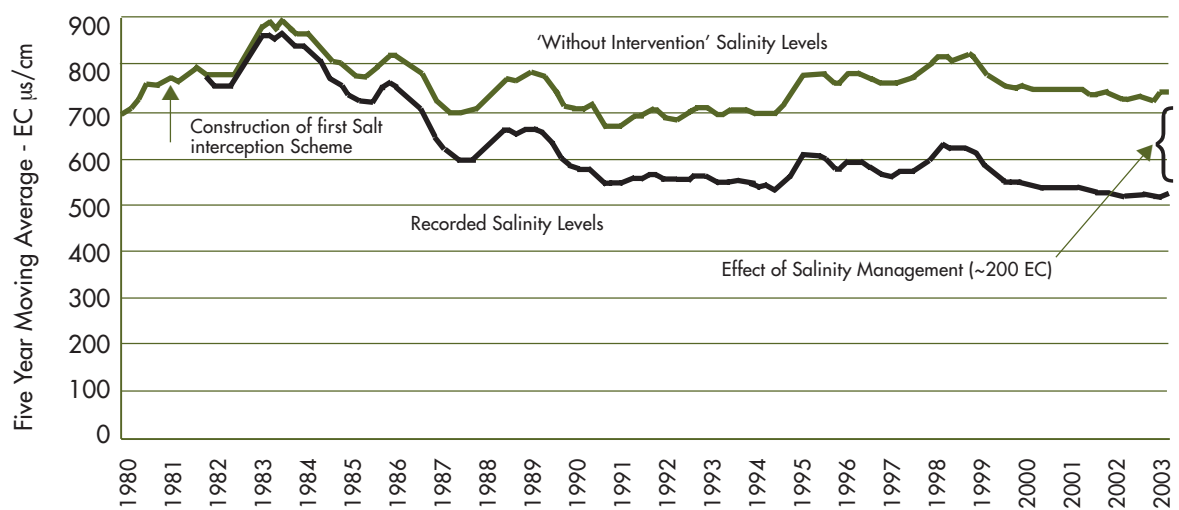
Data Source: Murray–Darling Basin Commission, July 2003

Figure 3: Salinity at Morgan, Swan Hill and Yarrawonga, 1982–2002



Data Source: Murray–Darling Basin Commission, July 2003

Figure 4: The effect of salinity management in the Murray–Darling Basin on average salinity levels at Morgan, South Australia



Data Source: Murray–Darling Basin Commission, September 2003

The MDBC has concurred with these findings and has stated that ‘average salinity in the River Murray has in effect improved during the last decade.’²⁵ The MDBC attributes the improvement to the salt-interception schemes and improved land management practices. Given yearly climatic variability and its potential impact on salt levels, the MDBC has indicated that plotting five-year rolling averages is more appropriate than, for example, yearly averages, in determining longer term trends, Figure 4. On the basis of a five-year rolling average, and by modelling the situation without salt interceptions, the MDBC has calculated that salinity has dropped by approximately 200 EC units as a consequence of the salt-interceptions schemes, Figure 4.

This information is not readily accessible on the MDBC Website and the Commission’s most recent publication implies an ongoing deterioration in salinity levels.²⁶

This information, showing that salinity levels are improving, was presented in a paper in August 2003, titled *Received Evidence for Deteriorating Water Quality in the River Murray*.²⁷ The CSIRO subsequently revised the text on their Website and replaced the reference to rising salinity with, ‘Land and water resource managers in Australia are under increasing pressure to meet stringent environmental guidelines’. At the same time, CSIRO Land and Water published a paper titled, *Is the River Murray Water Quality Deteriorating? A Salinity Perspective*.²⁸ The paper claimed that while salinity mitigation schemes have ‘halted the rising salinity trend at Morgan’ there are increasing trends in upland catchments. It further argued that over the next 50–100 years, long-term groundwater rises as ‘already seen in the Mallee’ will override the benefits gained through the existing measures.

The assertion that there are increasing trends in stream salinity from upland catchments purports to be based on CSIRO’s *Assessment of Historical Data for the Murray–Darling Basin Ministerial Council’s End-of-Valley Target Stations*.²⁹ This assessment concludes that there were sufficient data to establish stream salinity trends at 16 of 32 ‘End-of-Valley’ target stations. Yet, of those 16, the river salinity trend was not statistically significant at 7 stations, indicated statistically significant rising salinity at 5 stations and statistically significant falling salinity concentrations at 4 stations. Interestingly the study concluded that, ‘good quality data at Morgan showed that climatic

variability affected EC exceedance curves more than land use or management change’.

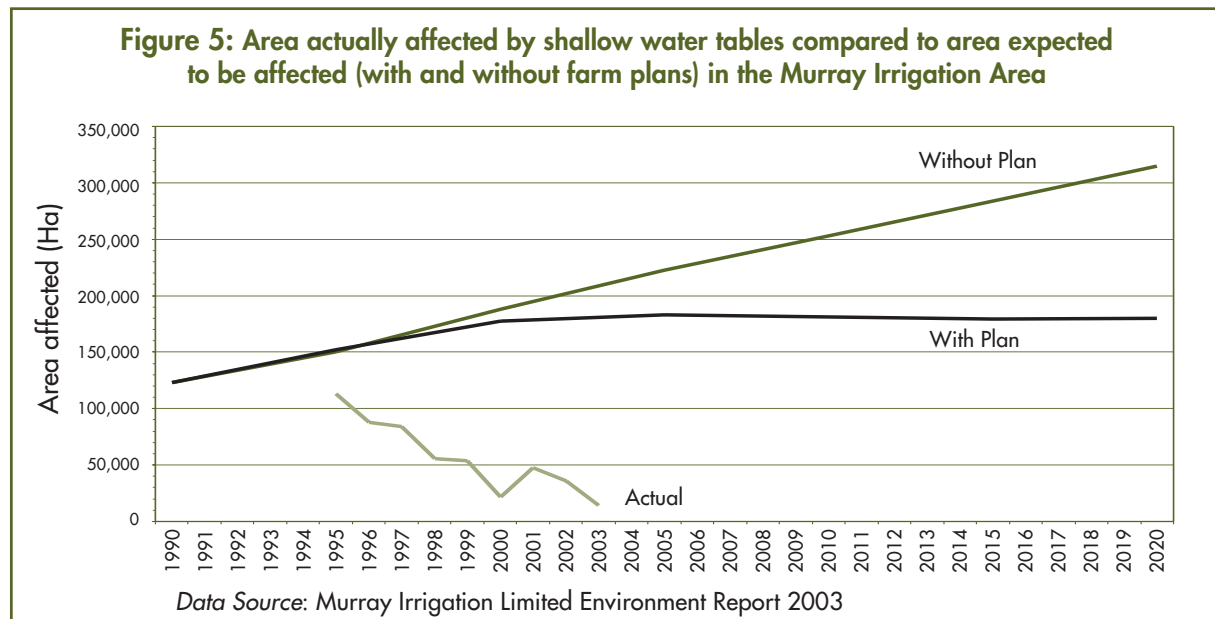
The reference to long-term groundwater rises in the Mallee cites the CSIRO technical paper, *Groundwater recharge in the Mallee Region, and salinity implications for the Murray River—A Review*.³⁰ Findings in this technical paper include, ‘The time for the increase in deep drainage to reach the water table is related to the deep drainage rate, the initial watertable depth, and the soil water content within the unsaturated zone. Throughout most of the (Mallee) area, watertables are more than 20m below the land surface, and this time delay is of the order of tens of years. Because much of the Mallee region was cleared between 50 and 100 years ago, watertables *should* [emphasis added] now be rising over much of the region,’ however, ‘in NSW and Victoria watertable trends have not been determined for most of the Mallee region, in part due to scarcity of data. In South Australia, there is a scarcity of data in crucial areas within 20km of the river.’ No data are presented to support a trend of rising groundwater in the Mallee.

According to the MDBC *Basin Salinity Management Strategy 2001–2015*, the Mallee region represents the greatest potential risk in terms of salt contribution to Morgan.³¹

Along the Murray River there has been a real fear of rising groundwater bringing with it water-logging and salinity. While the issue is marginal to the focus of this *Backgrounder*, which is concerned with river health rather than flood plain health, it is worth referencing some of the available data for completeness and to put the issue in some perspective.

In the mid-1980s, modelling carried out by the New South Wales Department of Land and Water Conservation, that was used to underpin the MDBC Salinity and Drainage Strategy,³² indicated that 127,000 hectares of irrigated land in New South Wales that had water tables within 2 metres of the surface, was at particularly high risk from irrigation salinity. Furthermore, this area was thought likely to increase to 331,000 hectares within the next 50 years if no action was taken, Figure 5.

In 1996, Murray Irrigation Limited, assisted by funding from the State and Federal governments, commenced the Murray Land and Water Management Plans—a suite of on-farm and district scale works aimed at keeping the area affected by shallow water tables to within 200,000 hectares, Figure 5. The programme has been spectacularly successful, with



monitored results from more than 1,500 sites showing a dramatic drop in the area affected by shallow water tables since 1995, Figure 5. The drop preceded the current drought and is expected to be maintained when wet years return. The last survey undertaken in August 2003 indicated that approximately 14,000 hectares now had water tables within 2 metres of the surface. This means water tables have dropped significantly over at least 113,000 hectares of agricultural land along the Murray River which was once considered a high salinity risk. No one is congratulating the farmers for this significant achievement.

3.6 Aquatic Macroinvertebrates (Bugs)

In 2001, the MDBC published an assessment of river health titled *The Snapshot of the Murray–Darling Basin River Condition*.³³ The Overview stated that ‘Every facet of the ecology of regulated rivers and their floodplains has been impacted by changes to the pattern of flow, so the current level of abstraction in the Basin makes it inevitable that more water must be returned to the rivers to restore and maintain balance commensurate with sustainable resource use.’ The document also stated that the scientific evidence indicating ‘decline’ in river health was inescapable.

The term ‘decline’ implies that facts have been assembled in a systematic way and show a worsening trend. In the report the term ‘biota’ is used as a surrogate for animal and plant life. However, results for biota are based exclusively on sampling of aquatic

macroinvertebrates with these sampling results then compared to expected levels given a near-pristine environment through the use of a mathematical model (AusRivAs). Aquatic macroinvertebrates are insects, snails and worms that are visible to the naked eye and that live in rivers and streams. Relatively easy to sample, the diversity of macroinvertebrates and changes over time can give an indication of river health including possible impacts from surrounding land use and the effects of pollution.

Before considering the findings in the recent publication, let us consider the results from an earlier (1980–85) comprehensive 5-year study of the aquatic macroinvertebrate fauna of the Murray River, also undertaken by the MDBC.³⁴ This study did *not* use mathematical models or compare sample results with a hypothetical pristine situation.

The 1980–85 study concluded that

the overall diversity is high at all sites with the exception of those downstream of impoundments and the sites along the River in South Australia. The number of taxa collected in the Murray (439) compares favourably with other Australian River Systems. ... The River Murray differs from the Meuse and many other large river systems in Europe and North America in that it has little industrial or domestic pollution. Consequently, water quality is high and this is reflected in a high diversity of aquatic animals. However, the influence of river regulation in the River Murray has modified the fauna with the more tolerant, slow water forms dominating the highly regulated reaches

downstream of Lock 9 (near Wentworth), and the true riverine fauna restricted to the stretch of River above Lake Hume.

Macroinvertebrates are considered very sensitive to pollutants, particularly pesticides. Since the late 1980s, many of the more persistent agricultural pesticides, including organochlorines, have been banned. As a consequence of this change, coupled with the adoption of minimum tillage techniques, an improvement in the macroinvertebrate fauna might be expected. The 2001 MDBC Assessment, however, concluded (based on results from a computer model's determinations relative to a pristine ideal) that macroinvertebrates populations were either in poor or extremely poor condition in all zones along the River Murray from Dartmouth Dam to Wellington.

The 2001 Assessment evaluated the entire Murray–Darling Basin and classified the largest area of 'severely impaired' river as the Lower Balonne, a tributary of the Darling in Queensland. Local irrigators refused to accept the interpretation of the expert scientists and commissioned their own data collection programme.³⁵ The results from this study and data collected by the Queensland Department of Natural Resources and Mines, was evaluated as part of the Cullen review into the science underpinning the assessment of the Lower Balonne Water Management Plan. The government-funded review headed by Professor Peter Cullen rejected the findings published in the 2001 MDBC Assessment for that section of the river and concluded instead that the aquatic macroinvertebrate fauna is in near-pristine condition.

While the 2001 Assessment states that macroinvertebrate communities are significantly impaired, this same report acknowledges that an Australian Water Technologies study³⁶ has determined that macroinvertebrate communities have shown improvement over the period 1980 to 1997. These findings are inconsistent when compared with the 1980–1985 MDBC assessment which concluded that overall diversity was high. At issue is perhaps whether or not the more recent study is making relevant comparisons when it uses a mathematical model that claims a

capacity to predict how many macroinvertebrates would have been present prior to European settlement.

3.7 Fish

Reports of declining native fish stocks have long been considered an indication of the declining health of the Murray River. In August 2003, the Deputy Prime Minister stated that 'though we are achieving environmental improvements in some areas, such as reducing the salinity of the Murray ... one indicator of a much broader problem is the decline in native fish numbers throughout the basin.'³⁷ According to the Murray–Darling Basin Commission's Website, 'Native fish are estimated to be at 10 per cent of their pre-European settlement levels and are still on the decline.'³⁸ However, neither the MDBC Website nor the Murray–Darling Basin Ministerial Council's draft Native Fish Strategy provide data to support the assertion that fish numbers are declining.³⁹ It is also unclear what assumptions and methodology underpin the 10 per cent determination.

There is a lot of information, much of it anecdotal, indicating that native fish numbers have dramatically declined relative to pre-European levels.⁴⁰ Five native species are considered extinct in the South Australian section of the Murray River including trout cod and Macquarie perch. Studies undertaken in the 1980s considered the effect of the barrages at the Murray mouth on fish species that need to spawn in estuaries. There is also a rich oral history relating to the introduction of the European carp, including its



Local fisherman, Steve Cooper, with a 16 kg Murray cod near Wentworth, April 2003.

subsequent population explosion and negative impacts on both river water quality and native fish numbers.

Since the 1980s, carp numbers have been observed to decline and downstream of Yarrawonga, numbers are thought to be about half what they were in 1997 and are now estimated to represent 21 per cent of total fish numbers.⁴¹ According to the MDBC a likely explanation for the decline in carp numbers is that the initial population boom resulted in an over-utilization of available resources and subsequent reduction to equilibrium carrying capacity for this species.⁴² In contrast, local fishermen attribute the observed reduction in carp numbers to predation from an increasing Murray cod population.⁴³

The Cooperative Research Centre (CRCFE) survey *Fish and Rivers in Stress: The NSW Rivers Survey*⁴⁴ is generally considered the most comprehensive survey of fish in the Murray–Darling Basin. The survey does not provide any data from which trends with respect to improvement or deterioration in fish numbers can be determined. However, the survey undertaken in the mid-1990s does claim to give an indication of the abundance of fish in the Murray River relative to other rivers.

The report's principal conclusions include that 'A telling indication of the condition of rivers in the Murray region was the fact that, despite intensive fishing with the most efficient types of sampling gear

for a total of 220 person-days over a two-year period in 20 randomly chosen Murray-region sites, *not* a single Murray cod or freshwater catfish was caught.' [emphasis added]

A good scientist is usually wary of an absence of data. An absence of data (namely, catching no fish) could be an indication that, for example, they got their sampling method (that is, their fishing technique) wrong, rather than that there were no fish.

While the scientists caught no Murray cod in the Murray, Lachlan and Murrumbidgee Rivers, it is evident from fishing magazines and the results of local fishing competitions that Murray cod are present. The annual Deniliquin Yamaha Fishing Classic registered a record 48 Murray cod in 2003.⁴⁵ A feature in the winter 2003 edition of *Freshwater Fishing Australia*'s titled *Riverina Revival* included comment that, 'The mainstay of the Edward River fishery (an anabranch of the Murray) is the Murray cod and numbers at present are high.... the number of juvenile fish of 45–50 cm just short of legal length of 50 cm, can be frustratingly high for anglers looking for a keeper.'⁴⁶ Perhaps most remarkable is that at the same time, in the same years, that the scientists were undertaking their now much-quoted survey that found no Murray cod, commercial fishermen harvested 26 tonnes of Murray cod from the same region.⁴⁷

Figure 6: Commercial catch per unit effort, 1984–85 to 1995–96



Data Source: *NSW Inland Commercial Fishery Data Analysis*, Fish Research and Development Corporation, 1997. The total represents the total weight in tonnes of Murray cod, golden perch, silver perch, freshwater catfish, carp, redfin and freshwater yabby caught in the NSW section of the Murray–Darling Basin. Annual average catch per unit effort is the catch weight divided by total recorded fisher days.

Although anecdotal information can provide useful background information, public policy should be based on a logical assessment of information that has been systematically and objectively collected. In the case of native fish populations in the River Murray, I was able to access only two sources of time-series data:

1. Information on the NSW commercial catch as documented in the *Inland Commercial Fishery Data Analysis*,⁴⁸ and
2. Numbers of fish ascending the Torrumbarry weir fishway as provided by the Reservoir controller.

The only historical information available on the MDBC Website was a misrepresentation of the *Inland Commercial Fishery Data Analysis* (see Section 3.7.2).

While the recreational fishing effort is considered significant, I could not find any data with respect to this activity that might have provided, for example, an indirect measure of changes in fish population numbers or insight into the potential impact of this activity on native fish numbers.

There has been a significant restocking effort with hatchery production in excess of 3.5 million Murray cod, 9.8 million golden perch, and 12 million silver perch from 1992–93 through to 2000–01. However, without information on survival versus mortality rates after release, it cannot be assumed that high levels of restocking will translate into increased population numbers of the fish species in the River.

3.7.1 The Commercial Catch

The NSW *Inland Commercial Fishery Data Analysis* provides information on the total annual commercial catch of native fish species (Murray cod, catfish, silver and golden perch) by weight in tonnes from 1947 through to 1995–96 for the NSW section of the Murray–Darling basin. Most of the fishing effort was in the lower Murray River, the Murray/Wakool/Edward rivers complex and the Menindee Lakes. Carp became a significant component of the total catch from the early 1970s. The number of commercial fishers varied over this period with a peak of 280 licences in 1971 dropping to 40 licences in 1996–97, before the eventual closure of the fishery in 2001.

The commercial catch has been used as an estimate of the size of the native fish stock. Given the decline in the number of fishers over the last 30 years, however, a better measure would be catch per unit effort. The number of days fished has been reported since 1984–85, providing a measure of catch per fisher day. Given fishing methods used in the inland

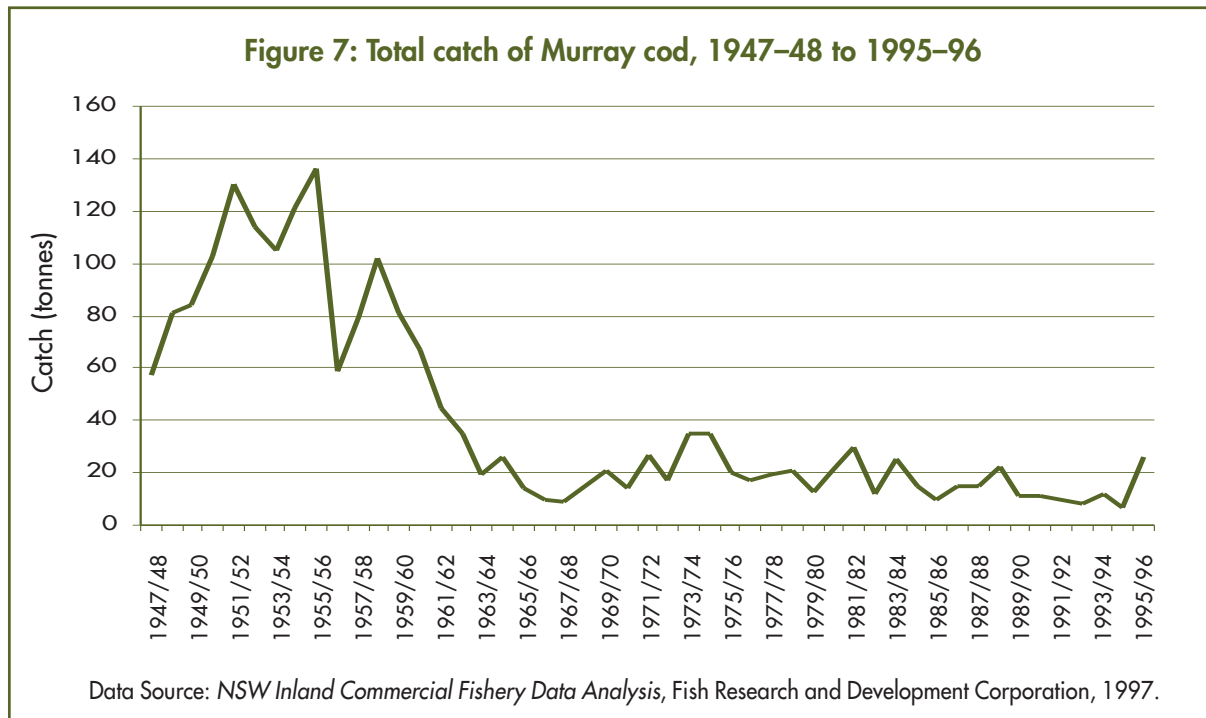
commercial fishery have apparently changed very little over this period, converting total catch into catch per fisher day can potentially give an indication of catch per unit effort. A plot of the total catch of Murray cod, golden perch, silver perch, freshwater catfish, carp, redfin and freshwater yabby caught in the NSW section of the Murray–Darling basin per year divided by the recorded number of fisher days suggests that from the late 1980s to 1995–96 fish numbers were increasing, Figure 6.

3.7.2 Misinterpretation of the Commercial Catch Data

In July 2003, the Federal Minister for the Environment and Heritage announced that the Murray cod was to be added to the national list of threatened species. In the associated media release, the Minister indicated that the reason for the listing was ‘The Murray cod has been assessed as having a 30 per cent decline in numbers over the last 50 years. This decline is inferred from the dramatic decrease in commercial catches from the 1950s until present.’

The media release is factually incorrect. The commercial fishery closed in 2001 and thus there are no data for the last 2 years. But of more concern is the statement that there has been a 30 per cent decline in numbers over the last 50 years. The commercial catch data suggest that the Murray cod fishery increased in the late 1940s, before crashing in the early 1960s, Figure 7. The average annual catch dropped from 103 tonnes during the 1950s to average 20 tonnes per year from 1960–61 through to 1995–96. This represents a decline of approximately 80 per cent from the high levels in the late 1950s. Over the period from 1960, the catch of Murray cod remained relatively stable. An alternative interpretation is that following the crash in the early 1960s there was an increasing trend from 1968 to 1978 followed by a decreasing trend from 1977 to 1996. There has been no ‘decline to present’ since the early 1960s.

It is important to be careful in assessing the limited available data, because if cod numbers have been gradually reducing, then the problem and solution are likely to be very different to a situation where there was an 80 per cent drop in numbers 40 years ago followed by a stabilization in numbers, Figure 7. There is a significant ecological literature that gives insight into how and why crashes in population numbers typically follow rapid population increases.⁴⁹



Single factors (for example, predation, food scarcity or pathological effects in response to crowding) are often key regulators of animal populations.

The Murray–Darling Basin Commission’s Native Fish Strategy⁵⁰ also misrepresents the information in the *NSW Inland Commercial Fishery Data Analysis* by suggesting that the data show ‘decline in catches per unit effort of the Murray cod’ when the report itself is careful to emphasize that the data represent ‘total catches of Murray cod’ and that ‘commercial fishing effort has been strongly reduced over this period (last 30 years).’

3.7.3 Recordings from Torrumbarry Weir Fishway

Concerned at the extent of the misinformation in the Draft Native Fish Strategy, the Wakool Landholders Association undertook a survey which determined that 96 per cent of local residents and tourists believed native fish populations are increasing. In response, the Murray–Darling Basin Commission (MDBC) produced an Information Paper titled *Native Fish in the River Murray: Status and Trend*.⁵¹

The only trend data presented in the MDBC paper shows a graph of total numbers of native fish each year for the period 1991–1992 through to 2002–2003 ascending the Torrumbarry Weir Fishway, Figure 8. Torrumbarry is situated just downstream from the town of Echuca in northern Victoria about half way

between the Snowy Mountains and the Murray River’s mouth. There is an obvious spike in fish numbers in 2000–2001 attributed in the paper to, ‘an environmental flow release to top up high flows and enhance the watering of the Barmah-Millewa forest’. The peak is followed by a dramatic decline in fish numbers. There is no explanation given in the paper for the decline.

The MDBC paper concludes that ‘There is considerable evidence that supports the decline in the range and abundance of many native fish species. There are also explanations why excellent fishing for some species can occur on occasion even if overall populations are in decline through time.’ Yet the only data presented in the paper do not indicate that fish numbers were in decline over the period for which data are available.

The Reservoir Controller at Torrumbarry Weir has overseen the collection of daily recording of numbers of adult and juvenile silver perch, yellow belly, bony bream, Murray cod and European carp passing through the fishway since the original fishway commenced operations in March 1991. The fishway was not operational for a period during 1995–96 when the weir was rebuilt and a new fishway constructed. During 2001–2002 an automatic carp sorting machine was installed at the fishway. The Torrumbarry fishway data appear to be the only recent direct measure of fish numbers, over time, available for the River Murray.

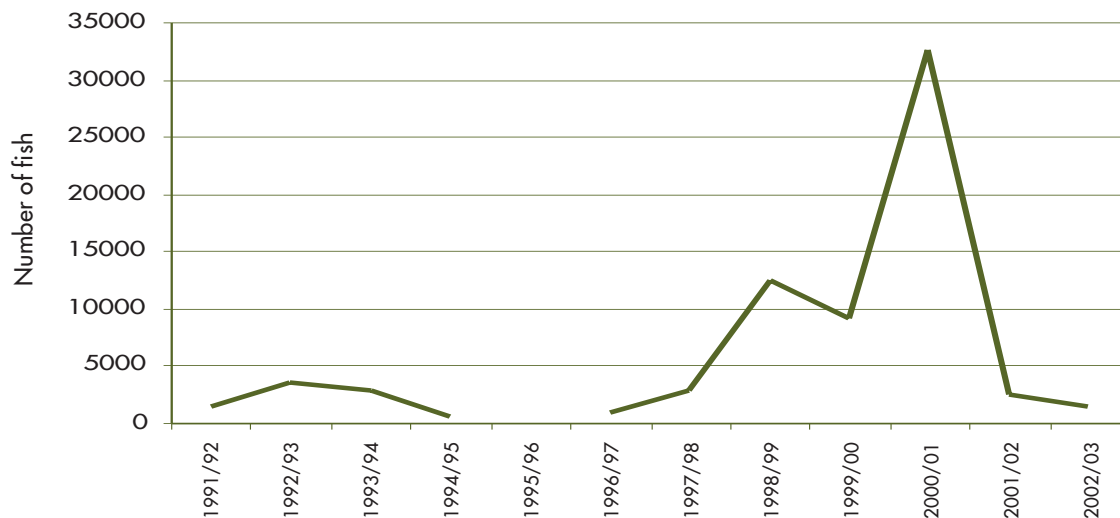
Myth & the Murray: Measuring the real state of the river environment

The MDBC Information paper interprets the numbers of fish moving through the fishway as an indication of changes in relative abundance. On this basis a plot of the total number of Murray cod passing through the fishway might suggest that Murray cod numbers were relatively stable through to 1998–99, increased during 2000–01, and declined during 2002–03, Figure 9. The dominance of adults relative to juveniles, however, suggests that the perceived increase in numbers is more likely to relate to an increase in cod moving along the river system rather than an actual increase in the population numbers in those years.

Murray cod are apparently territorial and do not normally migrate to the same extent as the introduced European carp and native silver perch, golden perch and bony bream. Large numbers of juveniles of these more migratory species were recorded in relatively high numbers passing through the Torrumbarry fishway, Figure 10.

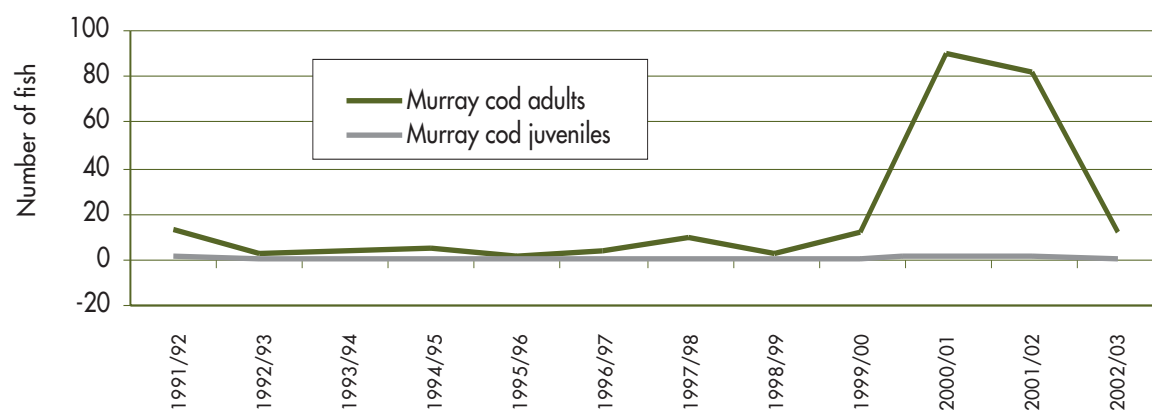
Silver perch are listed as critically endangered under Victorian legislation, endangered in the Australian Capital Territory, and vulnerable in NSW. Interestingly, silver perch were recorded in similar numbers to European carp ascending the Torrumbarry fishway, Figure 11.

Figure 8: Total number of native fish that ascended Torrumbarry fishway



Data Source: Terry Holt, Reservoir Controller, Torrumbarry Weir. The total number of native fish equals the total number of fish minus the total number of European carp. Data for 1995–96 excluded as per MDBC paper as weir was rebuilt during this year. There is a slight discrepancy in the values for 1992–93, 1994–95 and 2002–03 between the above graph and the graph in the MDBC Information paper—but the overall trend is consistent.

Figure 9: Total number of Murray cod passing through the Torrumbarry Weir Fishway



Data Source: Terry Holt, Reservoir Controller, Torrumbarry Weir.

Figure 10: Dominant class and species of native fish that ascended the Torrumbarry fishway, 1991-92 to 2002-2003

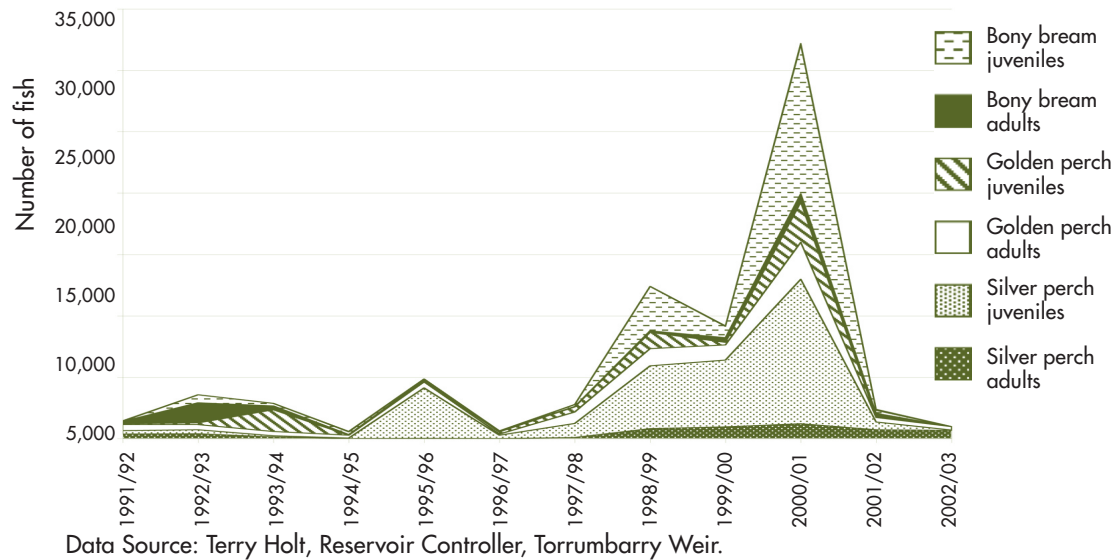


Figure 11: Total number of native silver perch and introduced European carp passing through the Torrumbarry Weir Fishway

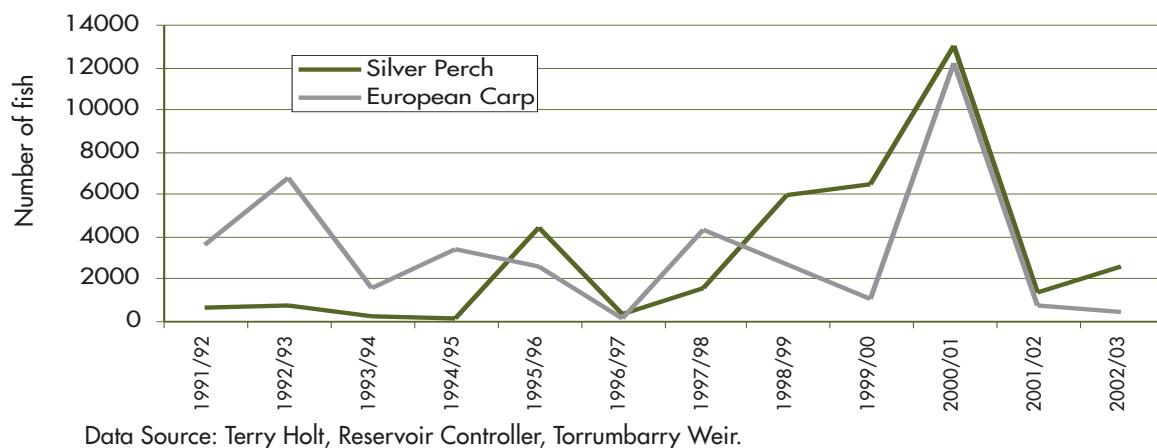
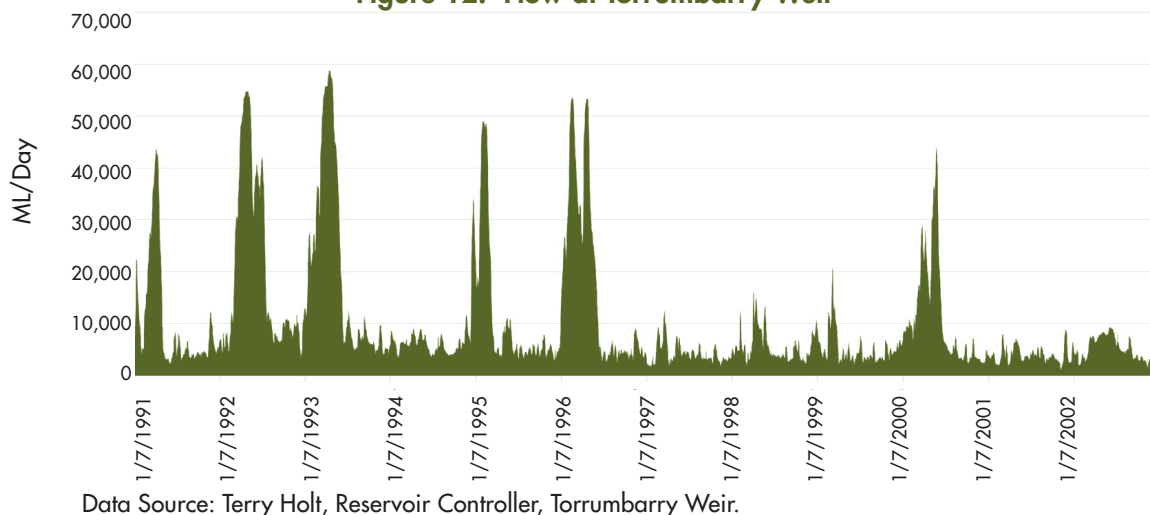


Figure 12: Flow at Torrumbarry Weir



The peak in European carp, silver perch and Murray cod numbers at the Torrumbarry Weir in 2000–2001 does not appear to correlate with flood events in this section of the Murray River over the period July 1991 to June 2003, Figure 12. However, the peak does appear to correspond with a 300 gigalitre allocation to the Barmah forest in the year 2000 to prolong major bird and fish breeding stimulated by natural flooding (see ‘Discussion’ below).

3.8 Sediment & Nutrient Loads

The Australian Bureau of Statistics (ABS) report that discussed water diversions as an indicator of river health (see section 3.4), acknowledged that, ideally, more direct measures of river health than the quantity of water extracted from the system should be used, but commented that ‘It is difficult to obtain national time series data that encapsulate the changes in Australia’s natural capital’ and ‘...such data are unavailable for much of the country, so we focus on water use, and consider the proportion of Australia’s water management areas within which water extraction is *thought* to be sustainable’ [emphasis added]. This statement suggests that the ABS is prepared to substitute opinion for measured and relevant environmental statistics. Furthermore, time-series data (in other words, trends) with respect to water quality indicators *are* available and have been measured for our major river systems for many decades.

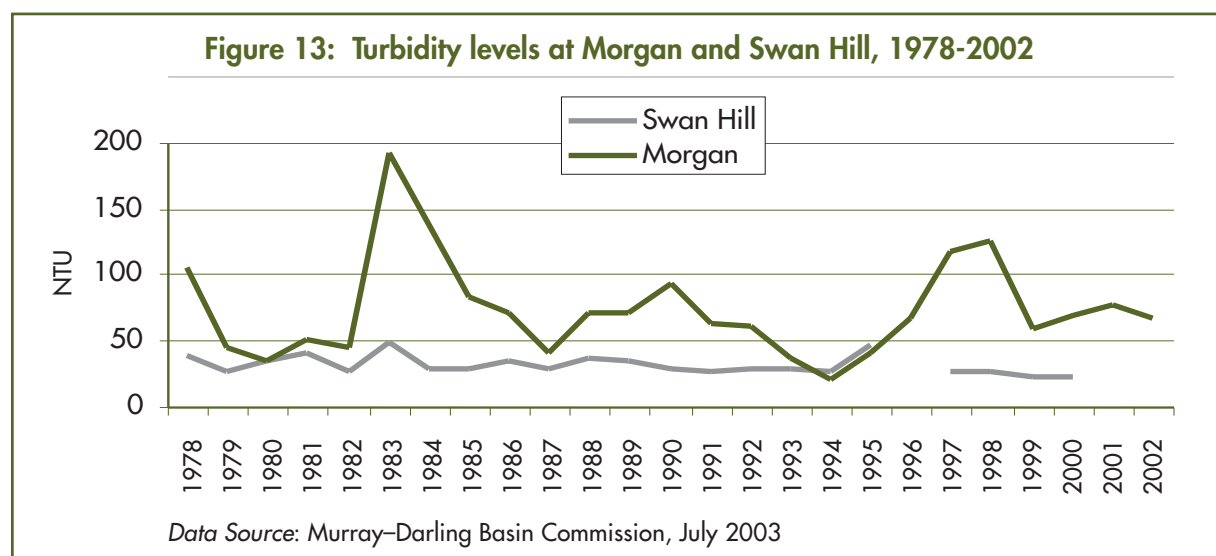
According to the *Australian Water Resources Assessment 2000*, we spend \$142–168 million each year on water-quality monitoring. We have already considered the salinity data (Section 3.5), but what is

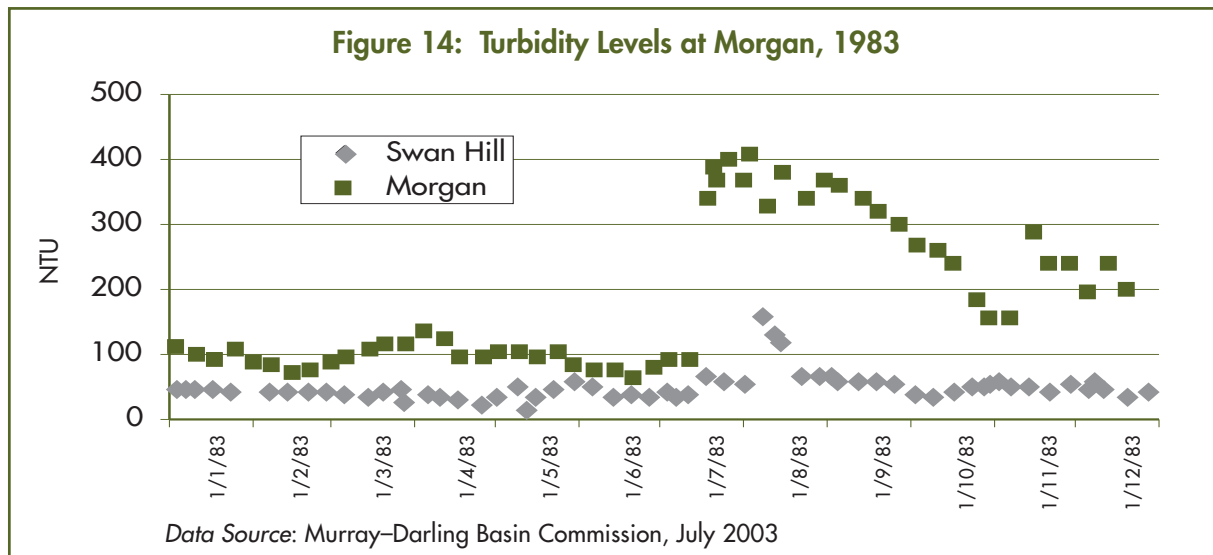
the situation with respect to other key water-quality indicators, including turbidity, nitrogen and phosphorus levels?

Turbidity is a measure of the suspended sediment load. Turbidity levels generally rise with increased discharge (for example, increased rainfall). Australia’s inland river systems are considered to be naturally turbid. Since European settlement, the most significant change to water quality in many inland river systems is thought to be an increased sediment input from the early years of land clearing and the introduction of sheep, cattle and rabbits. As a result of improved management practices over recent decades, erosion is likely to have stabilized or reduced to pre-European levels.⁵²

Data sourced directly from the MDBC, show that turbidity levels (measured in nephelometric turbidity units, or NTUs) at Morgan fluctuate but with no apparent trend, Figure 13. Turbidity levels upstream at Swan Hill appear to be relatively stable, Figure 13. Turbidity has been measured at both sites since 1978. Average yearly turbidity levels have *not* increased over this period.

Mean daily turbidity levels at Morgan exceeded 400 NTU in July 1983, Figure 14. The relatively high turbidity levels during the second half of 1983 contributed to the high yearly average in 1983, Figure 14. The high levels probably resulted from drought-breaking rains carrying higher than usual sediment loads because of increased erosion from reduced vegetation during the drought in the early 1980s. During years of low mean turbidity, mean daily values for both Morgan and Swan Hill are typically in the 20–40 NTU range.





The most detailed study of turbidity within the Murray–Darling Basin is an analysis of flow in the Murrumbidgee River at Wagga Wagga, NSW, from 1949 to 1990. This study found that most sediment was discharged during years of high flow, with the flood years of 1950, 1952, 1956 and 1974 contributing approximately 35 per cent of the sediment load for the 41-year period.⁵³ High concentrations were short-lived. There was no trend of increasing concentrations over time.

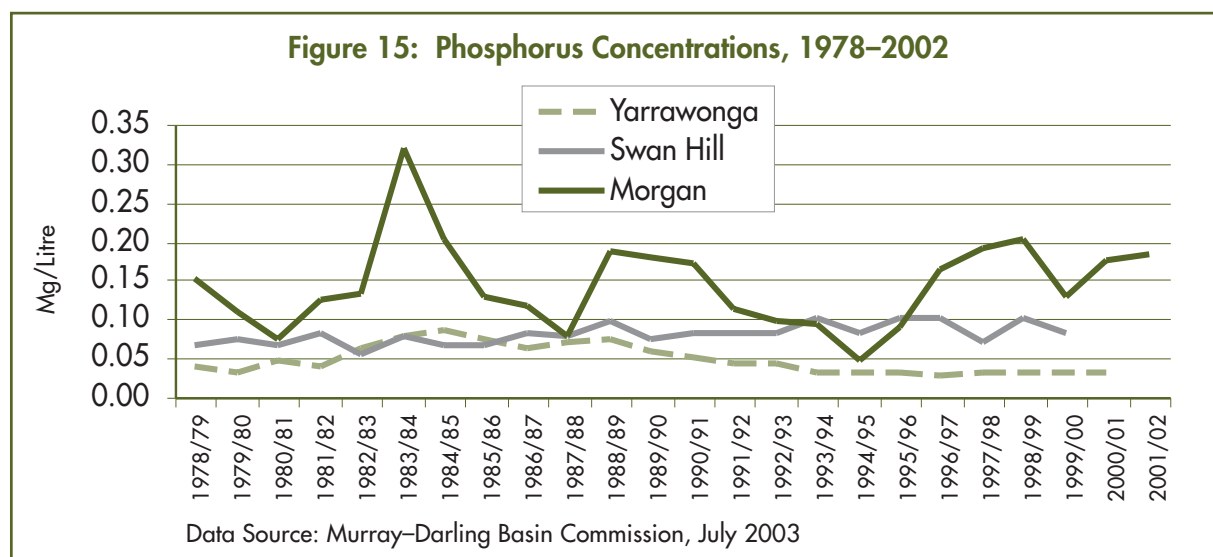
Interestingly, the study also determined that approximately 14 years of daily data are required to produce a mean annual load for Wagga Wagga with an acceptable level of uncertainty. Related studies determined that most of the sediment came from upstream tributaries⁵⁴ and most of this sediment is deposited immediately downstream of Wagga Wagga

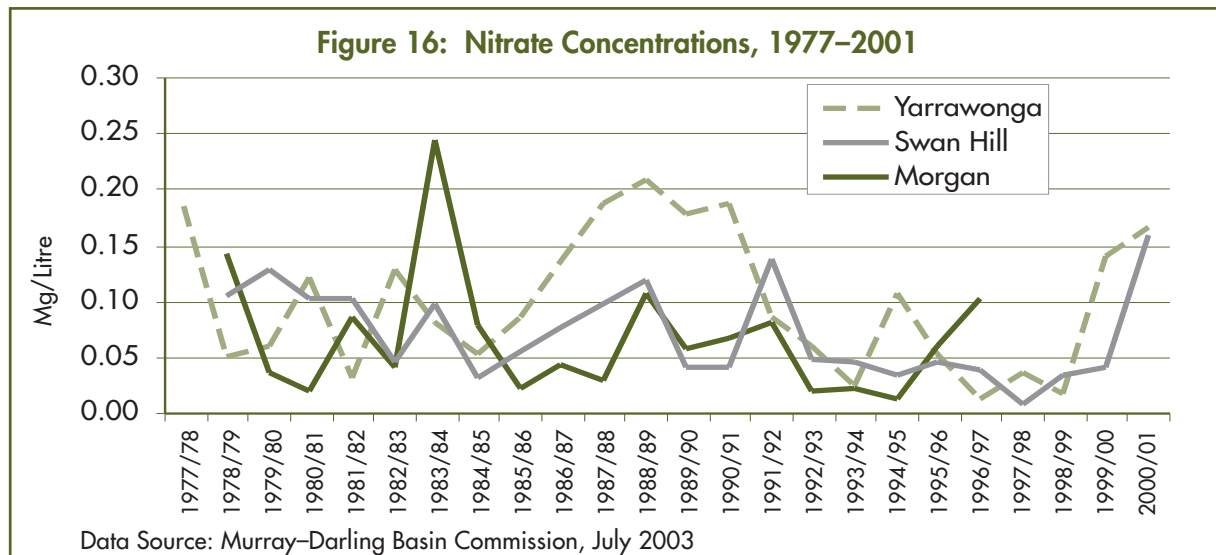
with less than 10 per cent reaching the Murray River 870km downstream.⁵⁵

Despite an absence of supporting data, the contention that the sediment load of the Murray River (measured through turbidity) is increasing, continues to be promulgated.⁵⁶

It is generally believed that algal blooms in inland rivers are due to elevated nutrient levels, particularly phosphorus. While it was thought previously that the major sources of these nutrients were agricultural fertilizers, sewerage treatment plants and feedlots, the most recent and relevant report on the MDBC Website suggests that a large proportion of the phosphorus may come from natural sources, in particular basalt-derived soil.⁵⁷

Whatever the origin of the phosphorus, a plot of yearly average phosphorus levels (Mg/l) for key sites





in the middle and lower Basin show levels have fluctuated but with no increasing trend, since data were first collected in 1978, Figure 15. The peak in 1984–85 may correspond with increased relative inflows from the Darling River system.

High nitrate levels can be an indication of excess runoff from agricultural fertilizers. Nitrate levels also fluctuate, but with no increasing trend, at least since levels were first measured by the MDBC in 1977, Figure 16.

3.9 Red Gums

As vast numbers of 300-year old red gums die along the Murray floodplain due to extreme drought following a severely depleted river flow, we must ask how much longer can we survive as a nation without changing the way we use water.

The Wentworth Group, 2003

In 1994, the Council of Australian Governments (CoAG) consisting of the Prime Minister, Premiers, Chief Ministers and the President of the Australian Local Government Association agreed to the implementation of a water reform process with the objective of achieving a more efficient and sustainable water industry. Underpinning the reform agenda was a commitment to minimize the ‘unsustainable use of our precious water resources.’⁵⁸ Many reforms have been implemented, including catchment-based plans (that include an environmental flow component) now underpinning water allocation across much of Australia. Other aspects of the water reform framework are still being determined, notably water property rights and trading issues.

In the lead-up to the CoAG meeting in August 2003, the Wentworth Group released a paper titled *Blueprint for a National Water Plan*. Funded by the World Wildlife Fund (WWF) and given legitimacy through the involvement of the CSIRO, the Wentworth Group has been accorded great respect and standing by the media, and apparently by government as well, on the basis that its members deal in science—in facts. Many of the purported facts in its documents, however, including the assertion (see the quotation above) that vast numbers of red gums are dying as a consequence of depleted river flow, are misleading.

During the recent drought, and citing significant media interest as the catalyst, the MDBC undertook a preliminary investigation into observed river red gum decline.⁵⁹ The report clearly states that findings were based on visual assessment and that this method of assessment can be quite subjective. Quantitative, physiologically-based tree health data were not collected because of ‘time limits imposed on this Project’.

While the Wentworth Group cites this study exclusively as evidence for vast numbers of 300-year-old trees dying along the Murray River, the survey did not distinguish the number of trees visually assessed as stressed from the number of trees actually dying, and does not comment on the likely age of the trees. The report stated that the problem is limited to the lower section of the Murray and, in particular, that while many of the trees on the riverbank remain healthy, the problem is the health and regeneration of floodplain trees with, ‘80 per cent of trees on the River Murray floodplain in South Australia stressed



Swan Hill 1896, view of Murray River from upstream of punt. The absence of riparian vegetation is striking. There are two schools of thought: one attributing the absence of river red gums to the impact of logging; a second claiming aboriginal burning impacted on river red gum regeneration and resulted in an open landscape. Note there are no tree stumps in the photograph.



Swan Hill 1996, view of Murray River from bridge that now crosses the river at about the same spot as the punt once did. There are now healthy river red gums on both banks of the river.

to some degree, with between 20–30 per cent of them severely stressed’.

The report suggests that the symptoms exhibited by the trees are, ‘not surprising as this part of the catchment is in its sixth year of drier than average conditions’ but then goes on to conclude that the ‘tree decline’ is due to a combination of the Basin-wide drought, reduced flooding regimes and rising saline groundwater. No studies or data are cited to support the contention that groundwater levels are rising.

Furthermore, the report is not consistent on the issue of rising groundwater, proposing that there is a need to replenish groundwater sources because levels are currently low as a consequence of the reduced flooding.

River red gums are not unique to the Murray, but occur naturally throughout Australia in all mainland States. River red gums and black box trees tend to dominate the Murray River landscape because of their capacity to tolerate relatively high levels of water stress, flooding and salinity and also their capacity to be opportunistic and variously access surface and groundwater.

A recent study of black box on the Chowilla floodplain (eastern South Australia) had hypothesized that trees would become more reliant on groundwater following river regulation, but surprisingly the study concluded that river regulation has had little effect on tree water sources over time.⁶⁰ The analysis constructed an historical record of soil water versus groundwater use from 1900 to 2000 based on stable isotopes from black box tree rings.

Relative to South Australian, river red gum populations along the New South Wales and Victorian sections of the Murray are considered healthy and continue to support commercial forestry operations. A 1996 audit of river red gum forests in New South

Wales and Victoria gives an indication of the potential size and economic importance of these forests, with 86,112 m³ of sawlogs, 51,000 m³ of railway sleepers and 31,000 tonnes of chipwood harvested annually.

The Barmah-Millewa Forest (between Deniliquin and Echuca, Map 1) has been identified as a priority site for receiving additional environmental flow.⁶¹ A review of the history and management of this forest⁶² gives an indication of the current health of this forest relative to earliest records. In the early 1800s, the forest

is thought to have been more open than it is today and composed of fewer, larger, older trees. During the late 1800s, large quantities of timber were cut for building and operating river boats, gold mining and as sleepers for local and overseas railways. The extent of the logging, including along the entire river frontage to a distance of approximately three kilometers from the River bank, resulted in concern that the forest would be entirely cut out. A Conservator of Forests was appointed in 1888. His focus was on protecting the forest from over-cutting, controlling over-grazing, introducing silviculture treatment and protecting the forest from fire. Export duties were imposed to reduce timber removal. During this period the average annual harvest of Victorian red gum is estimated to have been approximately 48,000m³. The current extent of the Barmah forest (23,000 hectares) is thought to be a result of the extensive regeneration that also occurred at this time, in part a consequence of wet years during the 1870s coinciding with the decline of Aboriginal burning practices and preceding the introduction of sheep, cattle and rabbits.

Significant quantities of timber continued to be harvested from the Barmah forest during the 1900s. There was an official assessment of the Barmah forestry resources in 1929–30 and then again in 1960–61. The 1960–61 assessment indicated a considerable increase in growing stock and total sawlog volumes, notwithstanding that significant volumes had been harvested in the intervening period and despite the fact that river regulation since the construction of the Hume Dam in the 1930s had changed flow regimes.⁶³

An assessment was again conducted in the late 1980s. By this time, however, the focus had changed from assessing the forest for its timber resources to recognizing its value as a wildlife habitat. The Barmah forest was listed as a Ramsar site⁶⁴ in 1982 making it a 'Wetland of International Importance' because it is, 'a particularly good representative of a natural or near-natural wetland' and 'regularly supports more than 20,000 waterbirds.' According to the 2002 *Barmah Forest Ramsar Site Draft Strategic Management Plan*,⁶⁵ 'Barmah is of special value for maintaining the genetic and ecological diversity of the region because of its size, variety of communities and its high productivity.'

Over recent years, the Victorian Government has regulated down commercial forestry activities to the extent that commercial harvesting is now limited to 2,500 hectares with a limit of 370m³ of sawlogs per annum from the Barmah forest.

The impression given in the Wentworth Group's documents, and generally reported in the media—that vast numbers of ancient red gums are dying along the entire length of the Murray River—is not substantiated by the available evidence.

4. DISCUSSION

Rather than employ scientists whose aim it is to find out about the world because it interests them, government agencies now instead employ managers whose aim it is to tell us, often at the behest of environmentalists, how we can and can't enjoy our natural heritage.

Bob Carter 2003

It would appear that the more distant we are from an environment, the more likely we are to believe it is in crisis.⁶⁶ Most Australians live in cities a long way from the Murray River. We are dependent on media reports as a primary source of information. Not only do 'bad news' stories sell more papers, but 'bad news' stories with a human touch—villains in the form of irrigators who take water from red gums and fish—sell even more papers.

The media are the gatekeepers, but ultimately they rely on scientists to give authority to their stories. We rightly expect our scientists and research institutions to give us an honest appraisal of the situation. After all, research is fundamentally about establishing the facts. The available data do *not* suggest that indicators of river health show general decline. Indeed, with the possible exception of native fish stocks, the river environment appears to be in a relatively healthy state. Yet this is seldom the story presented by key research institutions which overwhelmingly promote the myth of an ecological disaster—a crisis.

It is not generally understood that the many scientific reports that have led to the perception that the River is in poor health actually make their comparisons with a natural river, but a natural river with water. The Murray River flows through a semi-arid landscape and there will inevitably be droughts. Without dams and locks, the river's water level will fluctuate wildly—gushing and then running dry, potentially leaving stagnant billabongs in its wake. When the explorer Charles Sturt discovered the Darling River in the dry season of 1829 he found the water too salty to drink. A year later, again at the

Darling, he found that 'The waters, though sweet, were turbid and had a taste of vegetable decay as well as a slight tinge of green'. These observations, which pre-date European agriculture in Australia, indicate that the catchment can be naturally highly saline and turbid with high levels of blue-green algae.

As a consequence of the engineering works, in particular the Snowy Mountains Hydroelectric scheme, the Murray–Darling system now has a storage capacity of approximately 36,645 ggalitres. When this is combined with an average annual flow of approximately 24,000 ggalitres, the system has a *potential* total annual capacity of approximately 60,465 ggalitres. Although diversions have increased over the last 50 years to 11,041 ggalitres, because storage capacity has increased at a much greater rate, the actual percentage of water used by irrigators relative to the system's total *potential* capacity has only increased marginally from 13 per cent in 1950 to 18 per cent in 2002. Permanent water in the dams has benefited not only agriculture but increased the carrying capacity of large areas for native wildlife.

While the impression we have been given is that up to 80 per cent of the Murray River's average annual flow is diverted for irrigation, this is a misleading representation of the MDBC's hydrological modelling. The reality is that diversions for irrigation average 34 per cent of total Murray River inflows, while approximately 41 per cent of inflows flow to the sea in an average year. Most key reports published by the MDBC do not present the information in a form where the total water budget can be understood in this way. Instead, there is an emphasis on diversions and on comparing actual flows with natural flows estimated from computer modelling studies.

If the ultimate objective is a natural river, then we must reject the cultural heritage and economic wealth created by the engineering works, including the Snowy Mountains Hydroelectric Scheme. If we want a truly natural system then the problems of saline water and algal blooms, particularly during droughts—phenomena endemic to the Murray—should be accepted as natural rather than decried as unhealthy. 'Healthy' and 'natural' may be mutually exclusive in the context of a semi-arid environment. The current approach, where a decline in all indicators of river health is assumed, and more water is promoted as the solution, is not supported by the available evidence.

The MDBC information paper on fish⁶⁷ that was developed in response to the landholder's survey which

suggested that native fish stock were improving, began by acknowledging the 'gulf between scientific advice on native fish populations in the River Murray System, and the beliefs of many people that live and fish along the river'. The difference is about two different world views. The position of the scientists, while purporting to be based on an evaluation of the data, perhaps really just reflects their strong conservation ethic and belief in 'the Litany': that resources are running out, that air and water are becoming more polluted—even in situations when there is tangible evidence of improvement.⁶⁸ In contrast, those who live and fish along the river have a less pessimistic philosophy. The locals believe that the end of commercial fishing, a substantial restocking effort, significant improvements in on-farm practice and the construction of the many salt-interception schemes must have done some good for the environment.

River salinity levels were particularly high during the drought of the early 1980s. But thanks to the major salt-interception schemes built over the last 20 years, the salinity level at Morgan—a key site just upstream from the offshoot pipes for Adelaide—has actually halved. That salinity levels continued to improve during the recent drought surprised many people and contradicted information on the CSIRO Website. The CSIRO has still not made public acknowledgement that salinity levels are falling. Instead, they continue to promote the impression that groundwater and salinity levels are rising. The reality is that irrigators along the Murray River have met the challenge of rising groundwater and are effectively managing the situation to the extent that levels have dropped over almost 90 per cent of high-risk irrigated land since 1995. Importantly, CSIRO fails to recognize our ability to intervene with engineering solutions when required.

That salinity levels are generally improving, groundwater levels falling and nitrogen, phosphorus and turbidity levels stabilizing should not be surprising given the billions of private and public dollars spent on land care initiatives over the past two decades. These facts are good news, and should be more widely acknowledged.

Aquatic macroinvertebrates (bugs) are sensitive to pollutants and as such are a good measure of river health. The MDBC used macroinvertebrates as the surrogate for all biota in its recent assessment of Murray River health. However, instead of comparing macroinvertebrate levels now with what they have been over recent decades, comparisons were made with

hypothetical pristine environments. In the context of the Murray River—a system that has been extensively modified with dams and locks—this choice of comparison could be construed as ensuring the river fails this important test of well-being.

The extent of the subjectivity potentially associated with modelling pre-European conditions based on limited data is illustrated by the revised findings for the lower Balonne—from severely impaired to near-pristine. That the revision only followed an outcry from local irrigators is significant and illustrative of the potential problem when conclusions are based on very limited data collection coupled with computer modelling. The MDBC's 2001 booklet *Snapshot of the Murray–Darling Basin River Condition*, in which the false picture was included, however, has never been revised nor have the efforts of the local community in pointing out the scientific errors been acknowledged. Instead, the document containing the incorrect information continues to be cited as an indication of the declining health of the Murray–Darling Basin system.

The status of native fish populations is potentially an important indicator of river health. With respect to the Murray River, expert opinion estimates that native fish numbers are currently at 10 per cent of pre-European levels. Given the closure of the commercial fisheries over the last decade and a significant restocking effort, as the locals suggest, it might be expected that native fish numbers would now be on the increase. Given the importance of the issue from both an environmental and economic perspective, the general paucity of statistics is remarkable and limits any detailed assessment of the current situation. It is evident, however, that government scientists have sought to establish and maintain the perception of declining native fish stock.

From an analysis of the commercial catch data, in conjunction with an analysis of the number and species of fish ascending the fishway at Torrumbarry weir over the last 11 years, I have made the following observations:

- In the early 1960s, there appeared to be a dramatic collapse in the Murray cod fishery;
- Over the last 40 years, Murray cod numbers have been relatively stable but low;
- Understanding what caused the apparent collapse in population numbers in the 1960s may be critical to developing effective policies to build current populations;

- Numbers of the endangered native silver perch may be on the increase and were recorded ascending the Torrumbarry fishway at similar numbers to European carp—an introduced pest species.

There are stressed River Red Gums and their plight was documented following a survey by the Murray–Darling Basin Commission in March 2003. This survey has been quoted as evidence for the claim that vast numbers of 300-year-old trees are dying along the entire Murray River. However, the survey did not distinguish the number of trees visually assessed as stressed from the number of trees actually dying and does not comment on the likely age of the trees. The problem was acknowledged as being limited to South Australia and due as much to the extended drought as river regulation.

In November 2003, State and Federal Agricultural and Environment Ministers agreed to return up to 500 gegalitres of water to the Murray River with a particular focus on six 'icon' sites. While less than the 1,500 gegalitres recommended in the MDBC report, the quantity is nevertheless significant. The water will have to be bought back from irrigators and can be expected to cost Australian taxpayers in excess of \$600 million. Rural communities expect reduced agricultural output as water is sold and some agricultural land retired.

The plan has been widely reported as the first time water has been given back to the Murray River. Again a myth is being promulgated. For example, the Barmah forest is one of the six icons and this forest has enjoyed an environmental flow allocation of 100 gegalitres per year since 1993. Allocations for the Barmah forest are typically carried over from year to year and then used to supplement floods. For example, 300 gegalitres was used in the year 2000 to prolong major bird and fish breeding stimulated by natural flooding.

An additional 80 gegalitres is now being proposed for the Barmah forest. This would bring its allocation with the 100 gegalitres already allocated, and a potential 25 gegalitres from Victoria's Flora and Fauna Bulk Entitlement for Northern Victoria, to 205 gegalitres. This, in effect, represents an investment by the Australian taxpayer of approximately \$246 million for the watering of this forest at current prices for irrigation water.

The 2002 management plan for the Barmah forest clearly states that it is a wetland area of exceptional

diversity and high productivity in terms of fish, birds and red gums. Clearly, since 1993, we have supported this diversity by making a water allocation to this forest of 100 giganlitres per year. Yet the media headlines, reflecting information in media releases and reports from high-profile scientists, suggest that most red gums along the Murray River are dying and that we are not currently allocating water as environmental flow.

The Australian Conservation Foundation (ACF) has indicated that it is not interested in 'engineering solutions' or the allocation of water for 'two or three museum pieces' with reference to the Barmah Forest and other 'icon sites'.⁶⁹ The ACF and others have suggested that real floods, but 'smaller than those that had caused major damage'⁷⁰ are needed to 'save the environment' and continue to campaign for the release of 1,500 giganlitres of water 'for the river'. It has been suggested that the process of returning the river to a natural state begin with the dismantling of the Torrumbarry and Euston weirs.⁷¹

The extent to which conservationists and government scientists have embraced a romantic reconstruction of nature that has little connection with reality, is evident in the MDBC report on the survey of the River Red Gums. The Summary begins, 'The shaping of the landscape by Indigenous people was mostly harmonious, and in comparison, the dramatic changes brought about by river regulation and European land use practices is relatively new in this timescale. Therefore, it is probable that we are only now beginning to see the widespread impacts of regulation and floodplain ecosystem response.' The reality is that much of the current extent of, for example, the Barmah forest, is thought to be a consequence of floods in the 1870s that occurred after the decline of Aboriginal burning that severely impacted on red gum regeneration. It is well documented that the Aboriginal presence, far from having a benign impact on the landscape, resulted in the extinction of many animal species⁷² and maintained the Australian flora, particularly in semi-arid regions, in a fire-mediated sub-climax.⁷³

In many regions, in the absence of fire, there has been a general and rapid thickening of woodlands resulting in more trees now than there were before European settlement. In other regions which were extensively cleared, including the Mallee region, problems associated with rising water tables should have already manifested themselves. Rising

groundwater was clearly a problem in the 1970s. However, since the 1980s, surface and subsurface drainage schemes and other land management techniques have brought the problem under control. Yet, MDBC reports continue to rehash old issues and invoke misleading notions of the landscape pre-European settlement. This suggests a lack of discipline and knowledge from the scientists involved.

5. In Conclusion

As a nation we are unclear how we really want the Murray River to be managed. We have not really thought through the implications of 'natural' as opposed to 'healthy' in the context of an old river that runs through a semi-arid environment. In such an environment, during the inevitable frequent droughts, 'natural' logically equals dead fish and stressed red gums as surface water recedes and groundwater levels drop.

Our scientists are currently compiling environmental indicators of river health all-the-while making their comparisons with hypothetical pristine environments where 'pristine' falsely equals 'well watered'. If, instead, we set our management goal as improving trends based on current conditions (that is, a healthy working river), then the issue of trying to estimate the natural or pristine environment becomes redundant.⁷⁴

The current environment is so modified as a consequence of the engineering works constructed to 'drought proof' the region that there is a need for honest discussion of these issues. After such a discussion we may be in a position to consider the real costs and benefits of watering river red gums as opposed to food crops—including when, how and who should pay.

Assuming that the agreed objective is a healthy river environment rather than a natural environment, there will be a need to separate the myths from the reality and to start making relevant comparisons. There will be a need to apply the scientific method in a disciplined way, including through the direct measurement of useful indicators so that relevant environmental statistics can be compiled.

If, on the other hand, the agreed objective is a natural system, then prepare to begin dismantling the Snowy Mountains Scheme at the River's source and the barrages at the Murray's mouth—but beware: the economic impact will be significant.

ENDNOTES

- 1 CSIRO Australia, *The Helix magazine*, February–March 2003.
- 2 See <http://www.acfonline.org.au/asp/pages/print.asp?IdDoc=1500> (8 November 2003)
- 3 MDBC, 'Ecological Assessment of Environmental Flow Reference Points for the River Murray System', Interim report prepared by the Scientific Reference Panel for the Living Murray Initiative, August 2003; See <http://www.acfonline.org.au/asp/pages/print.asp?IdDoc=1500> (8 November 2003); CSIRO Australia, *The Helix magazine*, February–March 2003.
- 4 The Wentworth Group of Concerned Scientists, 'Blueprint for a National Waterplan', July 2003.
- 5 Whalquist, A., 'National challenge needs steely courage', *The Australian*, 31 July 2003; 'Drying Out', *The Economist*, 12 July 2003; 'Rann calls for Murray crisis meeting', *ABC Online*, 13 August 2003; Robinson, R., 'No quick solution to an overdose of salt', *The Australian Financial Review*, 14 August 2003.
- 6 'Water—are we being sold down the river?', Petition to the Ministerial Council from the Murray Valley Community Action Group, August 2003.
- 7 In the early 1990s there was recognition that the Barmah forest needed more water. Irrigators in NSW and Victoria made a voluntary contribution of 100 gigalitres per year from their then allocations for this forest. NSW Murray Water Sharing Plan, NSW Department of Land and Water Conservation December 2002; Brett Tucker, Murray Irrigation Ltd, personal communications, November 2003.
- 8 See <http://www.atse.org.au/publications/focus/focus-powell.htm>
- 9 See <http://www.abs.gov.au>
- 10 Lomborg, B. *The Skeptical Environmentalist, Measuring the Real State of the World*, Cambridge University Press, Cambridge, 2001.
- 11 MDBC, *An Audit of Water Use in the Murray-Darling Basin*, June 1995.
- 12 Annual inflow was calculated during the 2000 National Land and Water Audit, Andy Close, Manager Water Resources Group, MDBC, personal communications, November 2003
- 13 See, also, Andrew Brown, 'Water Trading in the Murray Darling Basin', The 2003 NSW Local Government Water Management Conference. Taree/Foster August 2003, <http://www.lgov.org.au/docs/policy/water/2003%20wmconf/abrownMDBC.pdf>
- 14 Reference has been made to storage capacity being 25 per cent of runoff (see <http://www.lgov.org.au/docs/policy/water/2003%20wmconf/abrownMDBC.pdf>). However, this figure does not include total capacity, i.e., on-farm storages associated with surface water diversion licences.
- 15 MDBC, *Water Audit Monitoring Report 2000/01*, September 2002.
- 16 Benson, L., A. Markham, R. Smith, 'The Science behind the Living Murray Initiative', Murray Irrigation Limited, Deniliquin NSW, October 2003. See <http://www.murrayirrigation.com.au/download/3176826.pdf>
- 17 MDBC, *An Audit of Water Use in the Murray-Darling System*, June 1995.
- 18 MDBC, *Review of the Operation of the Cap*, August 2000.
- 19 New South Wales Water Resources Council, 'Water Facts', June 1991.
- 20 See <http://www.dlwc.nsw.gov.au/care/salinity/references/execsumm/lachlan.html>
- 21 MDBC, *Murray-Darling Basin Environmental Resources Study*, 1987.
- 22 Hodge, A., 'States cut Murray lifeline', *The Australian*, 31 March 2001; MDBC, *The Living Murray Information Facts Sheet*, No. 11, (see <http://www.the-livingmurray.mdbc.gov.au/content/index.phtml/itemId/15579/fromItemId/2747>)
- 23 'The Impacts of water regulation and storage on the basin's rivers', Education Centre, MDBC Website. See http://www.mdbc.gov.au/education/encyclopedia/water_regulation/water_regulation_impact.htm (26th November 2003)
- 24 MDBC, *Salinity and Drainage Strategy—Ten Years On*, 1999.
- 25 Pradeep Sharma, Senior Modelling Engineer, MDBC, personal communications, July 2003.
- 26 MDBC, 'Ecological Assessment of Environmental Flow Reference Points for the River Murray System', Interim Report, August 2003.
- 27 See <http://www.onlineopinion.com.au/view.asp?article=632> and <http://www.ipa.org.au/Speechesandsubmsns/jmwaterforum2.html>
- 28 Charters, C., M. Stauffacher, G. Walker, T. Hatton, 'Is the River Murray Water Quality Deteriorating? A Salinity Perspective'. (see <http://www.clw.csiro.au/priorities/salinity/rivermurray/index.html>)
- 29 Smitt, C. Jolly, I, Dowling, T, Walker, G., 'Assessment of Historical Data for the Murray-Darling Basin Ministerial Council's End-of-Valley Target Stations', CSIRO Land and Water, Technical Report 40/02, October 2002.

- 30 Cook, PG F.W. Leaney and I.D. Jolly, 'Groundwater Recharge in the Mallee Region, and salinity implications for the Murray River—A Review', CSIRO Land and Water, Technical Report 45/01, November 2001.
- 31 MDBC, *Basin Salinity Management Strategy 2001-2015*, 2001. In particular, see Table 1, Lock 6 to Morgan.
- 32 MDBC, *Salinity and Drainage Strategy: Ten years on, 1999*, 1999. In particular, see Table 4 and sum the first four regions listed for New South Wales (Berriquin, Denimein, Cadell and Wakool).
- 33 Norris, R.H., P. Liston, N. Davies, J. Coysh, F. Dyer, S. Linke, I. Posser, B. Young, *Snapshot of the Murray-Darling Basin River Condition*, MDBC, 2001.
- 34 Bennison, G. Suter, P., 'Macroinvertebrates In The Murray', (Editors Mackay, N., D. Eastburn), MDBC. 1990.
- 35 Benson, L., A. Markham, R. Smith, 'The Science behind the Living Murray Initiative', Murray Irrigation Limited, Deniliquin NSW, October 2003. See <http://www.murrayirrigation.com.au/download/3176826.pdf> page 25 for a discussion of the issues.
- 36 Australian Water Technologies, *Water Quality Review—Stage 2. Data Analysis*, Report to the Murray-Darling Basin Commission, Report Number 50.
- 37 Address to a meeting at Moree, NSW on 6th August 2003, by the Deputy Prime Minister & Leader of the National Party, The Hon John Anderson.
- 38 See http://www.mdbc.gov.au/publications/factsheets/factsheet_nfs.html (Cited 4 November 2003).
- 39 *Draft Native Fish Strategy for the Murray-Darling Basin 2002-2012*, Murray-Darling Basin Ministerial Council, June 2002.
- 40 MDBC, 'Native fish in the River Murray: Status and Trend', Information Paper, (no date).
- 41 Jim Barrett, Manager, Native Fish, MDBC, personal communications, 14 August 2003.
- 42 *Ibid.*
- 43 John Lolicato, Chairman, Wacool Landholders Association, personal communications, August 2003.
- 44 *Fish and Rivers in Stress: The NSW Rivers Survey*, J.H. Harris and P.C. Gehrke (eds). Cooperative Research Centre for Freshwater Ecology, Canberra, 1997. See <http://enterprise.canberra.edu.au/WWW/RiverSurvey.nsf>
- 45 'Good Cod! Anglers refute threatened species claim', *Deniliquin Pastoral Times*, 4 July 2003.
- 46 M. Auldist, 'Riverina Revival' in *Freshwater Fishing Australia*, Issue 63, Winter 2003, page 32.
- 47 Reid, DD, JH Harris, DJ Chapman, *NSW Inland Commercial Fishery Data Analysis*, FRDC Project No. 94/027. December 1997.
- 48 *Ibid.*
- 49 Andrewarta, H.G & L.C. Birch, *The distribution and abundance of animals*, University of Chicago Press, Chicago. 1954.
- 50 *Draft Native Fish Strategy for the Murray-Darling Basin 2002-2012*, see www.mdbc.gov.au
- 51 MDBC, 'Native fish in the River Murray: status and trend', Information Paper No. 4, (no date).
- 52 MDBC, *Rivers as Ecological Systems: The Murray Darling Basin*, 2001. See page 48.
- 53 Olive, L.J., JM Olley, A.S. Murray & P.J. Wallbrink, 'Variations in sediment transport at a variety of temporal scales in the Murrumbidgee River, NSW, Australia. Effects of Scale on Interpretation and Management of Sediment and Water Quality', *Proceedings of a Boulder Symposium*, July 1995, IAHS Publication No. 226.
- 54 Olive, L.J. , J.M.Olley, A.S. Murray & P.J. Wallbrink, 'Spatial variation in suspended sediment transport in the Murrumbidgee River, NSW, Australia. Variability in Stream Erosion and Sediment Transport', *Proceedings of the Canberra Symposium*, December 1994. IAHS Publication No. 224.
- 55 Olive, J.J., J.M. Olley, P.J. Wallbrink & A.S. Murray, 'Downstream Patterns of sediment transport during floods in the Murrumbidgee River, NSW, Australia', *Z. Geomorph. N.F. Suppl.-Bd*, 105, 1996, pages 129–140. Berlin.
- 56 MDBC, 'Ecological Assessment of Environmental Flow Reference Points for the River Murray System', Interim Report, August 2003, see in particular page 13.
- 57 R.L. Oliver, B.T. Hart, J. Olley, M. Grace, C. Rees and G. Caitcheon, *The Darling River: Algal Growth and the Cycling and Sources of Nutrients*, MDBC Project M386, 1999.
- 58 See <http://www.deh.gov.au/water/policy/coag.html>
- 59 MDBC, *Preliminary Investigations into Observed Decline along the River Murray below Euston*, Technical Report 03/03., March 2003.
- 60 Akeroyd, M.D., G.R. Walker and M.B. Kendall, 'Historical water use of *Eucalyptus largiflorens* in response to river regulation and salinity', *Proceedings of the International River Symposium*, Brisbane 2002.
- 61 McKenzie, D., 'Murray Boost Surprise', *The Weekly Times*, 12 November 2003.
- 62 Dexter, B., 'Notes on management of the Barmah River Red Gum forest: past-present-future', Unpublished report, July 2002; Fahey, C., 'Barmah Forest—A history', Department of Conservation, Forests and Land, Victoria, 1986; Department of Sustainability and Environment, 'Forest Management Plan for the

- Mid-Murray Forest Management Area', Revised May 2002. (http://www.dse.vic.gov.au/web/root/domino/cm_da/nrecfor.nsf/TOC/3251B7AD854ADBC1CA256BB9001BF1C2)
- 63 Department of Sustainability and Environment, 'Forest Management Plan for the Mid-Murray Forest Management Area', Revised May 2002.
- 64 Ramsar is the name of the town in Iran where the International Convention on Wetlands was signed in 1971. The convention is an intergovernmental agreement for the conservation of important wetland areas. Wetlands listed under the agreement are referred to as Ramsar sites. See <http://www.ramsar.org>.
- 65 Parks Victoria, *Barmah Forest Ramsar Site—Draft Strategic Management Plan*, October 2002.
- 66 Lomborg, B., *The Skeptical Environmentalist: Measuring the Real State of the World*, Cambridge University Press, Cambridge, 2001.
- 67 MDBC, 'Native fish in the River Murray: Status and Trend', Information Paper Number 4, (no date).
- 68 In *The Skeptical Environmentalist: Measuring the Real State of the World* (Cambridge University Press, 2001) Bjorn Lomborg explains how people lament the poor state of the environment, including that resources are running out, air and water are becoming more polluted, including in countries and situations when there is tangible evidence of improvement. This is referred to as subscribing to the litany of environmental woes.
- 69 Hunt, P., 'Call to save five Murray sites', *The Weekly Times*, October 29 2003.
- 70 Dalton, S., 'Bring on the royal flush', *The Weekly Times*, October 29 2003.
- 71 Hodge, A., 'Dam-buster goes with the natural flow', *The Weekend Australian*, 21 February 2001.
- 72 Lyons, K., F.A. Smith, J.H. Brown., 'Of mice, mastodons, and men—human caused extinctions on four continents', 2002 Denver Annual Meeting, The Geological Society of America (http://gsa.confex.com/gsa/2002AM/finalprogram/abstract_45023.htm); for a discussion of associated issues see: http://www.usyd.edu.au/publications/news/010727News/2707_bones.html
- 73 Burrows, B., 'Tree clearing—rehabilitation or development on grazing land?' *IV International Rangelands Conference*, 1999, Townsville, Australia; Neldner V.J., Fensham, R.J. Clarkson, J.R. and J.P Stanton, 'The natural grasslands of Cape York Peninsula, Australia. Development, distribution and conservation status', *Biological Conservation*, 1997, 81, pages 121–136.
- 74 Benson, L., A. Markham, R. Smith, 'The science behind the Living Murray Initiative', Murray Irrigation Limited, Deniliquin NSW, October 2003.



Caspian Tern with chick. In the year 2000, 300 gigalitres of water was used to prolong major bird and fish breeding stimulated by natural flooding in the Barmah Forest (near Echuca). This forest was listed as a Ramsar site in 1982 because it is a particularly good representative of a natural or near-natural wetland and regularly supports more than 20,000 waterbirds.

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When Mike Nahan asked if I would look at key indicators of the Murray River's health, I thought it would be a fairly straightforward task of reading and analyzing relevant government reports and scientific papers. Instead, I found that the most relevant data were unpublished and not easily available. I am indebted to the individuals who helped me track down this information—in particular, local fishermen, and officers at the Murray–Darling Basin Commission and Murray Irrigation Limited. I would like to acknowledge the work of Terry Holt, Reservoir Controller, Torrumbarry Weir, for collecting detailed information on fish (apparently the only current time-series data available for the river) and for making this information generally available. And I would like to thank colleagues and friends at, and associated with, the IPA for their encouragement and advice—in particular, Alan Moran.

PHOTO CREDITS

Front cover: Murray River water running into Gulpa Creek, near Barmah, just downstream of the Edward River anabranch. Photo taken by Catherine Norwood, Murray Irrigation Ltd.
Map 1: Adapted from an image courtesy of the Murray–Darling Basin Commission.
Photo of Dry River Bed: Courtesy of Daryl McDonald, farmer and fisherman from Murrabit, near Kerang.
Map 2: Adapted from an image courtesy of the Murray–Darling Basin Commission.
Photos at Swan Hill 1896 and 1996: Courtesy of Roy Threadgold, Swan Hill.
The photo of the Caspian Tern and chick was taken by Peter Merritt.

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Dr Jennifer Marohasy joined the IPA on 1 July 2003 as Director of the newly formed Environment Unit. The Unit has been established to provide market-based, science-driven solutions to environmental problems.



Jennifer started life on a cattle station in the Northern Territory before attending boarding school in Brisbane. After completing a science degree at the University of Queensland she worked for seven years in remote parts of Africa in search of biological control agents for some of Queensland worst rangeland weed species. She was awarded the Australian Cattlemen's Union Research Medal in 2001 in recognition of her contribution towards the biological control of rubbervine (*Cryptostegia grandiflora*).

During the 1990s, Jennifer published 12 papers in international and Australian scientific journals and 2 book chapters. Her PhD research challenged the theoretical basis for the protocols then used to test host specificity in potential biological control agents and is recognised as contributing to a paradigm shift in biological control research. In 1998, she was invited by the United States Department of Agriculture to give the keynote address at the annual general meeting of biological control scientists in Hawaii.

Jennifer worked for the Queensland Canegrowers Organisation as Environment Manager from 1997 to June 2003, overseeing the development of an industry-wide best management programme, endorsement of the first commodity-specific code of practice under the Environment Protection Act 1994 (Queensland), development of submissions to government enquiries and also assisted regionally-based officers develop plans and strategies particularly in the areas of environmental management and pest management.
