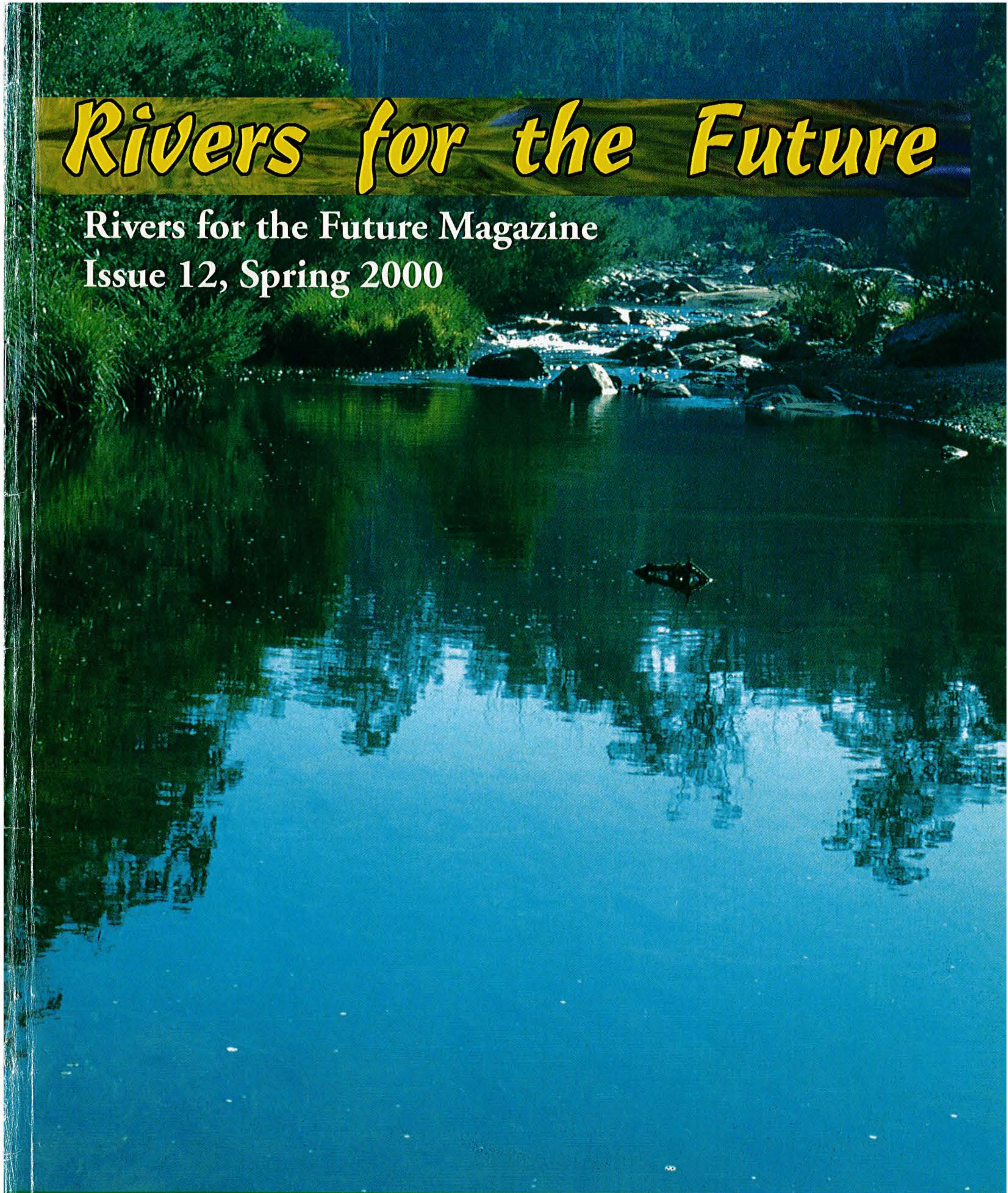
Rivers for the Future



Rivers for the Future Magazine
Issue 12, Spring 2000

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Land & Water Resources
Research & Development Corporation

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Land & Water Resources Research & Development Corporation

LWRRDC Mission

To provide national leadership in utilising R&D to improve the long-term productive capacity, sustainable use, management and conservation of Australia's land, water and vegetation resources. The Corporation will establish directed, integrated and focused research and development programs where there is clear justification for additional public funding to expand or enhance the contribution of R&D to sustainable management of natural resources.

Key to acronyms used in this publication

AFFA - Agriculture, Fisheries, Forestry - Australia
ARCWIS - Australian Research Centre for Water in Society
CRDC- Cotton Research and Development Corporation
EA - Environment Australia
EFDSS - Environmental Flows Decision Support System
FNARH - First National Assessment of River Health
LWRRDC - Land and Water Resources Research and Development Corporation
MDBC - Murray-Darling Basin Commission
NEMP - National Eutrophication Management Program
NRC - National Rivers Consortium
NRHP - National River Health Program
NSESD - National Strategy for Ecologically Sustainable Development
NWRDP - National Wetlands R&D Program
RRMP - River Restoration and Management Program

Rivers for the Future

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Cover: Genoa River, Victoria - Photo Victorian EPA

Editorial

This issue of Rivers for the Future includes a marvellous range of articles, from the extremely positive actions of Waterwatch, to new knowledge on previously neglected inland rivers and coastal estuaries, to some warnings on issues and activities still largely ignored by the science and policy community.

It is amazing to think that rivers are so integral to Australian life and valued by the community but afforded so little protection. Whilst there is a commitment within Australia's Biodiversity Strategy to protect biodiversity through reserves, and progress has been made on setting aside forest, grassland and marine ecosystems for conservation, there is no process in place for river systems despite the immediacy of the threats. Dr Helen Dunn, in her article 'Identifying and protecting rivers of high ecological value' argues for a National Strategy for establishing a Comprehensive, Adequate and Representative system of protected rivers, which has maintenance of conservation values as the over-riding management goal. Dr Dunn has developed a scheme for identifying high value rivers based on 'naturalness', 'representativeness', 'diversity', 'rarity' and 'special features'. These criteria are beginning to assist managers plan for a system of river reserves, classify river groups of high priority for conservation, select rivers for priority conservation intervention, and incorporate river ecological values into catchment management.

The issue of salinity in Australia has been known from the early 1900s and well recognised by scientists and governments since the 1970s. With rapidly increasing land and stream salinisation now occurring in eastern Australia, the issue has risen to new community and political heights. Concerns for agricultural production and rural and urban infrastructure are now well recognised but astonishingly the ecological impacts of salinity continue to receive scant attention. A recent review of the ecological impacts of salinity on rivers and wetlands by Dr Paul Bailey and Dr Kimberley James (published by LWRRDC) identified vast gaps in knowledge of the effects on flora and fauna and consequently on riverine and wetland ecosystem functioning. The small amount of information available is sufficient to ring alarm bells - sublethal and lethal effects across all biotic groups at relatively low salinities (1000-2000 mg/L total soluble salts). Ecological costs of salinity are likely to far outweigh other costs, so research investment in this area must become a high priority.

To finish this cautionary tale on a positive note, Dr Jane Roberts has just published through LWRRDC a new manual on the water requirements of large floodplain wetlands. As noted by Jane, floodplains have also been weakly researched in Australia and there has been a dearth of knowledge on the ecological connections between floodplain ecosystems and river flows. The new manual is built on knowledge gained from a number of substantial studies and will provide managers and community groups with much needed assistance in floodplain management.

This is the final edition of Rivers for the Future. The magazine has been extremely successful is disseminating information and results from LWRRDC's river programs over the past three years.

The reasons for deciding to conclude the magazine are that:

• A number of the programs featured in Rivers for the Future, such as Wetlands, the National River Health Program, and the National Eutrophication Management Program are drawing to a close.
• LWRRDC has reviewed its printed publications and decided to reduce the number, to strengthen a smaller number of publications, and to direct additional resources to the website and Internet based information.

Editorial continued

• The Riparian Lands Program magazine RipRap will continue to be published and will be broadened in scope to cover a wider range of river management issues.

RipRap will also be the main newsletter for disseminating information and results from projects funded by the National Rivers Consortium. The Consortium is now up and running and initiating projects on:

- Protecting rivers with retained natural values
- Restoring degraded rivers
- Training river managers
- Turning research into practical river management solutions
- Regional catchment projects

A check of our database shows that about two thirds of people who receive Rivers for the Future also receive RipRap. If you are not one of these people, and you would like to receive RipRap in the future, please register on our website at <www.rivers.gov.au/subscribe.htm>.

I am indebted to Russell Moran for his superb work in coordinating and publishing the magazine over the last 4 years. I am also grateful to Leith Boully and Glenn Conroy for their editorial assistance.

Dr Nick Schofield
Editor

NEWS IN BRIEF

Books

Assessing the biological quality of freshwaters - RIVPACS and other techniques. Edited by John F. Wright, David Sutcliffe and Mike T. Furse and published by the Freshwater Biological Association, Ambleside, June 2000; 400 pages, ISBN 0 900386 62 2. Price £40 softback, £60 (including postage). FBA members get a 25% discount. This book is based on a 1997 international workshop that took place in Oxford England that was co-sponsored by LWRRDC and EA through the NRHP. It provides an up-to- date account of developments in predictive bioassessment systems for classifying and monitoring fresh waters, based on macroinvertebrates. The FBA can be contacted by E-mail at <info@fba.org.uk>.

Global Perspectives on River Conservation - Science, Policy and Practice. Edited by P J Boon, B R Davies and G E Petts. Published by Wiley (<www.wiley.co.uk>), ISBN 0 471 96062 4, cost £125. A review of the current state of river conservation world -wide, providing a regional assessment of conservation strategies and practices and a synthesis of opportunities for the conservation and management of rivers. The chapter on river conservation in Australia and New Zealand was authored by Nick Schofield, Kevin Collier, Peter Davies, John Quin, Fran Sheldon and Martin Thoms.

Recent LWRRDC publications:

The National Eutrophication Management Program - A Review - LWRRDC Occasional paper 05/00 ($12 - photocopy); **Cost of Algal Blooms** - LWRRDC Occasional Paper 26/99 ($20); **A Rehabilitation Manual for Australian Streams,** (Vols. 1 & 2) ($25 set); **Riparian Land Management Technical Guidelines** (Vols 1& 2) ($25 set); **Riverine and Wetland Salinity Impacts - Assessment of R&D Needs** - LWRRDC Occasional Paper 25/99 ($10); **Identifying and Protecting Rivers of High Ecological Value** - LWRRDC Occasional Paper 01/ 00.($20); **Estimating the Water Requirements for Plants of Floodplain Wetlands** - LWRRDC Occasional Paper 04/00 ($20).

Available from the AFFA Shopfront, phone 1800 020 157.

Waterwatch: Communities Caring for Catchments

Craig Donovan, Wetlands Unit
Environment Australia

"We tend to take fresh water for granted, but we do so at our peril. We are utterly dependent on water for our lives. We all use it, and increasingly, we all pollute it. So water is not just their responsibility, whoever they are, it is our responsibility. We are all water managers"

- Malcolm Hollick

Of all the inhabited continents, Australia experiences the lowest river and stream flows, the most variable groundwater and rainfall levels, and has the smallest area of wetlands. Australia has the highest level of water storage per capita in the world, with Sydney storing over fifty times more drinking water than London. However, despite the crucial importance of water to the Australian people, our record of protecting waterways has been relatively poor.

In 1992, a particularly dramatic reminder of the general decline of our waterways occurred when the world's largest algal bloom stretched across more than 1,000 kilometres of the Darling River. In the same year, the Federal Government initiated a national water monitoring program known as Waterwatch Australia, in recognition of community concerns over outbreaks of blue-green algae and rising levels of salinity and pollutants in our waterways.

Waterwatch Australia

Waterwatch Australia is a national, community-based water monitoring network that unites people who share a vision for healthy waterways. The program is funded through the Natural Heritage Trust, and administered at the national level by Environment Australia. The program is implemented at the State/Territory and local level by a national network of state facilitators and regional Waterwatch coordinators.

From relatively small beginnings, Waterwatch has made great leaps in the protection of waterways, and it is now the largest community-based water quality monitoring program in the world. During 1999, more than 50,000 Australians were involved in the program, regularly monitoring, protecting and repairing over 5,000 sites in 250 catchments.

The four major goals of the Waterwatch program are:

- to raise awareness about water quality issues;
- to collect water quality data;
- to encourage and facilitate the community to take action to address water quality issues within their local catchments; and
- to empower the community to be involved in the environmental management of land and water.

The strategy for achieving these goals has been to assist communities to gain meaningful insights into their environment, primarily through the collection of accurate water quality data. To an unprecedented extent, the program has enabled communities across Australia to become active partners in the management of their local waterways and catchments.

Water Quality Monitoring

The majority of Waterwatch groups monitor a variety of inland waterways, such as creeks, rivers, lakes, estuaries and wetlands. However, water quality monitoring is not confined to naturally formed waterways or surface water, and many groups monitor artificial waterways (such as channels or irrigation drains) and groundwater. Through regular monitoring, communities build up a picture of the health of their water resources and catchments.

Waterwatch monitoring not only helps to identify problems within waterways, but it can also provide valuable insights into the health of catchments. The 'whole of catchment' approach of Waterwatch means that the program can become a useful diagnostic tool for concerned individuals, communities, landholders and governments.

Data Confidence

Waterwatch groups collect water quality data, usually periodically or seasonally, using a variety of physical/chemical tests, habitat assessments and biological surveys. Physical and chemical monitoring involves testing for a range of parameters which can include pH, turbidity, flow, dissolved oxygen, temperature, salinity, dissolved solids, phosphates, nitrates, faecal coliforms and electrical conductivity. Biological monitoring involves a check of the number and type of invertebrates and macroinvertebrates living in or around the water, and habitat assessment.

Catchment managers and scientists often ask how data from the Waterwatch program is used. The answer is that Waterwatch is not one large monitoring program, but a network of many small, catchment-focused monitoring programs that are linked together by common aims, standards and activities. The standard guidelines and recording units developed by the program enable results to be stored, compared, analysed and shared at the regional or catchment level. In most cases, Waterwatch monitoring focuses on providing answers to questions arising from specific issues at the catchment level. This focus means that data collected by Waterwatch groups can be of interest to local government authorities, catchment management committees, water authorities and State governments. Waterwatch data has also been put to use in Catchment Management Reports, local planning studies and in State of the Environment Reports at the local, State and Federal level.

Therefore, one of the main objectives of the program has been to assist groups to collect water quality data that can be used by the community and government to guide management decisions. With more than 2000 monitoring networks across Australia collecting waterway monitoring data, guidelines and tools have been developed by the Waterwatch Program to record and interpret this information efficiently and consistently. These efforts to optimise data quality recognise that community participation in data collection for management and educational purposes will only be sustainable if data collection is accurate.

Waterwatch has encouraged accurate procedures and techniques for the collection of data through the development of a National Data Confidence Plan and a National Technical Manual. National consistency is ensured through the Waterwatch Data Entry Program. This augments the Waterwatch Database; a computer based program that enables groups to analyse their results, identify trends, and to produce short reports. Other data confidence resources include technical manuals produced at the State level, local and regional training programs, and quality control procedures for verifying the accuracy of monitoring equipment.

While it is important that monitoring yields accurate, robust and reliable data, Waterwatch acknowledges that not every group will have the same technical ability or objectives. The Waterwatch Data Confidence Plan has been created as a tool to assist groups develop a clear rationale and strategy for their monitoring. For instance, Waterwatch is often used at the primary school level to explain concepts relating to the measurement of water quality, and to encourage a general awareness of water quality issues. Particularly for younger students, the educational aspects of data collection are usually of more importance than the accuracy of the information. However, for other Waterwatch groups, the quality of data may be paramount. Consequently, it is critical that the end users of Waterwatch data have an understanding of how, why and when the data was collected, who conducted the monitoring, and the methodology and equipment which was used.

Although some scientists may question the quality of community collected information, data collected by Waterwatch groups has been used with success as a tool to influence decision making. In 1997, a Queensland Environmental Impact Statement incorporated data collected by a Waterwatch group. This was the first time that community data had been accepted for an official environmental review in Queensland. In another case, a Tasmanian Waterwatch Group was able to use their monitoring data to convince decision makers to allocate a guaranteed flow for a regulated river – the first time that such a result had ever occurred.

Those Waterwatch groups with a specific need to collect credible and useful data will go to great lengths to ensure that technical and quality assurance standards are observed. In situations where the accuracy of results is critical, Waterwatch groups have their results independently validated.

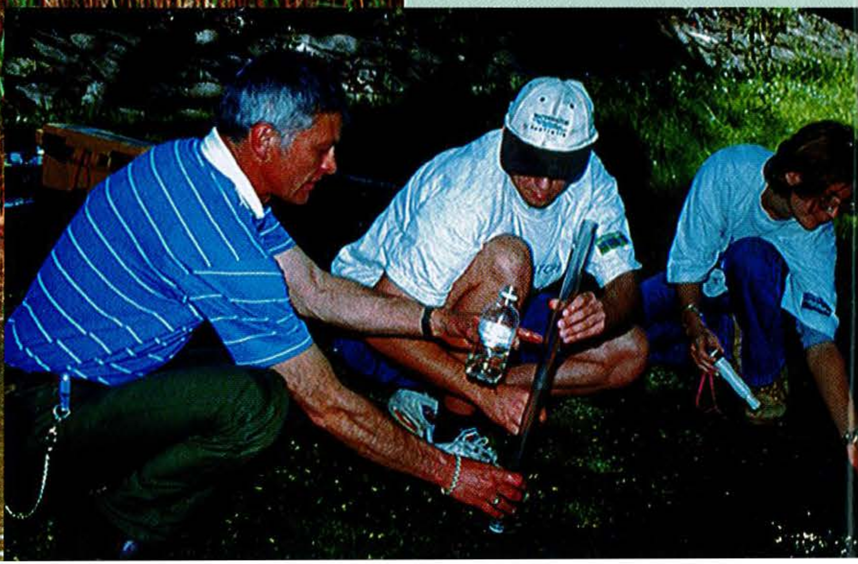
Awareness to Action

The public is becoming more aware of opportunities to be involved in environmental management, and there is an increased community commitment to the protection, monitoring and management of our waterways and wetlands. Waterwatch has successfully harnessed community sentiment by providing avenues for ordinary people to get involved in the management of their water resources. The water quality information collected through the Waterwatch program is focused at the local level, making the data both relevant and easy to understand. This focus on catchments and local areas enables communities to profile the health of their waterways and water resources, and provides the impetus for community action. The program has shown that a little knowledge, and an affinity for a local waterway is often all that is required to enable ordinary Australians to act as the monitors and carers of their water resources.

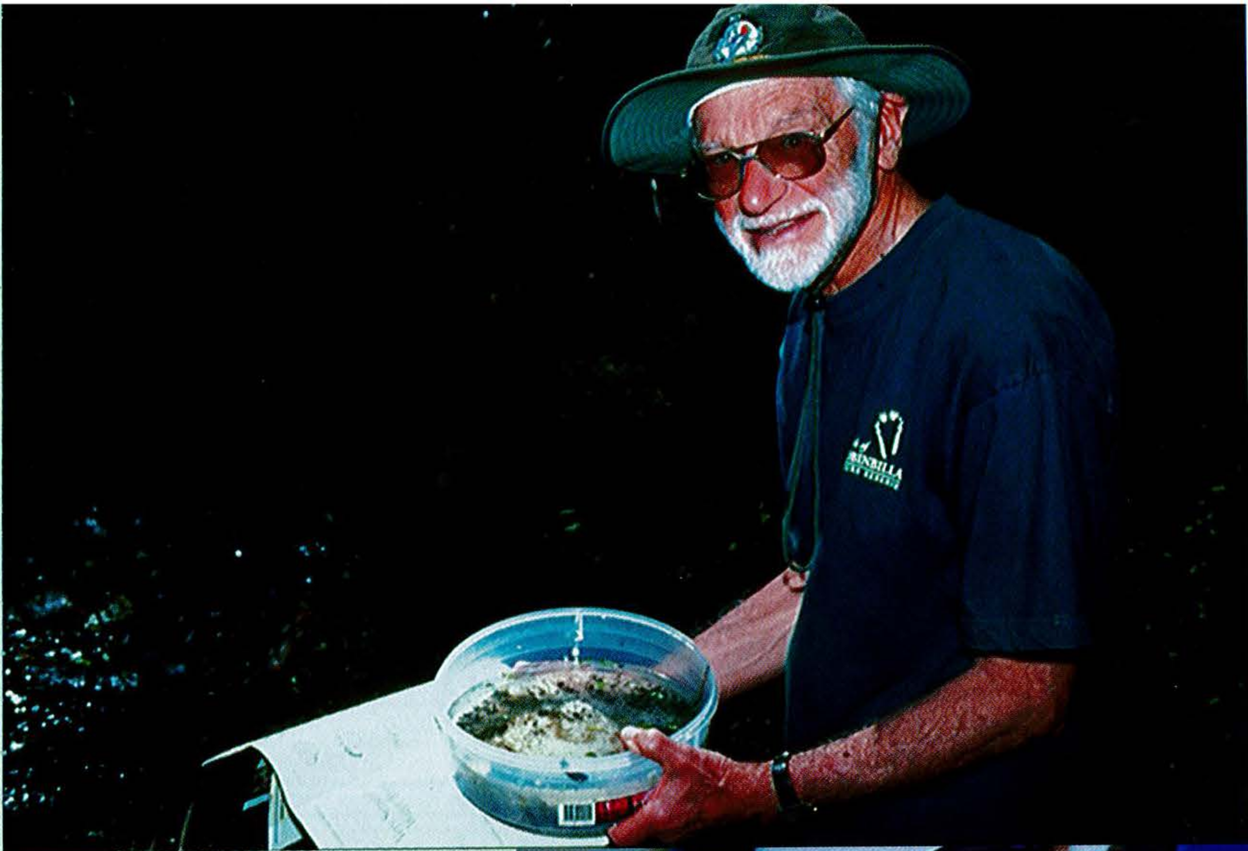
Through a better understanding of the environment in their own backyards, many Australians have successfully translated their concern about water quality into action on the ground. Relatively easy, low cost solutions (such as fencing off areas of riverbank, removing litter from waterways, eradicating weeds and invasive species, or reducing the use of pesticides and other pollutants) have proven particularly effective. The unique combination of action and monitoring means that Waterwatch participants can take steps to rectify water quality problems, and then measure the impact of their environmental intervention.

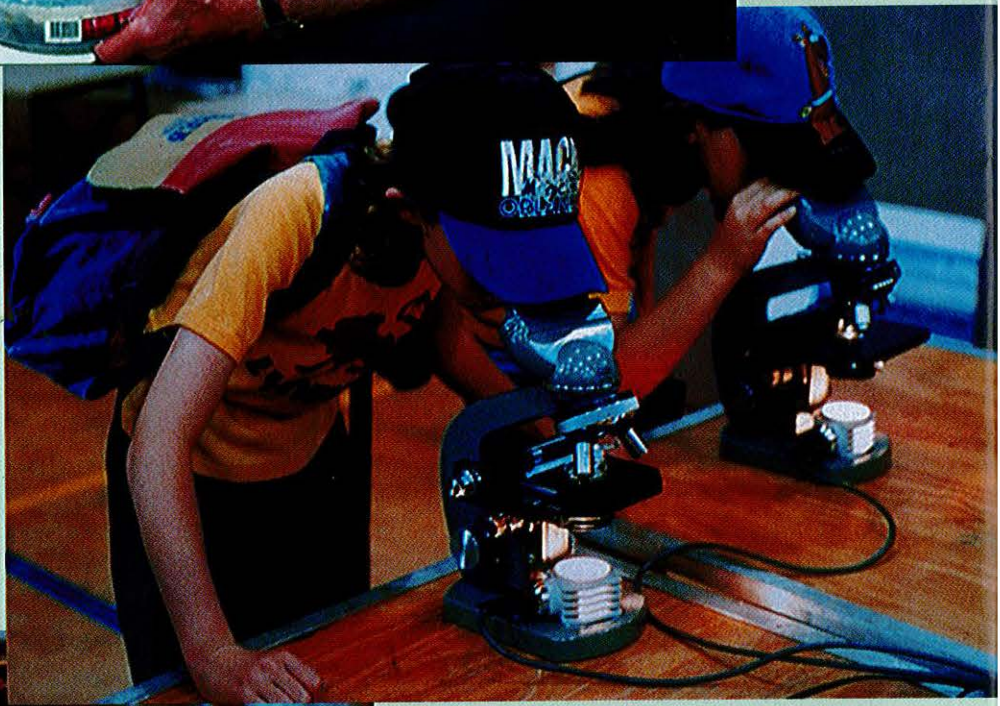
One of the major achievements of the Waterwatch program has been its success in empowering the community. The knowledge and understanding gained through Waterwatch has enabled communities to insist that catchment managers, scientists, governments and other policy makers make appropriate management decisions. In this context, Waterwatch groups are increasingly active and informed participants in water and catchment management, with the motivation, skills and knowledge to identify and confront the causes of unhealthy waterways.

To contact Waterwatch call Kate Gowland at Environment Australia, Phone (02) 6274 2797, Email <kate.gowland@ea.gov.au>. Photos supplied by Waterwatch.



A community water quality monitoring project
Site Code:
G O N 0 1 0
Site Name:
THE GONG, BUNINYONG
Monitored by:
BUNINYONG PRIMARY SCHOOL
site lies in the Barwon River Basin
WATERWATCH
Central Highlands
A Federal – State Partnership
Parameters monitored here include:
Electrical Conductivity (salinity)
Dissolved Oxygen (Oxygen in water)
Macroinvertebrates (Water bugs)





Waterwatch Case Study – Memories of the Mersey

"We are finding that we don't need a vision for the future," says Warren Butler, regional Waterwatch coordinator in the Five Rivers region of northern Tasmania. "All we need to do is draw upon our memories - and act". Butler has found that clear recollections of the environment are providing the blueprint and the inspiration for the renaissance of rivers in the region.

John Reed had watched the slow decline of the Mersey River after it was dammed in 1968, and its headwaters in the Cradle Mountain-Lake St Clair National Park diverted. After the damming of the Mersey, the native Black Fish and platypus disappeared from the river, and willows choked its beds. Nearer the Latrobe - where Reed remembered diving into crystal clear water - lay a muddy impoundment perhaps a metre deep. A sign read: 'No diving or swimming'.

"People had driven past that sign hundreds of times since the water stopped flowing and had just accepted it. They didn't notice. But I saw that sign every time."

In 1992, John helped form the Latrobe Landcare group, which began to transform the Mersey. The key to the life and future of the river was the water that was diverted by the Hydro-Electric Scheme. In 1995, John wrote what he calls a "very cutting" letter to the editor of the Launceston Examiner about the Hydro-Electric Commission (HEC). Within a fortnight, there was a knock on his front door. John was shocked to find two senior officers from the Commission determined to convince John that he was wrong. Three hours later they left convinced that, indeed, the Mersey had a problem.

It took almost three years to bring together Tasmanian water and land managers, including the HEC and community representatives. The result was the Mersey River Study. The water managers and politicians agreed to a minimum water flow of two cubic metres/second in the Upper Mersey. It was a landmark decision - the first time an environmental flow had been guaranteed for any regulated river in Tasmania.

As experiments with various levels of flow were taking place during the study, the Latrobe Landcare group had incorporated Waterwatch into their activities. Every fortnight, John goes out with Year 8 Latrobe High School students to monitor the river. He sees Waterwatch as a critical part of the project. "Waterwatch is so closely linked to Landcare that they cannot be separated. I think that eventually Waterwatch will drive Landcare".

Warren Butler later organised a public meeting to showcase John's story. "The Mersey, even though it was degraded, was still a beautiful river. People didn't realise how it had changed," Warren says.

John and the Landcare group have used their knowledge of how the river used to be to promote its rehabilitation. "They have restored six kilometres of waterway. You couldn't canoe down that river, it was covered in sediment. Now you can actually see the shingle (the river stones)".

Seventeen schools in the region are now involved in the Waterwatch program, and are incorporating historical information into their reports. "We can collect all the data we like about the state of a river now. But we have to look beyond the data. Data alone won't convince anyone," Warren says. "It's attitudes that we are trying to inform and change. So as well as our data, it is important that we don't forget how our rivers used to be. That collective memory can help us imagine and plan for how we want our waterways to be again".

In-channel Processes and Environmental Flow Requirements for the Barwon-Darling River

Martin Thoms and Fran Sheldon
CRC for Freshwater Ecology
University of Canberra

Introduction

Dryland rivers are a prominent feature of the Australian landscape, comprising approximately 80% (2595 m kilometres) of the total length of Australian rivers. Our understanding of biophysical processes in these systems is limited. Previous studies have shown that hydrological variability is a feature and this is often associated with highly variable effective rainfall and low rainfall–runoff ratios. Indeed, Australia's dryland rivers are noted to be among the most hydrologically variable in the world. The average coefficient of variation (CV) for annual runoff for dryland regions is 0.99 — much higher than for the humid regions of North America (0.3), Europe (0.2) and Asia (0.2).

Flow variability is important in a number of ways. Geomorphologically, variable flows maintain the complexity of the instream environment. In turn, river channel complexity influences the diversity of habitats available for various aquatic organisms and certain ecological processes, such as organic matter storage and breakdown. Ecologically, flow variability underpins the rates of most ecosystem processes and the transport of organisms, nutrients, organic carbon, and other materials within rivers and on their floodplains.

The character of Australia's dryland rivers has been altered since European settlement through large-scale floodplain development and the loss of connectivity resulting from flow regulation and the construction of levees. This is especially evident in the Barwon-Darling system of central New South Wales (Figure 1). Approximately 23.9 million ML of water is stored in large dams that influence flows along most of the river length. Water extractions for irrigation also influence the hydrology of the river. Indeed, water diversions in 1994 were equivalent to over 60% of the natural flow at Menindee on the lower Darling River, having increased from 20 abstraction licenses in 1960 to 267 in 1994, in response to increased pressure from the agricultural industry. This has occurred with little understanding of the impacts of this scale of development on the river ecosystem.

Ecosystem processes in the Barwon Darling River

Typical of many inland Australian rivers, the Barwon Darling is highly turbid and light penetration is limited. Aquatic macrophytes are few, and the main structural habitat occurs in the form of woody debris. Allochthonous organic detritus (organic matter derived from outside the river channel) is therefore likely to provide both an important habitat for aquatic organisms and a source of organic carbon and nutrients to the river. In smaller headwater streams the importance of allochthonous organic matter entering from the riparian canopy as both a habitat and nutrient source has been well documented. Allochthonous carbon is also likely to be important in large turbid rivers where structural habitat complexity is reduced and low levels of light penetration limit primary production.

In rivers where overbank flows are sufficient to maintain a substantial floodplain, a large

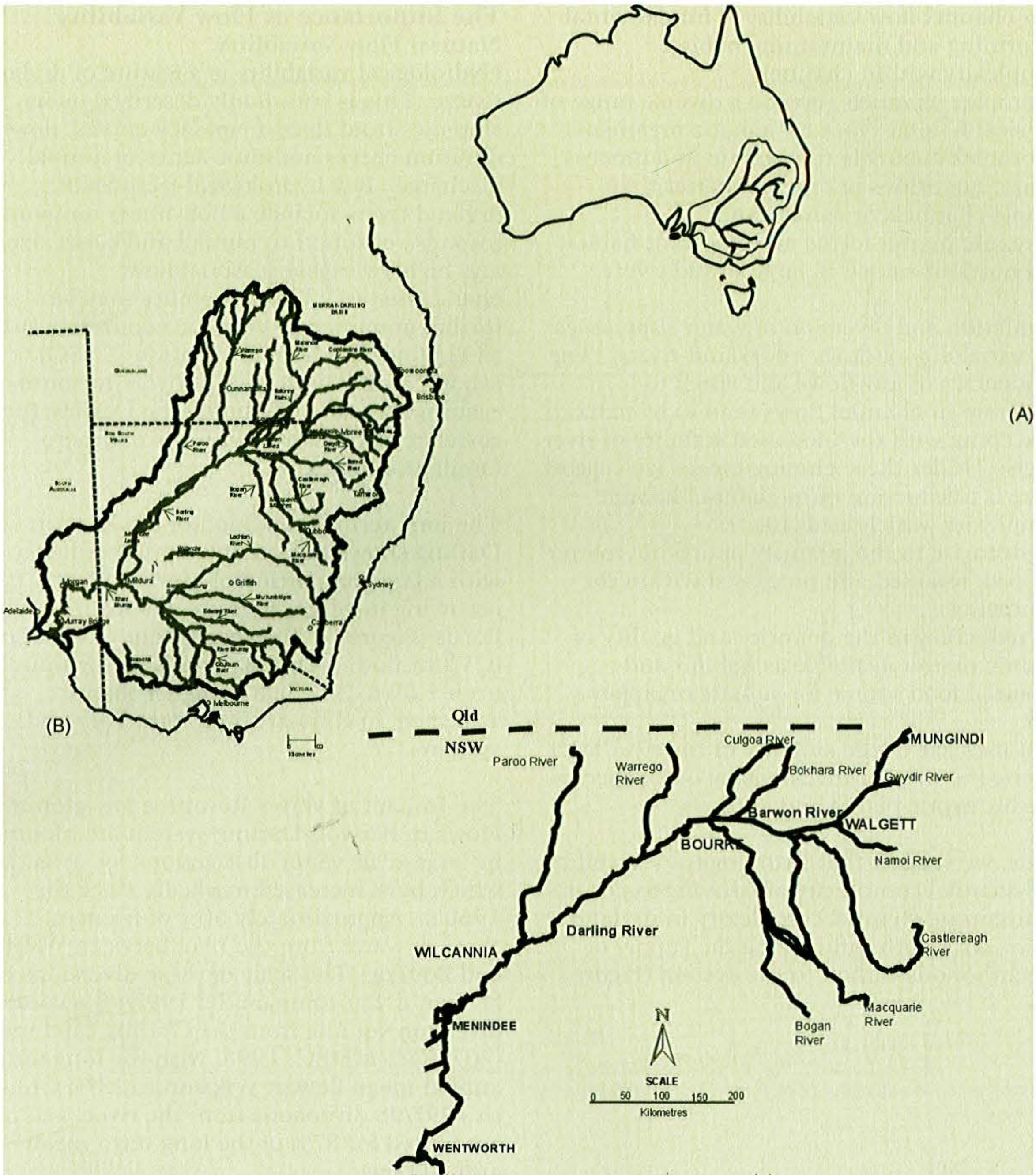


Figure 1. The Barwon-Darling River system.

proportion of the allochthonous organic biomass will enter the channel from the surrounding floodplain environment. Flows in the Barwon-Darling system, however, are highly variable with 90% of all flows retained within the channel. The Barwon-Darling has a compound river channel, with a series of in-channel bench features leading to enhanced in-channel habitat complexity. Compound or complex channels are characteristic of rivers with highly variable flows. In these systems we suggest that the in-channel benches act as 'miniature' floodplains; in the sense that they increase the habitat complexity of the main channel, provide surfaces for organic matter accumulation, retention and transformation, and promote invertebrate colonisation and productivity. Discharge and habitat complexity are known to influence the ability of a lotic system to retain and process organic material. The retention and processing of allochthonous organic matter is important in structuring aquatic assemblages as it provides a complex habitat and a vital food source. For dryland rivers subject to a naturally-variable flow regime, therefore, we suggest that:

• in-channel flow variability is fundamental in forming and maintaining habitat complexity within channels;
• complex channels provide a diverse range of physical habitat types for aquatic organisms;
• complex channels trap, retain and process greater quantities of organic matter than simple channels or canals; and
• organic matter forms an important habitat and nutrient source in large turbid rivers.

Regulation and diversion of water suppresses the variability of flows in dryland rivers. The frequencies of low flows and small to moderate in-channel flows tend to be reduced, in keeping with the increased stability of river levels. Under these circumstances we suggest there is a reduction of in-channel habitat complexity, which leads to:
• a decrease in the quantity of organic matter trapped, retained and processed within the channel;
• a reduction in the quantity and quality of organic matter available as habitat and potential food source for aquatic organisms and
• an increase in the stability of the river level paving the way for invasions by other species, notably exotic plants and animals.

Thus, we suggest that hydrological variability and channel complexity are driving forces in maintaining channel complexity in dryland rivers, with both influencing the supply of allochthonous carbon to the system (Figure 2).

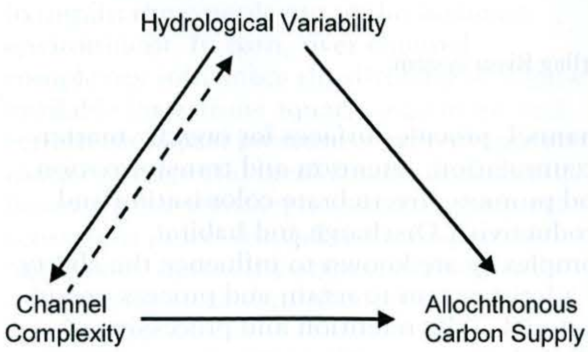


Figure 2. The influence of hydrological variability and channel complexity on the supply of allochthonous carbon in a large dryland river.

The Importance of Flow Variability

Natural Flow Variability

Hydrological variability is a feature of dryland rivers. This is commonly described using statistics from flood-frequency curves, flow duration curves and time series of annual discharge. Key hydrological features of dryland rivers include a non-linear temporal response of runoff to rainfall and basin size, and highly variable seasonal flow characteristics. This variability may be further amplified by climatic conditions such as El Nino-Southern Oscillation (ENSO) events, as the discharges of rivers in south-eastern Australia, including the Darling River, correlate significantly with the Southern Oscillation Index (SOI).

The long-term hydrograph of the Barwon-Darling shows the variable nature of flows, with a large proportion of average flows occurring in very wet years and during major floods (Figure 3). The coefficient of variation (CV) for flows in the Barwon-Darling ranges from 1.59 to 3, which is higher than 'expected' in comparison to other dryland systems.

The Impact of Water Resource Development

Flows in Barwon-Darling system are modified by large-scale water abstractions for irrigation which have increased markedly since the 1960's. Approximately 50% of licences abstract water from the river between Walgett and Bourke. The scale of these diversions can be seen if you compare the 1997/98 recorded diversion volume from the Darling catchment (2074 GL; MDBC, 1998) with the long term annual mean flow at Wilcannia (2370 GL). In 1997/98 diversions from the river accounted for 87% of the long-term mean annual flow.

A comparison of the simulated (Integrated Quantity Quality Model data from New South Wales Department of Land and Water Conservation) 'natural' and 'current' development data suggests that water resource development has the potential to change long term flow variability in the Barwon-Darling. For example, median flows at Wilcannia have been reduced by 73% and there have been flow reductions over a range of flow magnitudes. These results are consistent with other estimations of the impact of water resource development within the Barwon-Darling catchment. Between 1988 and 1994 there was a 32% increase in the flow diverted from the upper Darling

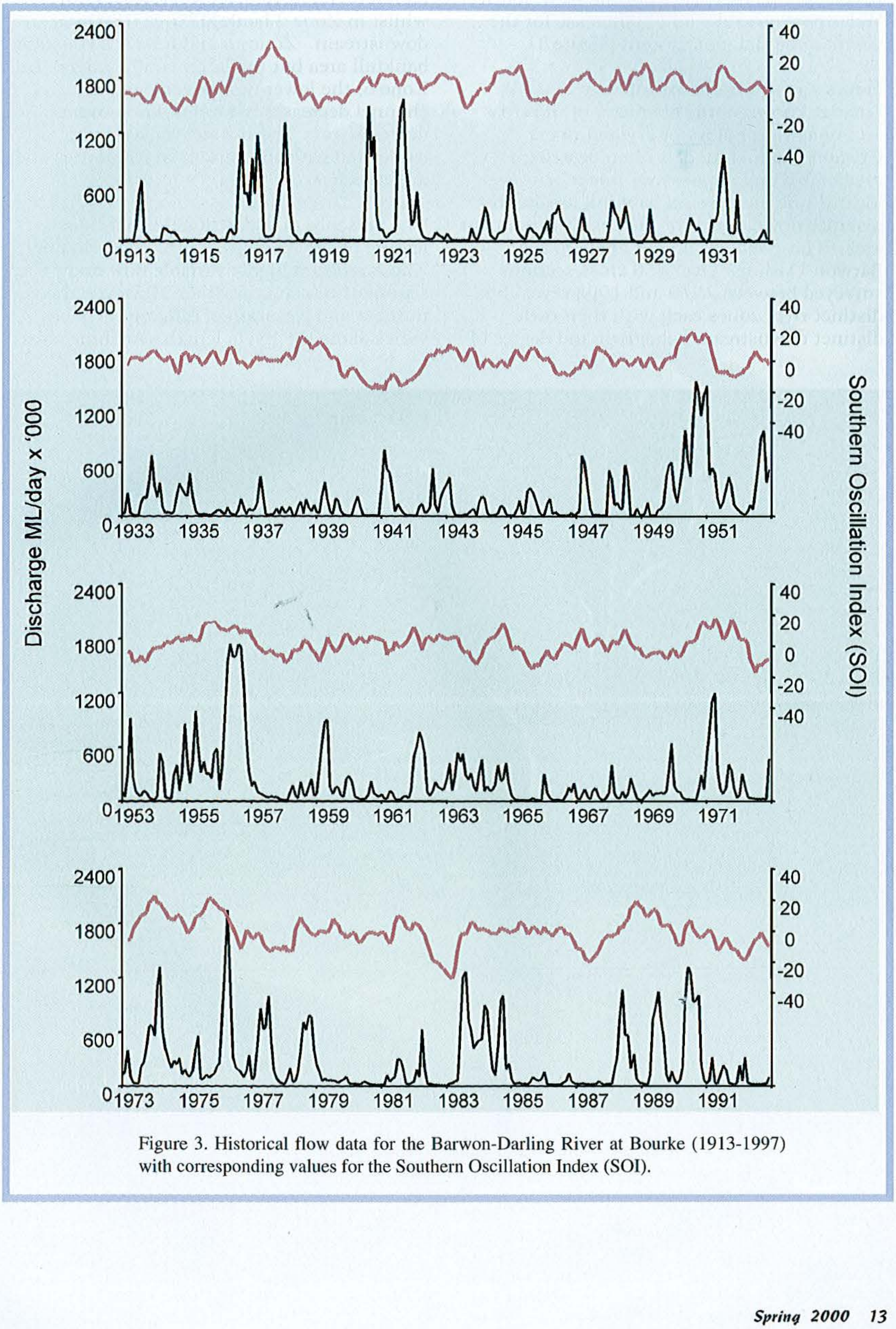


Figure 3. Historical flow data for the Barwon-Darling River at Bourke (1913-1997) with corresponding values for the Southern Oscillation Index (SOI).

system combined with a 187.2% increase from the Queensland portion of the Border Rivers, 38.2% increase from the New South Wales portion and a 63.5% increase for the Condamine-Balonne system (Figure 1).

Links to Channel Complexity

Little is known of the character of the cross sectional morphology of dryland rivers. Current channel models often describe a predictable and progressive, linear or logarithmic increase, in bankfull area with distance downstream or increasing catchment area. These models do not apply to the Barwon-Darling. Over 350 cross sections surveyed between 1970 and 1998 reveal five distinct river zones each with their own distinct downstream behaviour and degree of complexity. Zone 1, the uppermost zone, is characterised by an exponential decline in bankfull area with distance downstream, whilst in Zone 2 bank full area increases downstream. Zones 4 and 5 have a constant bankfull area but the latter is 50% larger. In Zone 5, the lower-most river zone, the channel decreases in size as you move downstream. These zones appear to be associated with the pattern of tributaries and anabranches.

The presence of depositional benches is a feature of the Barwon-Darling river channel. These reflect a highly variable flow and sediment transport regime. However, the number and elevation of different benches varies along the rivers length. At some sites

Benches on the Barwon-Darling

Lower Darling with no benches

there are up to seven different benches at different elevations within the bank full channel whilst at others there are none. The number of benches is directly related to the degree of flow variability at each site.

Complexity and Organic Matter

There are essentially three 'pools' of carbon associated with in-channel benches of the Darling River and each pool has a particulate (POM) and dissolved (DOM) component.

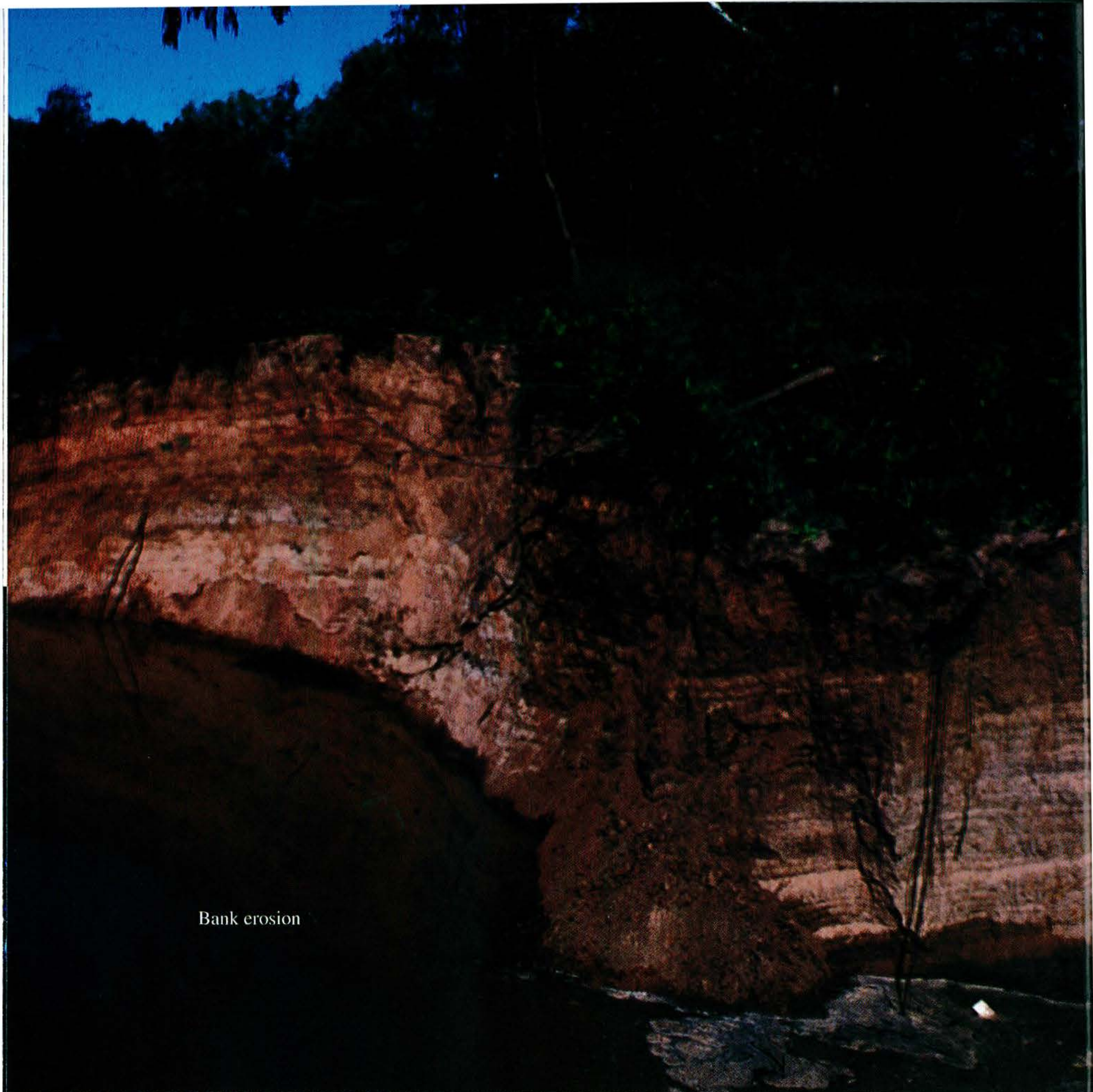
POM Pool A: Particulate organic matter,eg. twigs, bark, leaves and nuts, retained on the horizontal and vertical surface of the channel benches.

POM Pool B: The particulate organic matter buried within the surface sediments of the channel.

POM Pool C: The particulate organic matter buried deep within the in-channel benches.

DOM Pools A, B & C. The volume of dissolved organic carbon (DOC) released from organic material in each pool upon flooding.

In-channel benches accumulate and trap significant quantities of organic material. However, some appear to accumulate more than others (Figure 4). Differences in the ability of features to trap organic matter may relate to one, or a combination, of the following: the mode of formation of the feature, the surface roughness of each feature and the relationship between input of organic matter and the time of deposition. It is also apparent that horizontal and vertical surfaces differ in their ability to accumulate organic



matter. Differences in the amount of organic material retained on the horizontal surface of each bench for the range of features examined may reflect differing proximity to overhanging riparian vegetation. A consistent pattern, however, is that horizontal surfaces have a greater ability to collect organic matter than vertical surfaces (Figure 4).

The lack of horizontal surfaces in 'regulated' reaches of the Barwon-Darling River may limit the in-channel trapping of organic matter. Horizontal surfaces not only provide a site of deposition, hence the accumulation and retention of organic matter, but also influence the form roughness of the channel.

The quantity of organic material from Pool A (particulate and dissolved) released into the Darling on flooding of the various benches for the Wilcannia reach was modeled for 'Natural' and 'Current' levels of water resource development (Table 1). 'Current' estimates were made under riparian cover on the lower Darling near Wilcannia during 1996. 'Natural' estimates use the data generated for 'current' levels of development corrected for natural levels of channel complexity, generated from historical cross sections, and natural levels of flooding frequency and duration. This suggests that changes associated with water resource development, namely reduced in-channel

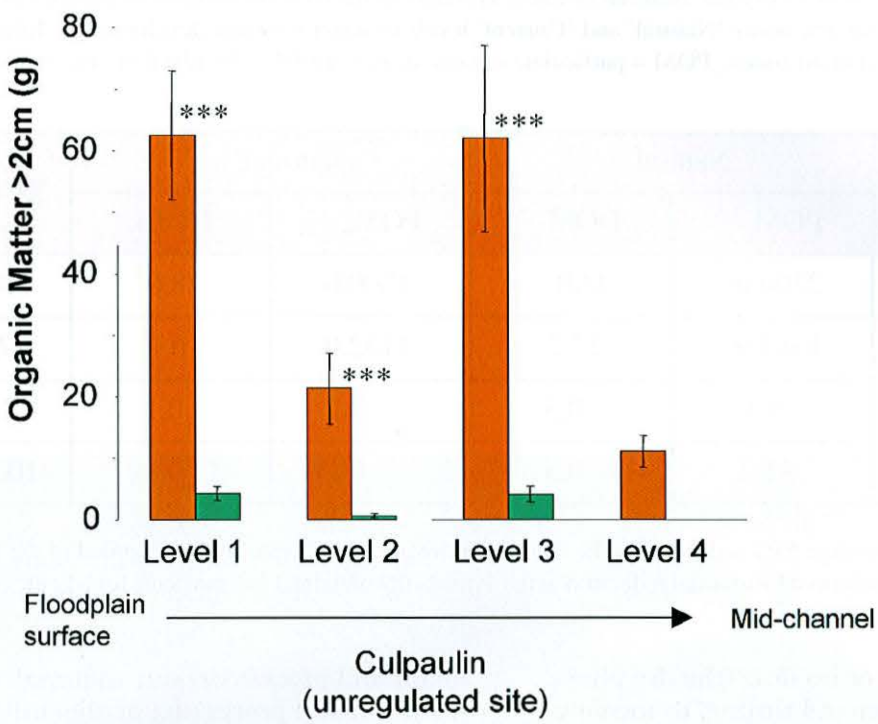


Figure 4.Means (±SE) for the weight of organic matter (>2 cm) collecting on horizontal (orange bars) and vertical (green bars) surfaces of benches at Culpaulin Station near Wilcannia. The outcomes of Mann-Whitney U comparisons between the surfaces of each bench are also given, significant levels are as follows *** = P<0.001, ns = not significant

complexity and reductions in the frequency and duration of flooding, have lead to marked decreases in the volume of organic material able to enter the channel. The greatest changes have occurred on the lower level benches where in-channel erosion is greatest and flooding frequencies and durations are most changed.

Management of Dryland Systems

Australia's dryland rivers are a valuable but threatened resource. It is difficult to place a monetary value on ecosystem functions but techniques are now available to do so. Applying these to the dryland rivers of the Murray-Darling Basin, for example, it is estimated that the rivers, wetlands and floodplains are valued at $187,302 million per annum for the various ecosystem services they provide. Previously, many management strategies for large rivers have been guided by commercial interests and are typically aimed at reducing floodplain area and regulating water levels. Now, the Council of Australian Governments (COAG) has recognised the fundamental importance of a whole-catchment approach in water resources planning. Water entitlements, both consumptive and non-consumptive, must now be allocated and managed in accordance with comprehensive planning systems that are based on a complete hydrological assessment of the catchment.

Given the uniqueness of Australian lowland rivers we suggest there is a need for specialist policies for the management of these systems. The formulation of policies based on our present knowledge of these ecosystems may seem premature, especially because we cannot easily extrapolate from experiences gained in systems overseas. However, the demand is urgent and we must learn from our management actions. There are many gaps in the knowledge required to determine appropriate environmental water allocations. Techniques and procedures developed elsewhere are not directly applicable to Australia's rivers because of enhanced ecosystem variability. In the interim, specialist policies for dryland systems must address the following:

Table 1. The volume of organic material (tonnes) available to the river on flooding of benches of different heights within the channel, under 'Natural' and 'Current' levels of water resource development. Estimates are made for vegetated riparian zones. POM = particulate organic matter. DOM = dissolved organic matter.

Bench	'Natural'		'Current'		%Change
	POM	DOM	POM	DOM	
1 (high)	2700.0	42.0	1800.0	28.0	-33.3%
2	1584.0	22.2	1152.0	16.2	-27.3%
3	8.3	0.5	3.2	0.1	-61.4%
4 (low)	31.2	0.5	0	0	-100%

Overall there is an average 55% reduction in the amount of organic matter entering the channel of the Darling at Wilcannia. This represents a substantial reduction in the availability of habitat and nutrients for aquatic organisms.

1. the importance of no flow (the dry phase), of variable duration and timing, to lowland rivers in dryland regions;
2. the need for integrated flow management on a whole-of-catchment scale;
3. maintenance of flow variability to promote a diversity of habitat types on a large time scale and spatial scale;
4. explicit recognition that the public perceive no flow (the dry phase) as a problem, and educational programs to remedy this concern.

Discharge and habitat complexity are known to influence the ability of a lotic system to retain and process organic material. The retention and processing of allochthonous organic matter is important in structuring aquatic assemblages as it provides a complex habitat and a vital food source. Both flow variability and channel complexity can be adversely affected by flow regulation thereby interfering with organic matter processes and ultimately impacting higher level organisms.

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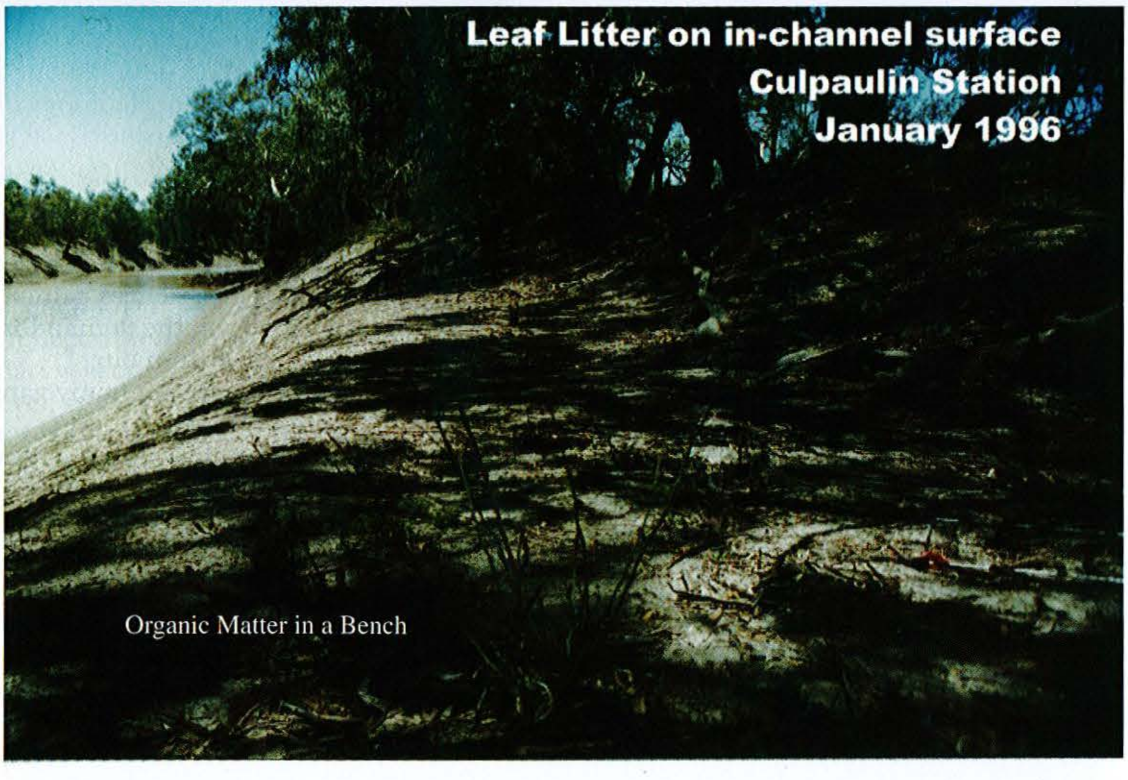


Organic Matter in a Bench


Stored organic Matter within a Bench
Buried Litter in Level 2 Bench
Culpaulin Station

Australian Estuaries: Comparisons around a Continent

Peter Saenger and Nick Holmes

Centre for Coastal Management,
Southern Cross University

Where rivers discharge into the ocean, the brackish water mixing zones, where river water comes into contact and mixes with seawater, are known as 'estuaries'. These may be quite small where river discharges and tide ranges are limited but in other settings, estuaries may be extensive. Due to their tidal locations, estuaries have 'tidal wetlands', mangroves, salt marshes and seagrass beds, associated with them. In turn, these tidal wetlands support an enormous array of organisms, ranging from crustaceans, molluscs and fish to birds, reptiles and mammals. The underlying cause of this faunal richness, is the high productivity of the tidal wetlands fed, on the one hand, by the nutrient-laden silts brought down by the rivers and by the salts and nutrients from seawater on the other.

Australian estuaries are important places of human habitation, providing a range of physical amenities (such as port and harbour areas, recreational space, transport links, coastal plains for agriculture and urban development) as well as ecological resources as fish habitat, fish stocks (commercial and recreational), aesthetic/scenic values and water quality enhancement.

These riches, obtainable from Australian estuaries, led to all early settlements being made around estuaries. While estuaries sustained early Australian settlements, the growth of those settlements, in turn, poses significant and increasing risks to the very estuaries that allowed those urban centres to prosper.

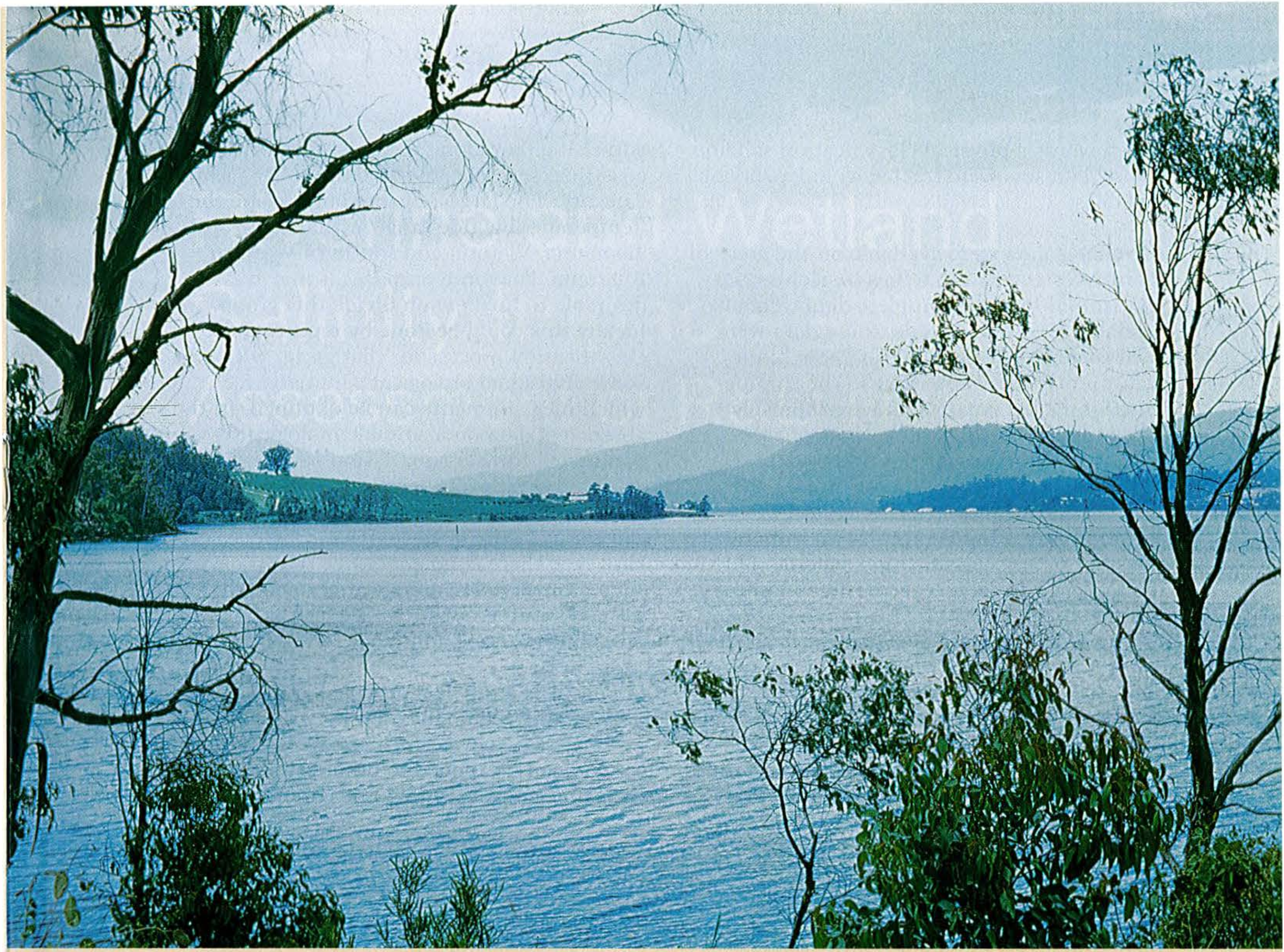
To ensure the survival of estuaries and to enable them to continue the delivery of ecological services, the ecological processes of river/estuary systems must be understood and maintained. This is now recognised, but it wasn't a decade ago.

Estuaries in Australia, as elsewhere, are subjected to many modifying influences, either via the catchment (ie. river waters) or direct to the estuarine system. The most widespread of these modifying influences are agricultural runoff, industrial and wastewaters, and physical alterations such as training walls, flood mitigation, drains and floodgates.

Estuarine management must necessarily be based on a systems-level approach, seeing the estuary as a complete dynamic system. The 'National Rivers Health Program' (NRHP), was initiated in 1993 as a way of providing a coherent nationwide approach to manage river/estuary systems.

As each of Australia's 700 or so estuaries is unique, reflecting individual geomorphological, hydrological and developmental histories as well as human influences, there is a need to understand similarities as well as differences on a national scale. Such comparisons between estuaries can be facilitated by a classification scheme that identifies major estuarine types and allows valid comparisons between estuaries – especially highlighting where differences between estuaries are due to human influences rather than to differing natural factors.

The challenge to develop an estuarine classification for Australian estuaries was given to the staff of the Centre for Coastal Management, Southern Cross University. Together with delegates to a technical



Huon River Estuary, Tasmania - photo Bill Williams

workshop held in mid-1996 they recognised early on that there were few data for most Australian estuaries, and data on geographical variables such as catchment size, rainfall, tidal range and river form were more accessible than data on biological parameters. An earlier estuarine inventory (Bucher, D. and P. Saenger, 1991. An inventory of Australian estuaries and enclosed marine waters: an overview of results. Aust. Geogr. Studies 29:370-381) provided essential information on occurrence of major habitat types and the geographical variables mentioned above.

The objectives of this project were to develop a national classification of estuaries based on easily quantifiable, biologically important physical characteristics to enable valid comparisons between biotic communities of different estuaries. This objective was based on the rationale that assessing the ecological health of an estuary would necessarily involve comparisons between estuaries that are significantly affected by human activities and those that are not. Such comparisons must be based on estuaries of a similar type, lest differences in the natural shaping forces distort or hide the differences due to human activities.

Any classification had to be consistent and readily applicable to all estuaries; as a result it was decided to use mapped geographic variables as the primary basis for classification. Additionally, there was a need also to restrict the number of classifiers to keep number of classified groups to a usable minimum while still being useful.

Due to these limitations, the approach adopted was to collate as much primary geographic data with even national coverage. Data included for each estuary consisted of catchment area, intertidal flats area, open water area, runoff coefficient, climatic category (BOM98 and BOM81), extreme tidal range, the biogeographic region (IBRA) and the coastal region (IMCRA). In addition, a morpho-hydrological categorisation of Australian estuaries was developed as a first step towards a physical classification scheme. These data sets were treated as independent variables.

As reliable data were available on the areas of mangroves and salt marshes in each estuary, and similar but less complete data were also available for seagrass beds, these data were used as dependent variables. These biotic communities are important to the trophic functioning of estuaries and are themselves a reflection of the physical features of each estuary, whichever sets of primary data, singly or in combination, could best explain the variance in the proportional areas of these communities, would comprise an important classifier in any classification scheme. Due to the incomplete data, seagrass areas could ultimately not be used. Thus, mangrove and salt marsh proportions formed the basis of the classification scheme because they are biological parameters that are easily measured and they are generally stable on a seasonal basis and from year-to-year (unlike seagrasses). In addition, they are important habitats and their contributions to primary productivity will largely determine the type of trophic relationships that can exist in the estuary and the range of animal life it can support.

A combination of General Linear Modelling and Analysis of Variance was used to determine which independent variables, singly or in combination, influenced changes in mangrove and salt marsh proportions. A complex model incorporating all interactions was used with any non-significant interactions being omitted from the model subsequently. Changes in the significance of the remaining factors were noted. SPSS for Windows (Version 9.5.1) was used for all statistical analyses.

In the final classification, estuaries were classed into five groups based on climate and three groups based on low (<4m), medium (4-8 m) or high (>8 m) tidal ranges. Of the possible 15 groups, 11 contained estuaries and this simple model accounted for around 40% of the variation in both mangrove and salt marsh proportions.

The value of the model is that it provides a methodology by which biologically-important physical factors can be identified. Clearly, estuaries that are geographically close will often experience similar climatic conditions and a similar tidal range. It is therefore not surprising that along many lengths of coastline, several estuaries fall into the same category. The largest of these blocks are the 'temperate, low tide range' estuaries of Tasmania, Victoria and southern Western Australia. For some purposes it may be desirable to further sub-divide this group. Ideally this could be done by repeating the classification process for that group with some additional biological parameter for which measurements can be obtained. In the absence of data on a suitable biological parameter, further subdivision could be achieved by arbitrarily selecting an additional classifier, such as the morpho-hydrological categories or the biogeographic provinces. However, there is no guarantee that the use of such arbitrary classifiers would divide the estuaries into groups that are biologically different from one another.

Finally, this study has provided an initial national bio-regionalisation for Australian estuaries whereby scientific studies in any one estuary can be applied to other estuaries in the same category with some confidence.

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Riverine and Wetland Salinity Impacts - Assessment of R&D Needs

The salinisation of land in Australia as a result of human activities is a significant problem for agricultural production, infrastructure and natural habitats. Salinisation also affects rivers and wetlands but its impacts on these environments have received less attention.

Recognising this LWRRDC commissioned Paul Bailey and Kimberley James of Monash University to conduct a scoping review of available information on salinity impacts on rivers. This article presents a summary of their report.

The review aimed to identify the current status of knowledge on the impacts of salinisation on rivers and wetlands, identify the management and other implications of current research, and to identify R&D gaps. The review focuses on the effects of salinity on the biology and management of wetlands and riverine systems, incorporating a comprehensive analysis of all biotic groups. The authors of the review consulted widely with senior resource managers at regional, state and federal levels and senior scientific researchers around Australia. The review process also involved collating and reviewing the scientific literature, government reports and reports from research and funding organisations on salinity impacts and management.

The principal impacts of salinisation of inland waters include:

Loss of aquatic biodiversity; negative changes to vital ecosystem processes such as primary productivity; nutrient cycling/spiralling, and decomposition; breakdown of food-web structure; decrease or loss of aesthetic, amenity, recreational and other values; loss of wetland and riverine habitat; decrease in water quality; and overall environmental degradation.

Secondary salinisation, as it is known, is a result of the disturbance to the hydrological cycle by the replacement of native deep-rooted perennial vegetation with annual crops and pastures. This development of agriculture has resulted in increased groundwater recharge, rising watertables and consequent mobilisation of salts naturally stored in the soil profile. Rising saline groundwater can directly impact wetlands or enter streams through groundwater seepage. Salt brought to near the soil surface can also be transported to streams by surface run-off or interflow. Saline discharges, for example from irrigated farms, can also be made directly to wetlands or streams.

The region most affected by salinisation to date is South-West Western Australia. However, extensive salinised areas also exist in South Australia, Victoria and New South

Wales. All these states anticipate a substantial expansion of the problem, and some areas in Queensland and Tasmania are also at risk. The environmental costs of salinisation in terms of loss of biodiversity and ecological assets is likely to be very high but are intrinsically difficult to quantify.

The impact of salt on the freshwater biota is complex, diverse, extensive and inevitably negative. The sensitivity to salt differs between different groups of the biota so that accurate predictions of the impact for particular groups is difficult. The extent of knowledge of the sensitivity to salt of biota is different for different groups, but overall is inadequate.

Findings and recommendations of the review

Aquatic environmental impacts of salinisation

• Representatives from all biological communities, particularly macroinvertebrates (detritivores, predators and herbivores) and plants (diatoms/algae, macrophytes and riparian vegetation) are salt sensitive. As a result, any deleterious effects to particular taxa are likely to translate into broader ecosystem processes, such as primary productivity, decomposition, nutrient spiralling/recycling, and the flow of energy and material through trophic webs. Such processes define ecosystems and underpin their fundamental health and integrity.

• Exposure to salinities of between 1,000 and 2,000 mg/L for even short periods is likely to have significant deleterious effects on biological communities in lowland streams, rivers and associated wetlands and as a result, impact on important ecosystem processes. More subtle sublethal and indirect effects are likely to occur at salinities below this. However, there are insufficient data to assess either the likelihood, extent or magnitude of such changes.

• Species diversity is significantly reduced as salinity increases, with more salt tolerant but less diverse taxa likely to become dominant. For temporary wetlands, the concentration of salts as water evaporates results in the exposure of biological communities to increasing salinities. Although flooding river water or groundwater may initially be of low salinity, final salinities may be four to five times initial ones, because of evaporation. In addition, combinations of high water temperatures and salinities during summer result in low concentrations of dissolved oxygen. Such low levels of oxygen, coupled with increasing bacterial respiration of organic material further contribute to oxygen depletion. An observed decrease in pH is of concern, particularly if widespread in poorly buffered wetland systems. The more acidic conditions would undoubtedly prove harmful for the biota, in some cases more so than changing salinities.

• The plant community (micro-algae and macrophytes) contains a range of species sensitive to small increases in salt concentration, including both lethal and sublethal effects. A concentration of 1,000 mg/L is sublethal; for some species, lethal effects become evident at 2,000 mg/L. The decline in macrophyte biomass has several significant repercussions:
- Reduction in plant cover causing changes in the light regime and subsequent shift towards a more phytoplankton-dominated system and algal blooms;
- Loss of food and breeding habitat for waterbirds, fish and lower, support levels of the food web (eg. insects and yabbies); and
- Reduction in concentration of dissolved oxygen, resulting in fish kills, adverse effects on decomposition and denitrification, liberation of phosphorus from sediments and production of noxious tastes and odours.
Such synergistic effects will compound resulting in significant loss of ecosystems of high conservation and public amenity value.

• Significant loss of abundance (biomass) in many invertebrate taxa reduces food availability for other taxa, including fish and waterbirds, and confounds impacts on in situ carbon/nutrient processing.

• As salinities increase over the drawing-down period significant increases in abundance of more salt tolerant fly species, including some mosquito and chironomids (midges), are likely to occur.

• Macroinvertebrates in wetlands consist of a diverse community that include species sensitive to small increases in salinity. Significant reductions in species diversity have been observed at a salinity of 800 mg/L. Sensitive taxa include cladocerans, gastropod snails, some hydrophylid water beetles, aquatic weevils, dragonflies, some damselflies and some dipteran fly species.

• Increasing salinity up to 5,000 mg/L significantly reduces the abundance of all major taxa, including water beetles, crustaceans, and dipteran flies, that emerge from flooded wetland sediments twelve months later. No gastropod snails emerged. Such long-term effects are significant given that over-wintering communities are the first animals to emerge after the wetland floods and are likely therefore to represent the initial processes involving detrital material, and so underpin later community development. This later community develops as a more diverse secondary wave of insects and bird consumers arrive in the wetland.

Knowledge gaps

Current knowledge is insufficient to make informed statements concerning the extent and magnitude of likely impacts of increasing salinity in riverine and wetland ecosystems. Few studies have examined community changes in either wetlands or rivers subjected to increasing salinity. Also, there is a significant lack of knowledge of fundamental processes affecting ecosystem structure and function in riverine and wetland systems. Lack of basic knowledge prevents reasonable predictions of the likely salinity effects to riverine and wetland ecosystems.

The relative contributions of phytoplankton, epiphytes and macrophytes to net primary production in wetlands or as food source for various consumer categories are not known. Little, if any, interaction between groundwater hydrologists and biologists/ecologists examining salinity effects in aquatic systems has yet occurred. The absence of such interdisciplinary research is seen as an impediment in assessing the potential environmental effects of salinisation of aquatic systems.

A review of salinity tolerance data indicates that, although some information on the sensitivity to increased salt concentrations of certain river and stream dwelling animal and plant species is available, there is little information on the effects of salinity on possible sensitive life-history stages, behavioural responses, and of sublethal effects. There is also a dearth of information on the effects of salinity on communities of plants and animals and their interactions. Deleterious effects on certain important taxa (so-called, keystone taxa) or groups of taxa (eg. micro-algae) in a community are likely to have more significant effects on ecosystem processes, such as production or the decomposition of organic matter, than effects on other groups.

It is difficult to predict the effects of increased salinity on lowland systems given the lack of detailed biological information. Little is known about animal and plant community structure in lowland rivers and streams, or how communities vary in space and time. Even less is known about the extent and magnitude of interactions between particular animal taxa or plant/animal functional relationships. Vital ecosystem processes within lowland streams and rivers are poorly understood and require elucidation.

General biological knowledge of Australian wetlands is extremely poor. In only a few cases are the plants and animals known that live in wetlands, apart from the obvious charismatic species. This lack of basic census information is the legacy of years of neglect by governments and researchers. This basic omission has been repeatedly cited as undermining informed opinion and management decisions.

Despite obvious links between groundwater intrusion and salinisation of wetlands and rivers, a poor understanding of the dependence of wetlands systems on groundwater exists. Changes in salinity over time in relation to draw down events and flushing are rarely monitored yet they are likely to be critical to any understanding of processes. There is also little information on how important leaching and flushing are in re-setting salinity levels, ie. the impacts of hydrological practices on salinity in wetlands, especially given that wetland and river systems are increasingly being regulated. Minimal information is available on the rehabilitation of wetlands and rivers following salt impacts.

Implications for research and management

The effects of salinity on the base of the food web, periphyton/epiphyton productivity and detrital processing should be quantified in some representative streams and wetlands as a matter of urgency. Longer-term studies should be undertaken to clarify and quantify the effect of increasing salinity at an ecosystem level in rivers and wetlands. These studies need to examine effects on temporal and spatial variation in rates of primary production, decomposition, organic matter processing and nutrient cycling over a range of different wetland and riverine types.

Broader interdisciplinary studies involving biologists, hydrologists, hydrogeologists and engineers should be encouraged and supported to examine and quantify interactions between groundwater intrusion, salinisation of rivers and wetlands, and associated ecosystem responses.

Pre-existing biological survey data and related stream and groundwater salinity data from a variety of impacted streams and wetlands should be collated and analysed to provide some baseline biophysical data and potential hazard maps of types of systems at risk. Studies should be undertaken to examine and quantify the connections between salinity, catchment hydrology and wetland/riverine catchment hydrology. Existing studies examining environmental flows should be expanded to incorporate salinity, groundwater flows and groundwater salinity.

Studies should be undertaken that link engineering options to ameliorate salinity problems with biological/environmental outcomes. The potential conservation or ecological improvement with engineering costs should be identified. Studies should also quantify the effects of rapid salinity increases (eg. resulting from overland flow, pulses of salt water moving down a stream) on biological communities in a variety of different riverine and wetland systems so as to identify effects and possible generic responses.

Broadscale surveys of wetlands should be undertaken to examine, validate and quantify the extent of any correlations between increasing salinity and pH changes in wetlands. Researchers and managers should be encouraged to work together on large-scale field experiments to quantify salinity effects per se before and after management intervention. Changes in salinity over time in relation to drawdown events and flushing should be monitored.

Studies should be instituted to determine the importance of leaching and flushing in re-setting salinity levels, ie. determine the impact of hydrological practices on salinity in wetlands, especially given that the management of wetland and river systems are increasingly involving regulation. The relationships between drawdown, flushing and salinity levels in a variety of wetlands should be elucidated.

Research is needed to quantify the effects of various management practices on wetland and riverine health as measured by community structure, biodiversity and ecosystem processes. Long-term studies should be set up to determine how long it takes community or ecosystem change in streams and rivers subjected to increasing salinisation. Given that salinity is intricately linked to environmental water flows, the amounts of water required to maintain wetland systems in the face of increasing salinisation should be determined.

The implications, in terms of environmental degradation, of transporting or temporarily holding saline wastewater in rivers and wetlands needs to be clearly offset against the short-term benefits gained. The distance that saline water is moved through natural drainage systems should be minimised and saline water should not be directed to a wetland that cannot be easily and frequently flushed.

Catchment level management plans need to have protection of wetlands and rivers as a primary objective. Where appropriate, methods involving replanting with deep-rooted tree species and increased efficiency of on-farm water use should be used to arrest the rise in saline groundwater in preference to surface and sub-surface drainage. Wherever possible saline water should be disposed of on the farm or in the region of its origin.

Until reliable data exist to suggest otherwise, where release of saline water into natural systems is unavoidable, salinity levels of the receiving waters must be maintained at less than 1,000 mg/L. Negative as well as positive effects of management strategies designed to protect riverine and wetland systems from salinisation must be considered when developing a management plan.

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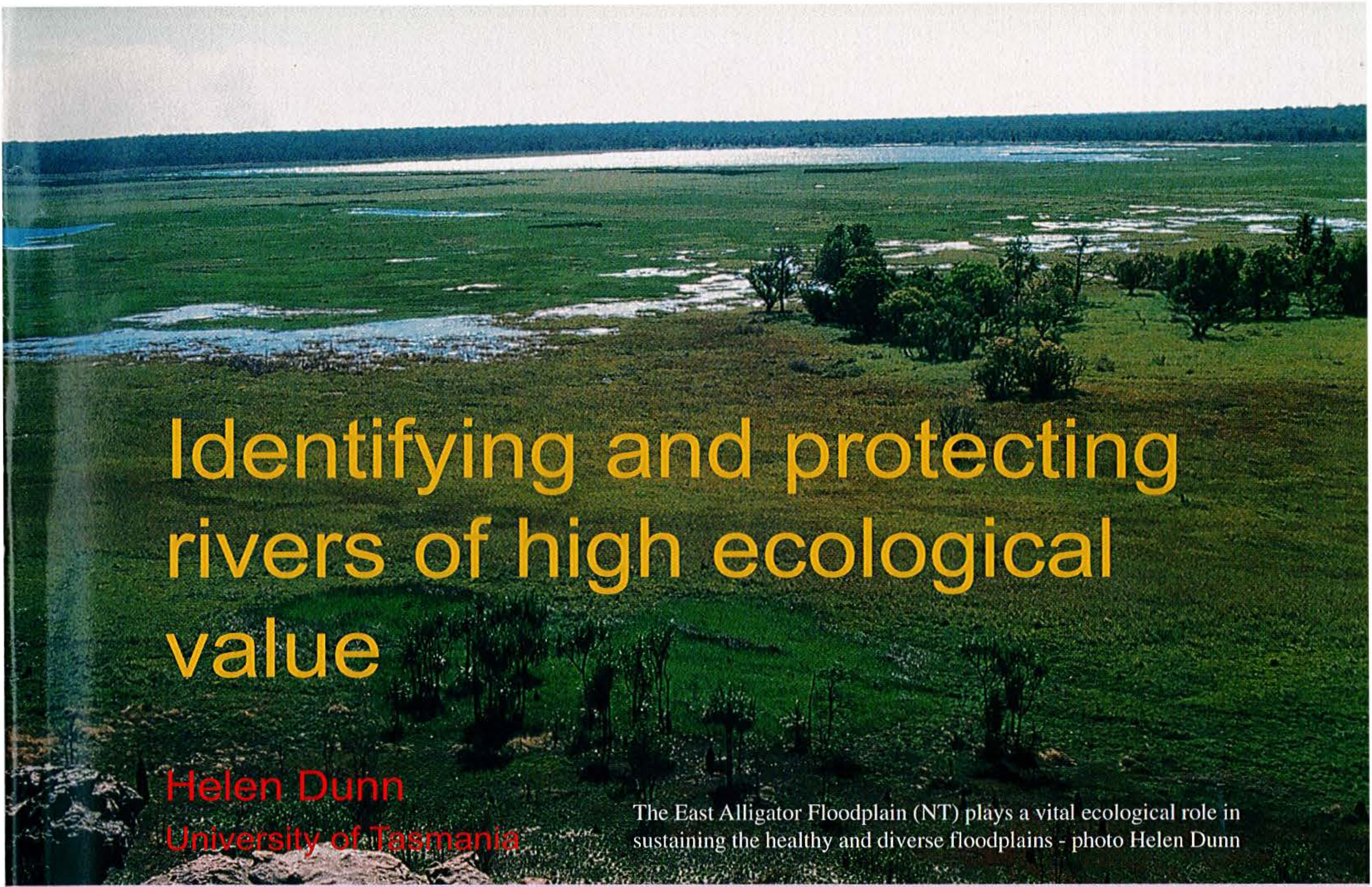
The review is published as LWRRDC Occasional Paper Series No. 25/99 and can be purchased for $10 from the AFFA Shopfront, phone 1800 020157. It is also available free on-line at <www.lwrrdc.gov.au/publicat/op2599/op25_99.html>.



Identifying and protecting rivers of high ecological value

Helen Dunn
University of Tasmania

The East Alligator Floodplain (NT) plays a vital ecological role in sustaining the healthy and diverse floodplains - photo Helen Dunn

Which Australian river would you nominate as being of high ecological value? And how would you justify your claim? Is the river in a National Park or Reserve, or if not, should or could, it be protected? And how?

Australia's rivers are of high conservation significance on a world scale. We have a wide variety of types of river systems ranging from unregulated tropical streams and high discharge rivers in temperate regions to rivers in dryland areas which rarely exit to the ocean. There are major rivers sustained by spring snow-melt and many ephemeral and highly seasonal rivers. Our rivers also sustain wetlands of international significance, spectacular karst systems and floodplains, and corridors which provide continuity of habitat and refuges.

The flora and fauna of Australia's rivers and associated ecosystems also have many special features. These include species that have affinities with the ancient continent of Gondwana, distributions that tell of ancient landmasses and climates, and highly adaptable life-histories to cater with the extremes of climate. There are notable differences between Australian and northern hemisphere waterways, for example the difference in carbon processing as a result of the distinctive eucalpyt flora.

As yet there have been no concerted or systematic efforts to protect the conservation values of Australia's rivers. On one hand, there is a government commitment, expressed in the Biodiversity Convention and Biodiversity Strategy that the Commonwealth and all state governments have signed, to conserve biodiversity across all types of ecosystems. At the same time there is increasing pressure for greater access to water from our rivers and consequently effects on river health and the biota.

A first step in moving to protect rivers of high conservation value is to seek ways of identifying which rivers might be considered the most important to protect. A LWRRDC-funded project[1] sought to explore these issues, and to recommend ways to identify and protect rivers of high ecological value.

It was agreed at the outset that a river did not have to be in 'natural' or 'pristine' condition in order to have ecological value. It may still provide habitat for a rare species, sustain important wetlands or maintain significant geomorphological or hydrological processes.

1. see references - page 31

Defining 'ecological value' of rivers was a key task. The Attributes of ecological value had to be capable of application to a wide range of types of river, river sections and riverine habitats. The Attributes also had to include all those aspects of riverine environments that make up the waterways, and the processes that sustain the ecosystem.

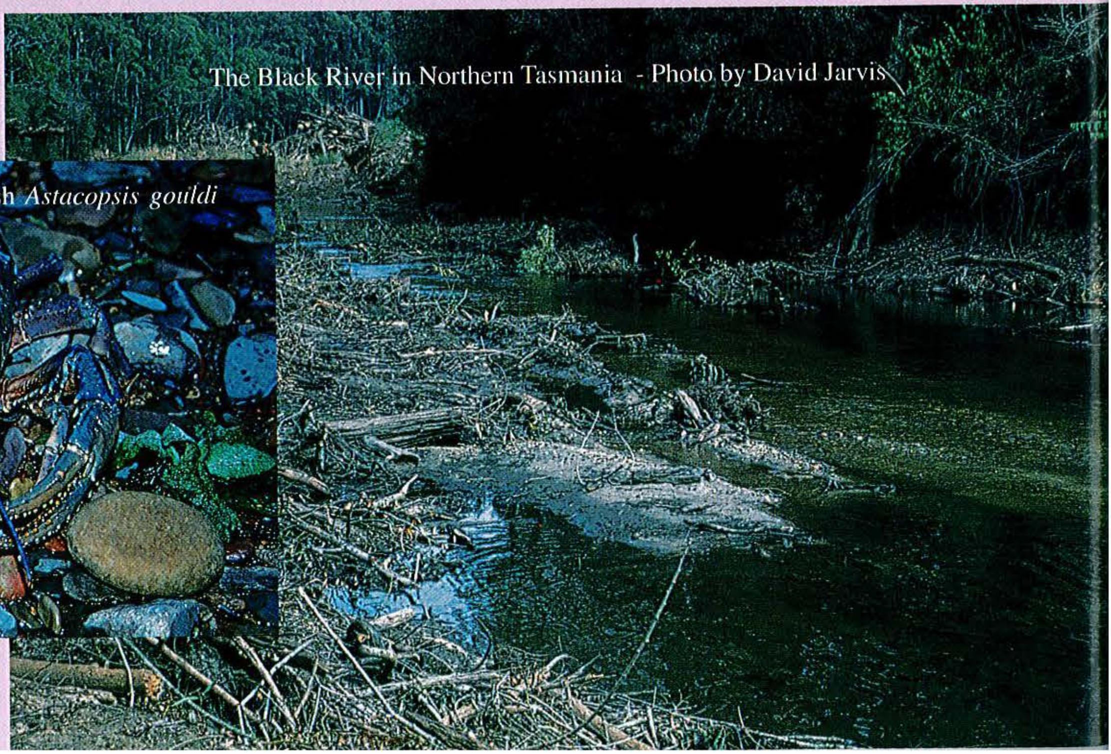
A survey of river scientists and river managers from across Australia was conducted in May 1999. The net was cast as widely as possible. No statistical analysis was planned because the purpose of the survey was to test, support and generate ideas, so there was no limit to the number of people who could respond. Contacts were made and the survey completed by electronic mail systems. The many community groups working on river projects were not included since the survey sought a broad rather than a local perspective. The survey also did not include other conservation values, such as historic, cultural or aesthetic values of rivers.

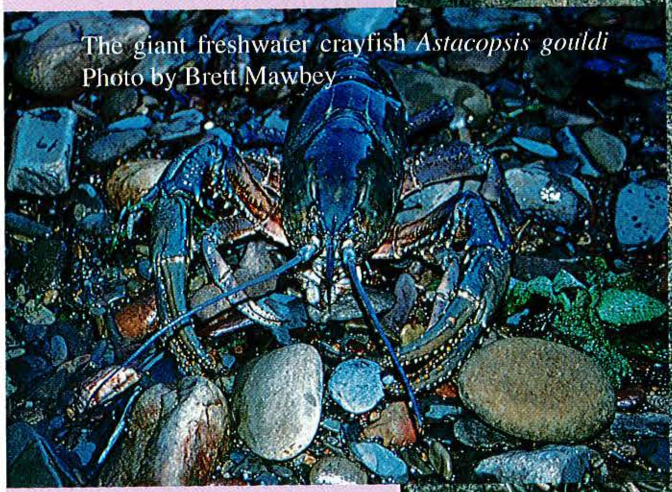
The results of the survey showed great consistency across research interests, and regions of Australia. The final Criteria and Attributes are listed in Table 1.

Possible Attributes are grouped under five general Criteria. It is not expected that rivers will meet all Criteria and some Criteria will not be relevant to all river systems. Geomorphological values such as river forms and dynamic river processes are included along with more obvious values such as fish, flora or invertebrates. The five general Criteria are Naturalness, Representativeness, Diversity, Rarity and Special Features. 'Naturalness' is considered by some people as an assessment of condition, but it is also an important value in its own right. 'Diversity' is an important element of biodiversity conservation, *but places that* have low diversity may also be significant for their natural characteristics and as representatives of that river type. So for example, rivers that have naturally low pH may have low species diversity but are nevertheless natural and representative and so can have high ecological value.

The report pursues further discussion of the Criteria and Attributes. If judgements are to be made about relative values of different rivers, it is important that comparisons are made between similar types of river or river section. There are many issues still to be explored in defining the bases for comparison and setting thresholds. In addition, the Criteria and Attributes themselves need to be field-tested and validated. Such assessment is currently underway in the NSW Department

The giant freshwater crayfish *Astacopsis gouldii* is an endangered species endemic to rivers with cool temperatures and woody debris in northern Tasmania, ie. the Black River. Willow infestations must be cleared carefully from the Black River if *Astacopsis* is to survive. It is essential to avoid accidental ecological damage to rivers by assessing all river values before commencing rehabilitation work.


The Black River in Northern Tasmania - Photo by David Jarvis


The giant freshwater crayfish *Astacopsis gouldi*
Photo by Brett Mawbey

of Land and Water Conservation (Ecological Processes and Conservation Unit) and two case studies are nearing completion. The Queensland Environment Protection Agency has also been examining these issues as part of its methods for defining conservation value (Phillips *et al* 2000).

This list of Attributes may be used in different approaches to assessing the ecological values of rivers. It provides a set of criteria that can be applied in different ways according to the purposes of the assessment.

The project report outlines four principal ways the criteria might be used or applied:
1) planning for a system of river reserves
2) determining groups of rivers which should be classified as high priority for conservation
3) selecting rivers for priority for management intervention for conservation or restoration
4) identifying the ecological value of individual rivers within the context of catchment management planning.

The report points out that there is a commitment within Australia's Biodiversity Strategy to protect the range of biodiversity through a system of Comprehensive, Adequate and Representative (CAR) reserves. For other types of ecosystem such as forests, grassland and marine habitats, there has been, or continues to be, progress towards identifying and setting aside for conservation such a system of reserves. There is no similar process in place for river systems despite the immediate threats to these ecosystems. The Criteria and Attributes defined in the study provide a key starting point for CAR reserve planning for rivers.

A system of Comprehensive, Adequate and Representative rivers to be managed primarily for conservation would not only contribute to conservation of biodiversity for many river values, they would also provide examples or models of rivers which may provide comparisons or goals for restoration. Rivers which are considered to be representative also provide opportunities to understand better how rivers work.

A second use for the Criteria and Attributes is to classify river systems or sections to determine groups of rivers of high conservation value. This would allow a State government agency to get an overview of the extent and nature of rivers of high value within their jurisdiction. The New South Wales Department of Land and Water Conservation [2] has already undertaken an exercise to classify its river systems according to level of stress. The stressed rivers report broadly groups together those rivers that are least stressed as being of conservation value. The list of Criteria and Attributes from the present LWRRDC project are now being applied to these rivers to identify specific ecological values as the basis of setting management priorities.

The third type of application of the Criteria is to identify the conservation significance of particular rivers and to assist in determining what levels or types of development may or may not be suitable. In this case thresholds for significance of each value, and decision rules about how these are applied and added together or weighted, must be made before the process begins. The Queensland EPA is developing its own somewhat similar protocol for use in the Water Infra-structure Planning and Development Implementation Plan (WIPDIP)[3,4,5]. This is a working example of the third type of use for the Criteria and Attributes.

Options for setting standards and levels of significance are discussed in the report. Numbers or scores always have to be treated with caution as a means of summarizing what is important but sometimes their use is inevitable. A central question is whether a river can be considered of high ecological value if it only scores on a single Attribute or Criterion. Most would argue that this should be the case. The difficulty comes if 'scores' for Attributes are added together and if rivers with high scores are therefore considered more important than ones with a lower score.

Each of the three previous uses for the Attributes is likely to be initiated and implemented by State or regional authorities. The fourth major use for the Attributes is to provide a checklist that can be used at individual catchment management or even local level. River managers and interest groups can then assess what characteristics and Attributes of their river are particularly important from an ecological perspective, and incorporate this into their river plans. This will assist as a basis for assessment of environmental flow requirements and alert river managers to Attributes which need to be retained in any restoration activities.

River conservation needs to be addressed on

The naturally eroding banks of the meandering North River in western Tasmania are an example of undisturbed geomorphic processes. Photo by Helen Dunn.

these different fronts if we are to be able to protect ecological values of our rivers. Due to Due to the nature of river systems and the critical need for water for life, an integrated and planned approach is vital. There is very little legislation that addresses conservation in ways that can readily be applied to rivers. In contrast, there are often several agencies and interest groups with responsibility for different aspects of the waterway. Providing for conservation values can often get left aside, or assumed that it will be covered by expectations of the maintenance of river health or provision of environmental flows. Assessment of ecological values should be an essential component of the values mapping for catchment management plans. Downstream effects and possible impacts of upstream activities must not be forgotten.

The work of identification of values should be addressed at an appropriate level of detail and expertise. Much existing information, records and material will contribute to the assessment process. For example, it may only be possible to use an expert panel approach because of time limitations. Drawing together people who know a river well will often yield useful information (though this must be checked for reliability). Collections made for other purposes such as the AusRIVAS biological monitoring program may be further analysed to contribute to knowledge of river ecology. Of course, specific research may be required where evidence is questioned or priorities for the river are contentious.

The work of individual catchment groups and management authorities towards identifying and protecting ecological values will be important at a local scale. However, more needs to be done to achieve systematic protection of our very special river systems.

The report suggests that this needs to happen at a national level with State involvement in the process. Through a recently successful LWRRDC application, the Queensland EPA will be developing guidelines for conservation assessment and planning which will be aimed at national adoption (N.Phillips, pers.comm. 8/3/2000). A strategy for the identification and protection of rivers of high ecological value should be developed for Australia. At the core of the strategy should be the setting aside of a Comprehensive, Adequate and Representative system of protected rivers which have maintenance of conservation values as the over-riding management goal. Other rivers should be added to the river reserve system based on particular Attributes of significance. Increased awareness of ecological values and their protection in all river systems will be a critical element of the strategy.

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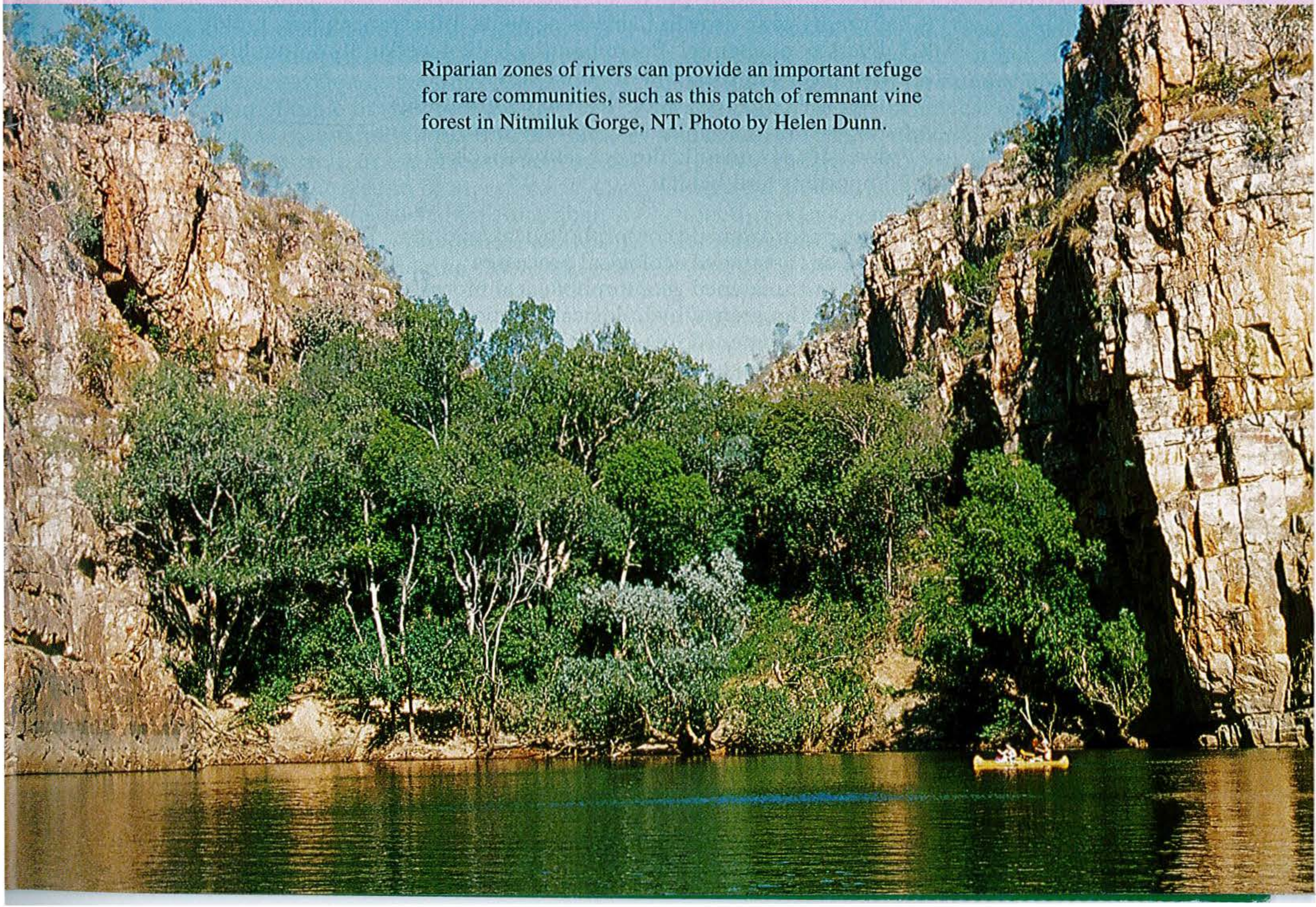


Riparian zones of rivers can provide an important refuge for rare communities, such as this patch of remnant vine forest in Nitmiluk Gorge, NT. Photo by Helen Dunn.

Trial. Internal report, Version 1.2, January 25 2000, EPA Brisbane

Criteria and attributes for assessing the ecological value of rivers

Criterion	Attributes
1.Naturalness	1.1 undisturbed catchment
	1.2 unregulated flow
	1.3 unmodified flow
	1.4 unmodified river/channel features
	1.5 natural water chemistry
	1.6 absence of interbasin water transfer
	1.7 intact and interconnected river elements
	1.8 natural temperature regimes
	1.9 natural processing of organic matter
	1.10 natural nutrient cycling process
	1.11 intact native riparian vegetation
	1.12 absence of exotic flora or fauna
	1.13 habitat corridor
	1.14 natural in-stream faunal community composition
	1.15 natural ecological processes, including energy base and energy flow thro' food webs.
2.Representativeness	2.1 representative river system or section
	2.2 representative river features
	2.3 representative hydrological processes
	2.4 representative aquatic macro-invertebrate communities
	2.5 representative instream flora or riparian communities
	2.6 representative fish communities or assemblages
3. Diversity/richness	3.1 diversity of rock types or substrate size classes
	3.2 diversity of in-stream habitats eg pools, riffles, meanders, rapids
	3.3 diversity of channel, floodplain (including wetland) morphologies
	3.4 diversity of native flora or fauna species
	3.5 diversity of in-stream or riparian communities
	3.6 diversity of floodplain and wetland communities
	3.7 diversity of endemic flora or fauna species
	3.8 important bird habitat
4. Rareity	4.1 rare or threatened geomorphological features
	4.2 rare or threatened ecological processes
	4.3 rare or threatened geomorphological processes
	4.4 rare or threatened hydrological regimes
	4.5 rare or threatened invertebrate fauna
	4.6 rare or threatened fish or other vertebrates
	4.7 rare or threatened habitats
	4.8 rare or threatened flora
	4.9 rare or threatened communities or ecosystems
	4.10 rivers with unusual natural water chemistry
5. Special features	5.1 karst, including surface features
	5.2 significant ephemeral floodplain wetlands
	5.3 dryland rivers with no opening to ocean
	5.4 important for the maintenance of downstream or adjacent habitats such as floodplain/estuary
	5.5 important for the maintenance of karst system or features
	5.6 important for migratory species or dispersal of terrestrial species
	5.7 drought refuge for terrestrial or migratory species
	5.8 habitat for important indicator or keystone taxa
	5.9 Habitat for flagship taxa
	5.10 Refuge for native species and communities in largely altered landscapes

Estuarine Health Assessment Using Benthic Macrofauna

John Moverley
Museum of Victoria

Introduction

Estuaries are home to a variety of animals and plants the least conspicuous of which is the benthos, the animals living in the sediments of the estuarine floor. The diversity and abundance of the benthos can indicate the overall health of the estuarine ecosystem. This project evaluates whether computer models applicable in river systems for the assessment of environmental health could be applied to Australian estuaries.To achieve this two questions needed to be answered. 1. Can such models be constructed for Australian estuarine habitats? 2. Would these models be useful for assessing estuarine environmental health?

What is an estuary?

The estuarine habitat is poorly defined. Different scientific disciplines define estuaries by geographical, topographical, chemical, biological and hydrographical terms. People from different disciplines draw different boundaries and there is even conflict as to whether a body of water is an estuary. For example it is frequently argued that only waters with diluted sea water and regular tidal influences can be estuaries. This would exclude many Australian river mouths because they have closed bars, and thus are not subjected to tidal influences, and/or the evaporation rate exceeds fresh water input so they become hypersaline.

Problems with defining the estuarine habitat were highlighted during the early 1990s in the United Kingdom when, due to there being different regulations for the discharge of effluent into estuarine and coastal waters, courts were required to assess whether discharges were estuarine or not. There is no official definition of an estuary in Australia and this is needed before estuarine health monitoring can be undertaken. For the purposes of this study, we assumed estuaries were the coastal plain regions of streams whether they openly discharged into the sea or formed a coastal saline lake that was intermittently open to the ocean.

What are benthic macrofauna?

Benthic animals are those associated with the bottom of seas, rivers, lakes, etc. Epibenthos lives on the surface and infauna buried within the sediment. Macrofauna is larger and meiofauna smaller. We considered only macrofauna, multicellular animals retained on a 1.0 mm sieve except nematodes and copepods. Nematodes and copepods are the major component of meiofauna and only a small proportion are retained on a 1.0 mm sieve.

Choice of sieve aperture is arbitrary. We used a 1.0 mm sieve because in estuarine sediments there are large amounts of organic detritus which needs to be sorted under a microscope to find the animals. Samples collected with a 0.5 mm sieve take 3–4 times longer to sort and many of the extra animals retained are juveniles that can not be identified to species.Since this work required identification to species it was more appropriate to use a 1.0 mm sieve and sort a larger sample.

There are advantages in using benthic animals for monitoring estuarine health over plankton or fish that live in the water column. Benthos lives essentially in a 2-dimensional dispersal. This makes sample design easier. The distribution of plankton and fish is influenced by tides and diurnal cycles which are additional factors to be considered when sampling these groups. Also, because of their low mobility, benthic animals take some time to recolonise an area after a pulse or intermittent pollution event. Therefore past events can be detected using the benthos which may not be detectable in more mobile plankton or fish.

During our survey 44,477 animals belonging to 275 taxa were collected. The most common group were annelid worms (33% of species, 20% of individuals), crustaceans (32% of species, 43% of individuals) and molluscs (18% of species, 30% of individuals). Unlike the river samples where insects are an important component of the benthos, insects made up only 4% of the species and 2% of the individuals in the estuarine samples.

What is an AusRivAS-type approach to environmental health?

The AusRivAS (Australian River Assessment System) method for assessing environmental health of our rivers was described by Richard Norris in his article 'Bugs and Computers' in the Summer 1999 edition of Rivers for the Future. The method provides a technique that allows managers to compare the environmental health of a river or specific site with reference sites.

Using a database of species and abiotic variables at reference sites, an AusRivAS computer model predicts the probability of collecting each species from a test site based on the site's abiotic variables. This information can then be used to assess the environmental health of the test site by dividing the number of species observed in the sample by the number of species expected to occur, the O/E ratio. Assuming the model is reliable, an O/E ratio of one is anticipated and any divergence indicates an environmental perturbation.

The model is most accurate for the most abundant species so we based predictions on species with a 0.5 or greater probability of being collected.

In the river health project pristine or near pristine reference sites are used. It is not possible to find pristine or near pristine estuarine sites because the catchments of most Australian estuaries have been modified by urban, agricultural, pastoral or forestry activities. Even where the catchment is included in national parks the collection of bait and fish, the upper level preditors, occurs. Therefore, at best, an AusRivAS approach to assessing estuarine health would only be able to compare reference sites from estuaries with low levels of environmental impact or to make temporal comparison to assess how environmental management practices were affecting species richness within estuaries.

Findings

Samples were collected from 89 sites in upper, mid and lower reaches of 30 randomly selected estuaries in Victoria and southern NSW (to Batemans Bay). At each site two methods were used to collect samples. An Ekman Grab was used to target infauna and a dredge for epibenthos. It was intended to use these as separate data sets to investigate which was the most appropriate sampling method. However, neither method collected sufficient numbers of species per site to develop an AusRivAS type model. To overcome this we amalgamated the two data sets. This was possible because AusRivAS type models require only that a standard sampling method be employed and uses presence/absence data rather than abundances of the different taxa.

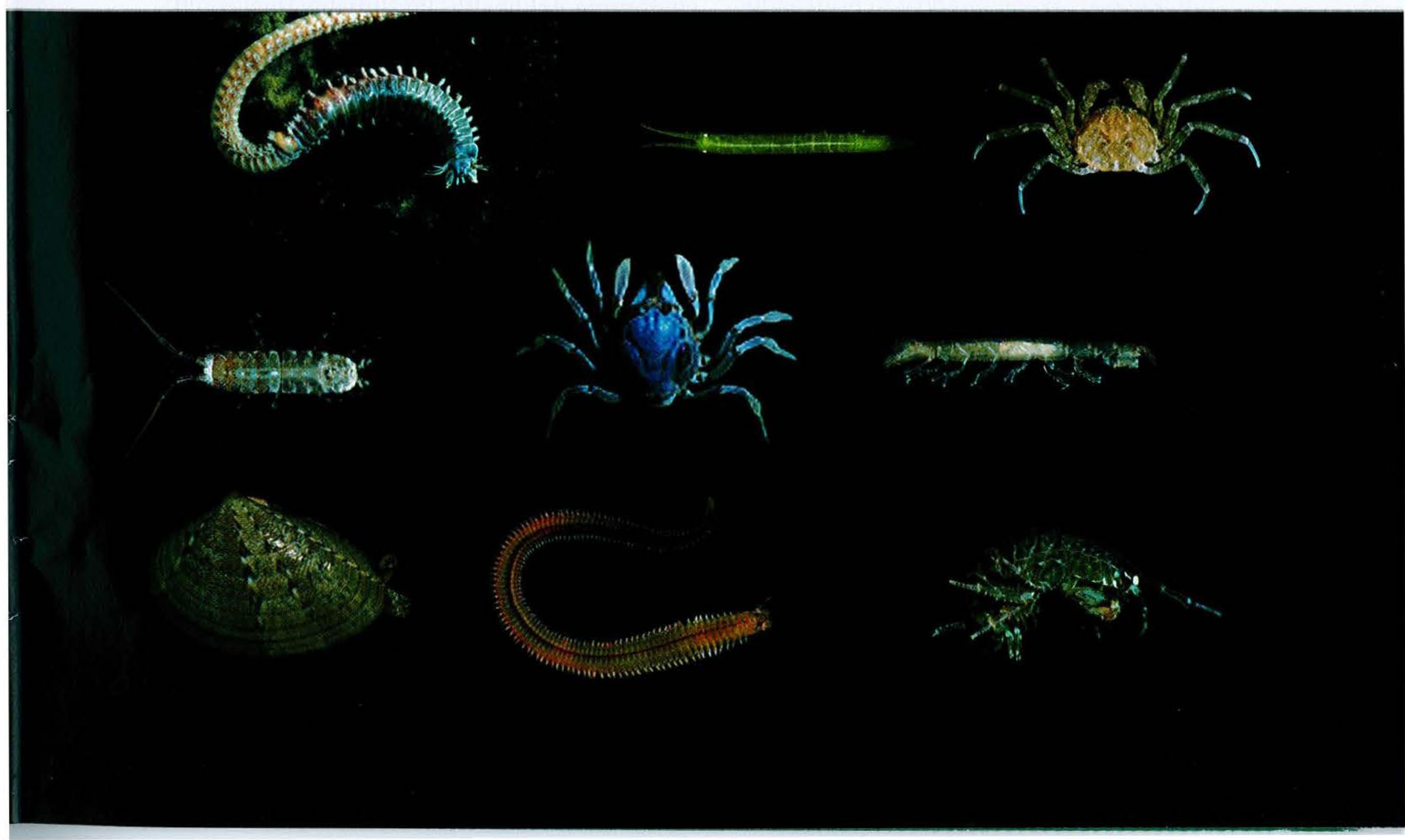
Almost a fifth of the estuaries visited were 'layered'. These did not have tidal mixing because the mouth was closed and had only limited opportunity for wind mixing because they were narrow, i.e. they did not flow into coastal lakes. Layered estuaries usually had fresh water on the surface and a submerged body of denser brackish water. Probably because of the low availability of oxygen, such estuaries had very sparse macrofauna, with numbers in samples being too low to give an accurate representation of the community. Data from some other sites were excluded from model construction due to incomplete biological or environmental data. The pilot model was based on 58 sites. This compares with several hundred reference sites in most AusRivAS models. Nevertheless, with the exclusion of the layered estuaries we found that our model was relatively accurate in predicting O/E ratios for our test sites.

The second part of our project was to assess if an AusRivAS type model would be of value for monitoring estuarine health. Sensitivity in detecting environmental impacts depends on the number of expected taxa in the O/E ratio. If there are 20 expected taxa, a 25% species loss results in the observed taxa being 15. A loss of five taxa would be seen as significant. However, if there are only four expected taxa, a 25% loss is the disappearance of only one taxon. This may be due to chance. Even a 50% loss of expected taxa is a decrease of only two taxa which would probably not be considered significant. With an expected number of four taxa, a loss of 75% would "set alarm bells ringing". But at this stage the environmental degradation would probably be obvious and not require the collection and sorting of samples.

The numbers of expected taxa for our six test sites ranged from 4 to 13 with the median being 6.6. These are too low for the model to be of practical value. Without any additional work the numbers of expected taxa could probably be increased slightly by using a different sampling design from that in the pilot study. However, to increase the numbers of expected taxa to values similar to those in the river models would require a massive sorting effort.

Another problem to be addressed before an AusRivAS approach could be used in estuarine health monitoring is to understand seasonal patterns in estuarine benthos. In southern Australia estuarine macrobenthos shows strong temporal but not seasonal variability. In tropical and subtropical estuaries there are strong seasonal patterns in numbers and diversity, though numerically abundant taxa change from year to year. When using AusRivAS models to assess river health it is assumed similar seasonal patterns exist from year to year. Consequently, providing they are all collected in the same seasons, the reference samples and test samples do not have to be collected in the same years. At least in southern Australia this may not be true for estuaries, so that a new set of reference samples would need to be

Some benthic macrofauna - photographer Michael Marmach, Museum of Victoria



collected whenever a test was required. This would be prohibitively expensive.

Considering that the AusRivAS approach could not be used in all estuaries and that the sampling effort required to give reliable data would be relatively expensive, it was decided to review other options for looking at estuarine health. Environmental health can be indicated by the macrobenthos community structure; the number of species present, the distribution of individuals among the taxa, the proportion of rare taxa, etc. Such community descriptors can be depicted graphically in *k*-dominance curves, plots of cumulative percent abundance versus species ranked from most to least common. The problems with using *k*-dominance curves for assessing national or regional environmental health is that only a limited number of curves can be compared on each plot.

Our field work generated a large database that could be used to construct *k*-dominance curves for Victorian and southern New South Wales estuarine communities. We investigated multivariate analysis to compare large numbers of curves with each other and test sites. Community indices, many of which described the *k*-dominance curve provided a multivariate ordination analysis of the samples. The ordination plots could be divided into sections containing communities indicative of good, questionable and poor environmental health.

We demonstrated that this ordination method could be used to rate samples from estuaries elsewhere in Australia. Following improved treatment of effluent being discharged from a Tasmanian pulp mill over time there was a clear movement from communities indicative of poor and questionable environmental health to good environmental health. When analysed with the south eastern Australian data, samples from Western Australian and Central Queensland estuaries were also found to fit into the same pattern with samples indicative of stressed communities falling in the same part of the ordination.

Temporal samples collected from the Calliope Estuary at Gladstone, Queensland, showed that frequently sites moved from having an unstressed healthy community to a stressed community, and vice versa. This probably indicates natural high variability in the estuarine environment and is a problem that will plague any attempts to assign estuarine communities into stressed and unstressed states of health. Our work with *k*-dominance curves from these four Australian states suggested that at any one time approximately 15% of Australian estuarine macrobenthic communities indicated they were collected from environmentally stressed sites, 15% had communities indicative of possible environmental stress and approximately 70% of estuarine macrobenthic communities indicated a healthy and unstressed environment. We do not know if these ratios are natural or the result of present day modified estuarine environments.

Our project demonstrated that AusRivAS type models can be developed for Australian estuarine environments but suggested that for the macrobenthic communities more work would be required to increase the numbers of taxa expected to occur in samples. The work demonstrated that an AusRivAS approach does generate a data set that allows regional and national assessment of estuarine health. It is worth investigating if estuarine health could be better assessed using an AusRivAS type model using meiobenthos rather macrobenthos.

Our work has also shown that it is relatively easy to assess estuarine health using *k*-dominance curves with samples collected by different methods at different times and from different regions. Such samples were shown to be good for monitoring an improvement to environmental health. Presumably they could also be used to detect deteriorating environmental conditions. This method appears ideal for assessing how catchment management programs are influencing estuarine communities.

This project was part of the National River Health Program Urban Sub Program (funded by Environment Australia and LWRRDC) and was managed by Water Services Association of Australia.

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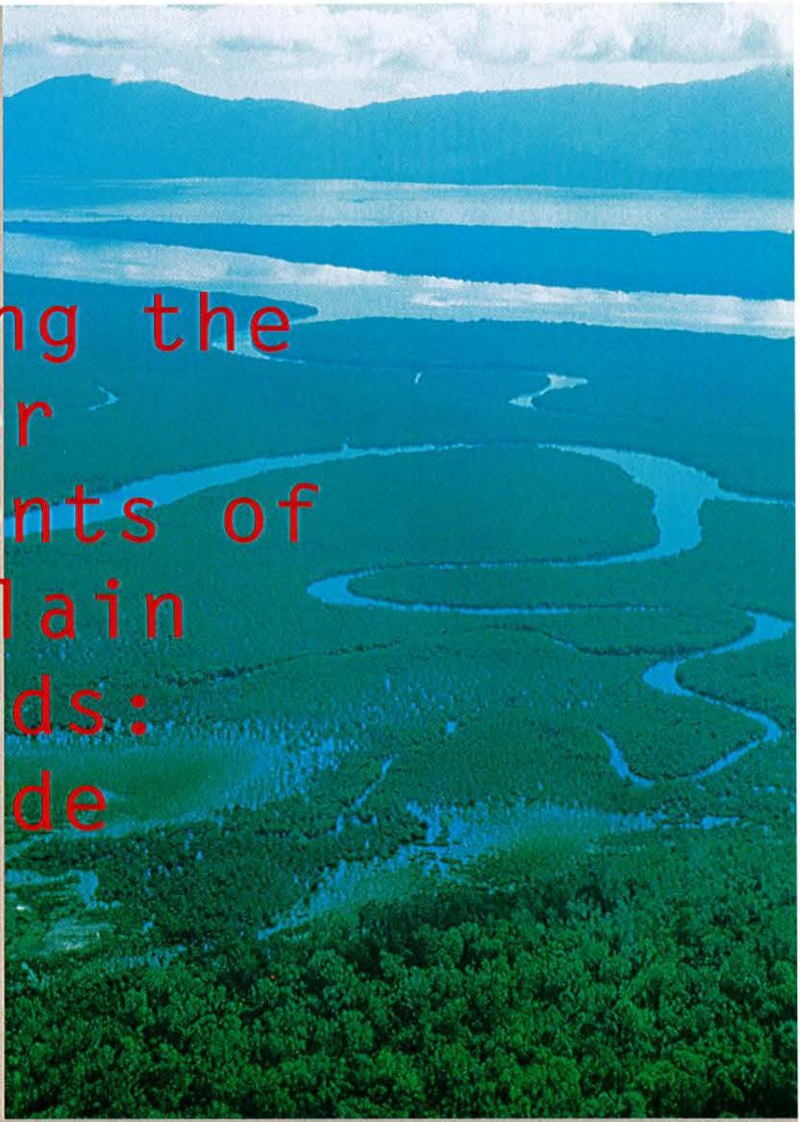
Estimating the Water Requirements of Floodplain Wetlands: A Guide



Jane Roberts, Bill Young and Frances Marston of CSIRO Land and Water have prepared a guide for estimating the water requirements of plants on floodplain wetlands in a project funded by Environment Australia and LWRRDC in the NHRP.

The future of water resources, water-dependent industries and aquatic ecosystems are under review throughout Australia. The principal users of river water, that is industries and ecosystems, are being identified and their respective needs are being formally recognised. Although the process of making allocations differs between jurisdictions, there is a common need for quantitative estimates of these needs. At present, the allocation process is faced with uneven knowledge, and ecosystem needs are inadequately articulated. The guide addresses one part of riverine ecosystem needs; the plants of floodplain wetlands.

In terms of flow management, riverine ecosystems can be divided into in-channel and overbank or floodplain. The links between in-channel ecology and flow regime are recognised and there has been considerable development in defining and quantifying in-stream flow needs. The recent publication of wetland books, reviews and manuals shows a similar advance in understanding for single wetlands. In contrast, knowledge of the over-bank riverine environment, or whole floodplain complexes, has advanced much more slowly.

Floodplain wetlands are large and diverse, but are typically well vegetated. This vegetation has value as habitats providing, for example, refuge and breeding opportunities - these values are not fixed but change through time. Because they support large waterbird populations after flooding, many floodplain wetlands have been listed as wetlands of national and international significance.

The guide combines the disciplines of hydrology and plant ecology, for which there was no previous reference text. It advises on how to estimate the water requirements of plants on floodplain wetlands and informs and increases understanding. It is not a prescriptive manual. The guide is directed at people charged with making decisions regarding water allocations who are not necessarily trained in all relevant areas. The guide draws on Australian case histories, mostly from inland rivers in eastern Australia, which is where the pressures of agricultural development have been most acutely felt. It is not a critical review.

Restoration has been a management goal in wetland management world wide, but in Australia there has been a drive to restore wetlands to their 'natural' or pre-European water regime. This is achievable for smaller, discrete wetlands, often with the aid of structures such as regulators, but is much harder to achieve for floodplain wetlands. Rehabilitation has been the primary management goal for the in-stream environment. Rehabilitation is the reality of managing heavily regulated rivers where the goal is to obtain small improvements while working within operational constraints. Resolution of what is desirable or achievable for floodplain wetlands is within the social and political sphere, and outside the frame of this guide, which instead outlines approaches suitable for restoration and rehabilitation.

Note that the guide is concerned primarily with water quantity. Neither water quality or land management, factors that can adversely affect the condition of plants on floodplain wetlands, are included.

The guide has seven sections.

1) Introducing floodplain wetlands
Understanding floodplain geomorphology and hydrology is the key to understanding ecological diversity of floodplain wetlands, and for understanding the vegetation. In this section, the key features of geomorphology and hydrology are introduced, to show the diversity within and between floodplains. Floodplain water balance, which is an important part of the guide, is also introduced, and its link to water regime outlined.

2)Introducing the vegetation
This section gives an ecological background to floodplain vegetation, by looking at some of the ways that water and water regimes affect plants. First, water is considered as part of the plant environment and described as environmental gradients across the floodplain, then it is considered as a resource, and finally as a resource and as an environment that affects other resources. Vegetation attributes that are routinely used to describe terrestrial vegetation are presented, in the context of Australian floodplains. Descriptive approaches such as growth-forms and plant functional types are outlined in relation to the floodplain environment. Plant water regime and its seven main components are presented and the value of focussing on depth is emphasised.

3) A stepwise procedure
The process for determining the water requirements for plants of floodplain wetlands can appear complicated and even circular to those involved in the process, but in fact it follows a series of well-defined steps. These steps are similar regardless of political process or which floodplain wetland is being considered. This section describes the five steps in this general procedure. Only Step 3 and Step 4, both purely biophysical, are treated in detail in this Guide.

4) Old and new data
One of the first decisions is whether to use existing vegetation-hydrology relationships, or to develop new ones. An assumption of the guide is that existing hydrological data is likely to be adequate, so the question is how to use what water regime is available and how to improve it. However, as it is likely that there will be little useful vegetation data this will have to be collected. This section discusses evaluating existing knowledge, then outlines options for developing new relationships based on held studies. There is a definite role for special studies and experimental research, which tend to be overlooked.

5) Obtaining vegetation data
When there is little or no previous information about water regime for relevant species, then vegetation-hydrology relationships must be established from scratch. This section describes what sort of vegetation data to obtain, and whether to do this at the species or community level. If at species level, ways of choosing species are outlined. Different measures of vegetation are described, abundance, character and vigour, and examples given for species, community and different growth-forms. Techniques for measuring abundance, character, and health are outlined, rather than given in detail. Examples are given of Australian studies and experiments to show how these complement field-based vegetation-hydrology relationships.

6) Using water regime data

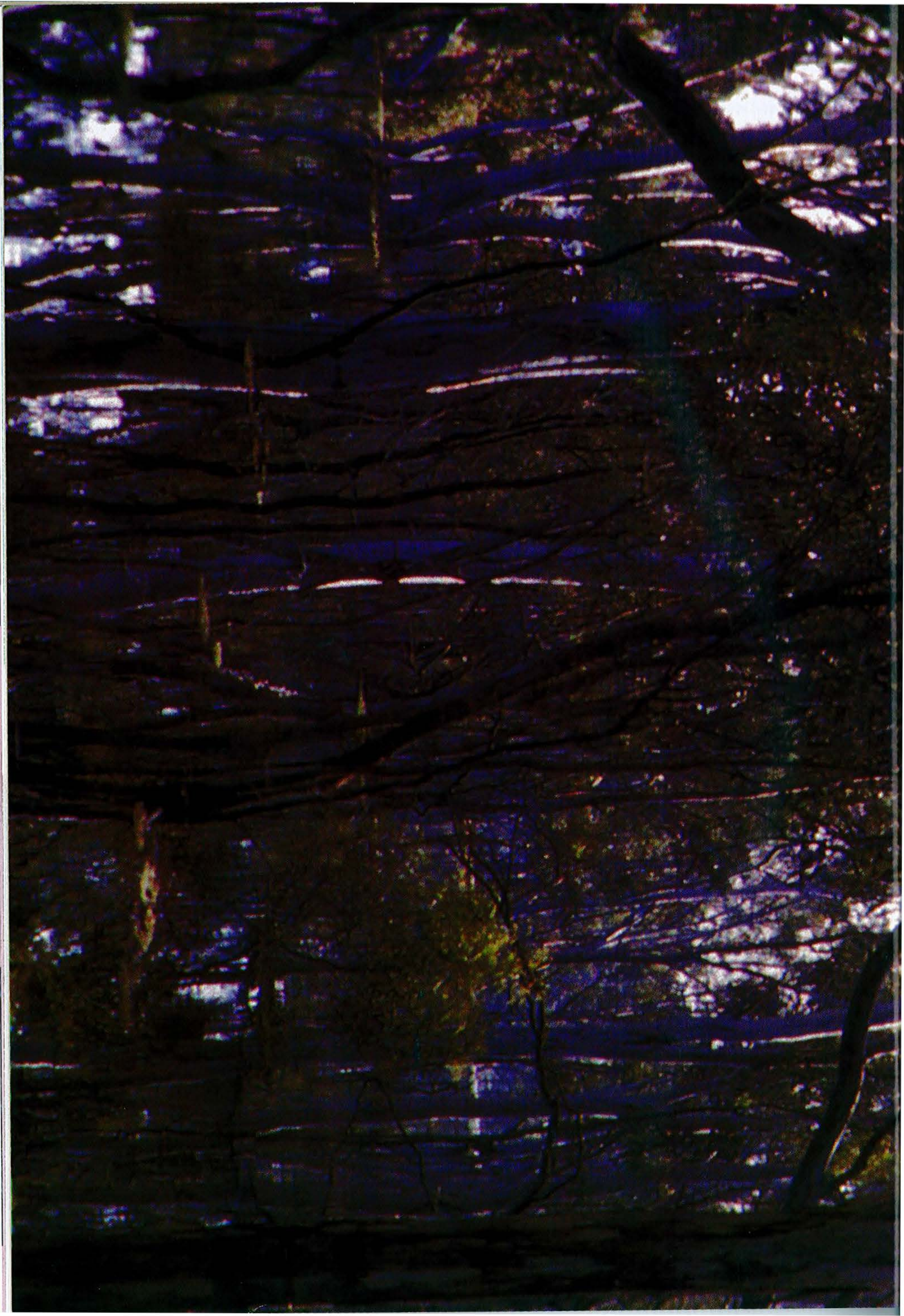
The hydrologic variable of most relevance to plants is water depth. However, water depth data are rarely available for large wetlands. Depth can be obtained directly or indirectly by water balance calculations from existing data. This section focuses on the indirect ways for obtaining depth, but also recognises that water regime can be defined in other ways. Options for estimating the different components of a floodplain wetland water balance are described, with emphasis on spatial and temporal variations across the floodplain wetland. The application of water regime data for hydrological modelling is described with current Australian examples, although these are rarely based on depth.

7) Predicting vegetation responses

The general procedure advocated in the guide is to use vegetation-hydrology relationships to predict the likely future state of floodplain wetland vegetation as a result of proposed changes to water regime. The process of making these predictions is referred to as modelling. While modelling may be as simple as expert predictions based on a conceptual model, it generally involves repetitive calculations that describe the temporal and or spatial patterns in vegetation response. This section identifies four different categories of modelling, based loosely on the complexity of the modelling approaches, and describes them using examples from Australia and North America.

The guide is published as "Estimating the water requirements for plants of floodplain wetlands - A guide", LWRRDC Occasional Paper 04/00, and is available from LWRRDC, Phone (02) 6257 3379, Email <public@lwrrdc.gov.au>.

For more information about the guide contact Dr Jane Roberts, CSIRO Land and Water, GPO Box 1666, Canberra City, ACT 2601; Email <jane.roberts@cbr.clw.csiro.au>.



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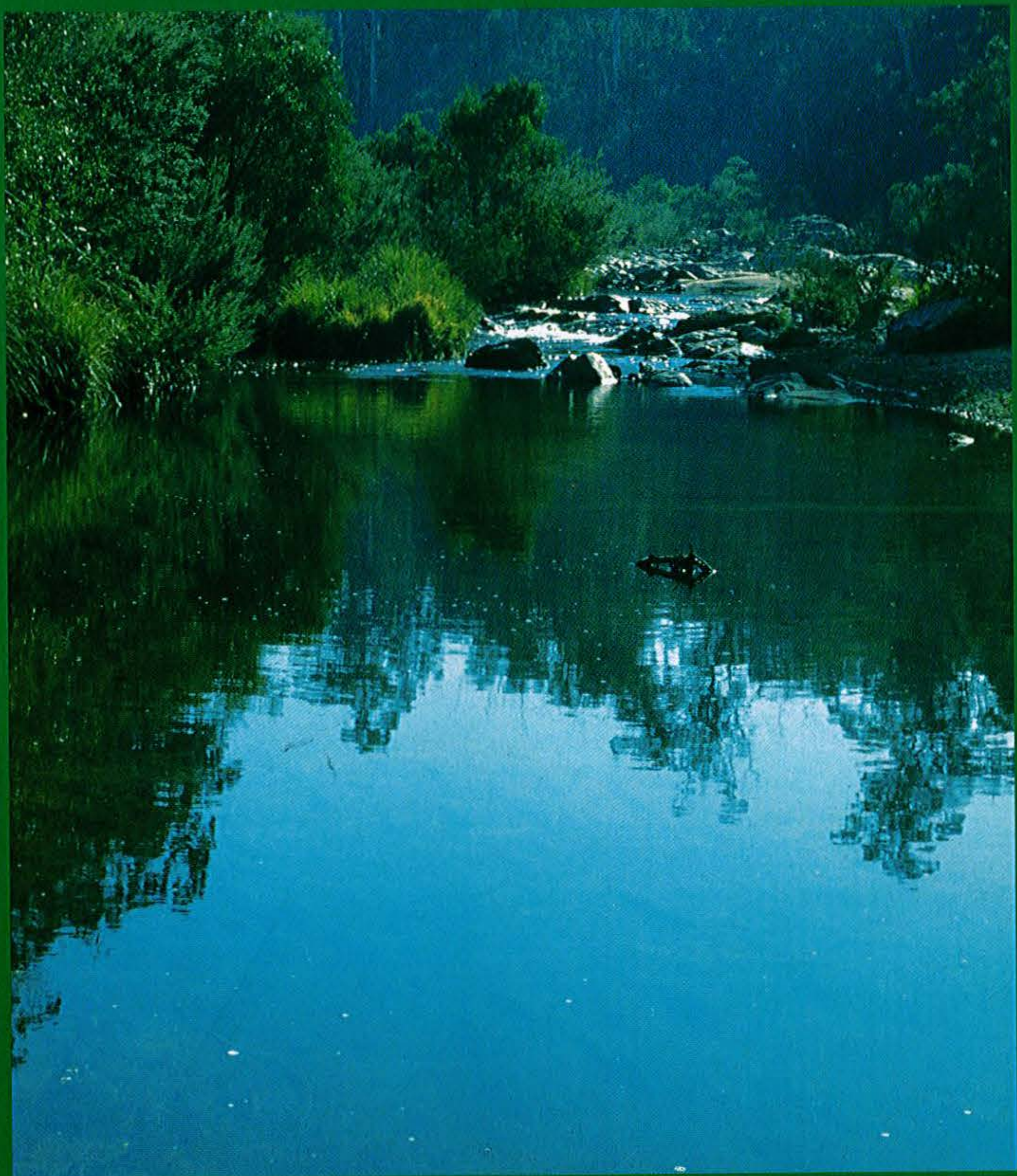

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