Rivers for the Future

Rivers for the Future Magazine
Issue 11, Autumn 2000

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Land & Water Resources
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Editorial Panel

Contact: c/o LWRRDC,
GPO Box 2182,
CANBERRA, ACT 2601.

Phone (02) 6257 3379
Fax (02) 6257 3420
Email <public@lwrrdc.gov.au>
WebSite <www.lwrrdc.gov.au>

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

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Cover: Upper Durack River, WA - Stuart Halse

EDITORIAL

Welcome to the first edition of Rivers for the Future for the new millennium. This issue brings two feature articles on pesticides and legislation. The article on pesticides covers for the first time the full results of the highly successful joint LWRRDC/CRDC/MDBC program to minimise the impact of pesticides on the riverine environment. It brings readers up-to-date with progress on implementing best pesticide management practices in the cotton industry developed through the program. This model of implementing scientifically-based practices through a well structured, appropriately resourced and auditable industry program is achieving wider recognition and interest from other large pesticide users. Indeed the model is generically applicable across all natural resource management issues and is already being expanded by cotton growers into other practices such as water use efficiency and soil health management.

The review of river legislation in Australia has uncovered a wide range of issues. Whilst recognising that rivers are receiving more attention and significant progress has been made in specific areas, the review notes that: there has been limited application of Commonwealth powers to protect rivers; no national binding standards have been set for river protection or management; the focus has been narrow and not holistic; there is strong opposition to security of environmental flows; and there is an absence of a national/state policy framework to ensure a level playing field. The review goes on to identify best practice criteria for river legislation and related policy and institutional frameworks. It notes that the legislative framework is at a crossroads – one model being to strengthen and move the regulatory framework forward (favoured by stakeholders outside decision-making circles) – the other model proposing inclusive, co-management, multiple mechanisms approaches with a lower but still critical role for legislation.

A number of other interesting articles include the application of AUSRIVAS to Western Australia and wetlands and the emerging results from the National Eutrophication Management Program.

Nick Schofield, Editor

Appointments to rivers programs

The Consortium has appointed two program coordinators, Phil Price and Brendan Edgar, to assist with the implementation of this new initiative. Phil will be well known to readers as the past LWRRDC Executive Director whilst Brendan has come across from Environment Australia where he managed the Wetlands Unit. Siwan Lovett has also been re-appointed as the Riparian Program Coordinator and will help carry this valuable program forward into the next five-year phase.

Brisbane River Festival

Arrangements are now well under way for the next Brisbane River Festival and International Rivers Symposium, to be held on 6-8 September. Its key features will be maintained and enhanced: analysis of all aspects of river management, focus on case studies and the international River*prize* which recognises excellence in river management. Case studies will be drawn from Australia, Asia, Africa, Europe and north America. The keynote theme "Sustaining Rivers – defining the new international agenda" will be explored through three sub-themes: rivers in development, rivers in restoration and rivers in partnership. To enhance the future of the symposium LWRRDC and the Ausralian Water Association have been approached to partner the event and negotiations are in progress.

New Publications

Available from the AFFA Shopfront for the prices indicated, plus postage, phone 1800 020 157

Cost of Algal Blooms, LWRRDC Occasional Paper 26/99 $20.

Evaluation of the LWRRDC Rehabilitation and Management of Riparian Lands Program, LWRRDC Occasional Paper 03/00 $20.

Limiting nutrient workshop 1997, LWRRDC Occasional Paper 7/99 $15.

Available from Environment Australia on toll-free 1800 803 772 Email <civ@ea.gov.au>

A phytoplankton methods manual for Australian Freshwaters, LWRRDC Occasional Paper 22/99 $20.

SEEM (Simple Estuarine Eutrophication Models) User's Manual, LWRRDC Occasional Paper 20/99 free.

Estuarine eutrophication models. LWRRDC Occasional Paper 19/99 free.

Assessing the ecological health of estuaries in Australia, LWRRDC Occasional Paper 17/99 free.

A physical classification of estuaries. LWRRDC Occasional paper 16/99 free.

Sediment chemistry macroinvertebrate fauna relationships in urban streams, LWRRDC Occasional Paper 15/99 free.

Basic decision support system for management of urban streams – development of the classification of urban streams, LWRRDC Occasional paper 8/99 free.

Holistic river restoration in Australia:

Observations, Tools and Approaches

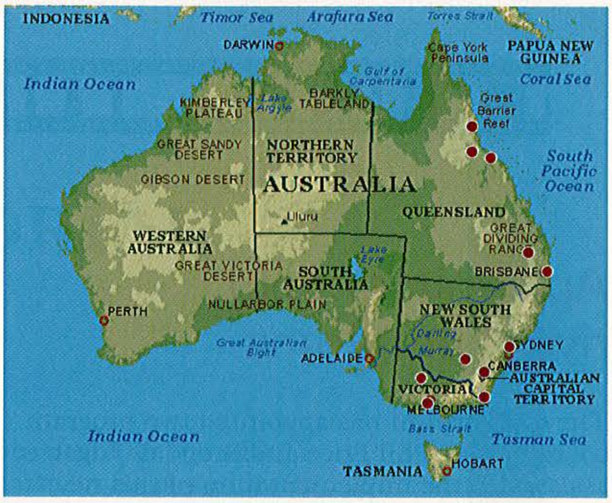


Figure 1. Sites visted during Dr Imhof's 1999 study.

Jack Imhof, an eminent aquatic ecologist with the Ontario Ministry of Natural Resources, visited Australia in 1999 on a LWRRDC travelling fellowship grant to interact with some key river research groups and provide insights to Ontario's river restoration approaches and initiatives. As part of his study tour Jack was requested to report on his observations of Australian research and what can be learnt from Ontario.

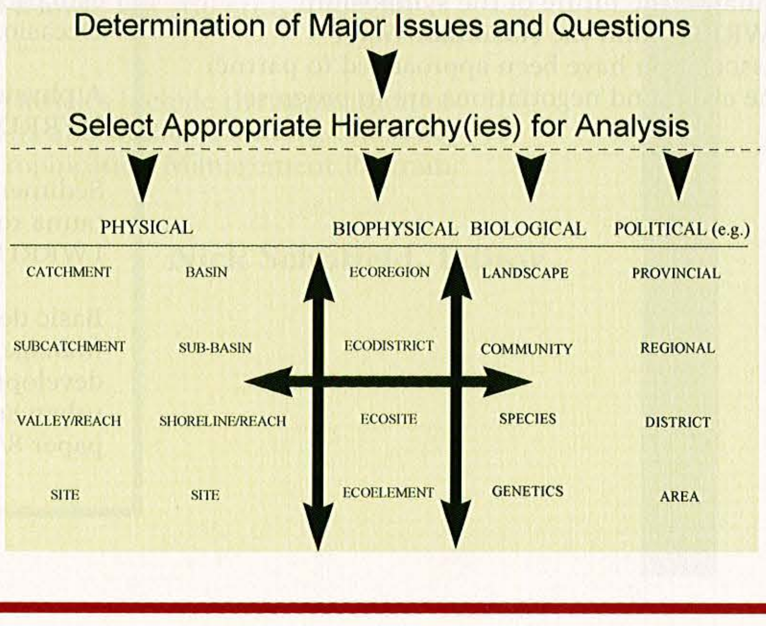
His report is divided into several sections: observations from field trips; river restoration framework considerations, including tools and training materials; and considerations for developing integrative inter-disciplinary teams. It adds to the comprehensive work that has already been published on river restoration in Australia by Brierley, Rutherfurd and Kapitzke.

Jack observed that the state of development for river science, riparian lands and ecological functions of river systems in Australia is world class and ahead of much of the work being done in North America. He noted several areas of additional focus that could be developed:

- integrated studies that examine physical, chemical and biological processes in common study areas;
- research that can improve our understanding of changes in structure and function of systems at different scales of landscape;
- analytical planning and design protocols that are hierarchical in nature and provide an

Figure 2.(from the report)

A variety of hierarchical systems can be considered to answer management issues. The appropriate system is chosen based upon the specific major issue to be resolved. The key concern then is in choosing the right hierarchy, being able to identify which scale(s) need to be assessed to scope and understand the issue and finally how to navigate between hierarchies when the understanding of the issue identifies secondary questions that can only be addressed using a different hierarchy.



understanding of the abiotic and biotic cause:effect relationships at different landscape scales; and

• determination of which hierarchical system is appropriate for what types of issues (Fig 2).

Jack was very impressed by the fine work that is underway in Australia and thought that the strategic approach to R&D being implemented by LWRRDC is an excellent model for other regions to follow. He proposed that further tools are needed to provide a stronger foundation for implementing the research, including:

• standardised definitions of terms used in discussing river restoration objectives;

• guidelines for system-based analysis and planning; scientific and management principles to be applied in all studies and projects; classifications of catchments, valley systems and channel forms that can aid in understanding formative processes and evolutionary characteristics of these systems;

• development of integrated studies that can be used to train a generation of inter-disciplinary practitioners;

• guidelines for community-based planning and community capacity building; and

• hydraulic information on habitat requirements of fish.

Jack reviewed the river restoration management work of Katitzke, Koehn and Rutherford (see below), amongst others, and suggested that it would be worthwhile to identify the range of goals and objectives of river rehabilitation in Australia, based upon the types of environmental degradation, and to compare this list to that formulated by the National Research Council for North America. This list would be useful in determining Australia's unique research requirements.

Jack also recommended that a flow chart, guide or "map" could be developed for manager, scientist, community group or individual to assist them in the selection of the appropriate river restoration manual for the major issues and scale of implementation. The major focus for an International River Network would be to synthesize the research from Australia, South Africa and Canada into an international framework and procedure for catchment and stream management and restoration.

Jack suggested some approaches for linking R&D to planning and policy making in Australia.These included the development of technical, analytical and planning tools for Integrated Catchment Planning, communicating to major decision-makers, catchment authorities and industry and developing organizational tools and principles for community based management.

Jack suggested that river restoration programs in Australia should also consider focusing on the dilemma being experienced by cities attempting to cope with the costs and consequences of stormwater management in urban streams.

For more information contact Dr Nick Schofield at LWRRDC, Phone (02) 6257 3379, Fax (02) 6257 3420, Email <nick.schofield@lwrrdc.gov.au>.

Related references

'Evaluation of the LWRRDC Rehabilitation and Management of Riparian Lands Program' - LWRRDC Occasional Paper No. 03/00 79pp.

Kapitzke, I.R., R.G. Pearson, S.G. Smithers, M.R. Crees, L.B. Sands, S.D. Skull, and A.J. Johnston. 1998. 'Stream stabilisation for rehabilitation in North-East Queensland' - LWRRDC, Occasional Paper Series No. 05/98 216pp.

Koehn, J. et al. 1999. National River Restoration Framework: LWRRDC and National Rivers Consortium.

Rutherfurd, I.D., A. Ladson, J. Tilleard, M. Stewardson, S. Ewing, G. Brierley, and K. Fryirs. 1998. 'Research and development needs for river restoration in Australia' - LWRRDC, Occasional Paper No. 15/98. 91pp.

Rutherfurd, I.D., K. Jerie, and N. Marsh. 1999. A rehabilitation manual for Australian streams, Volume One. LWRRDC and CRCCH. Download from www.rivers.gov.au. 187pp. (Volume Two now also available on www).

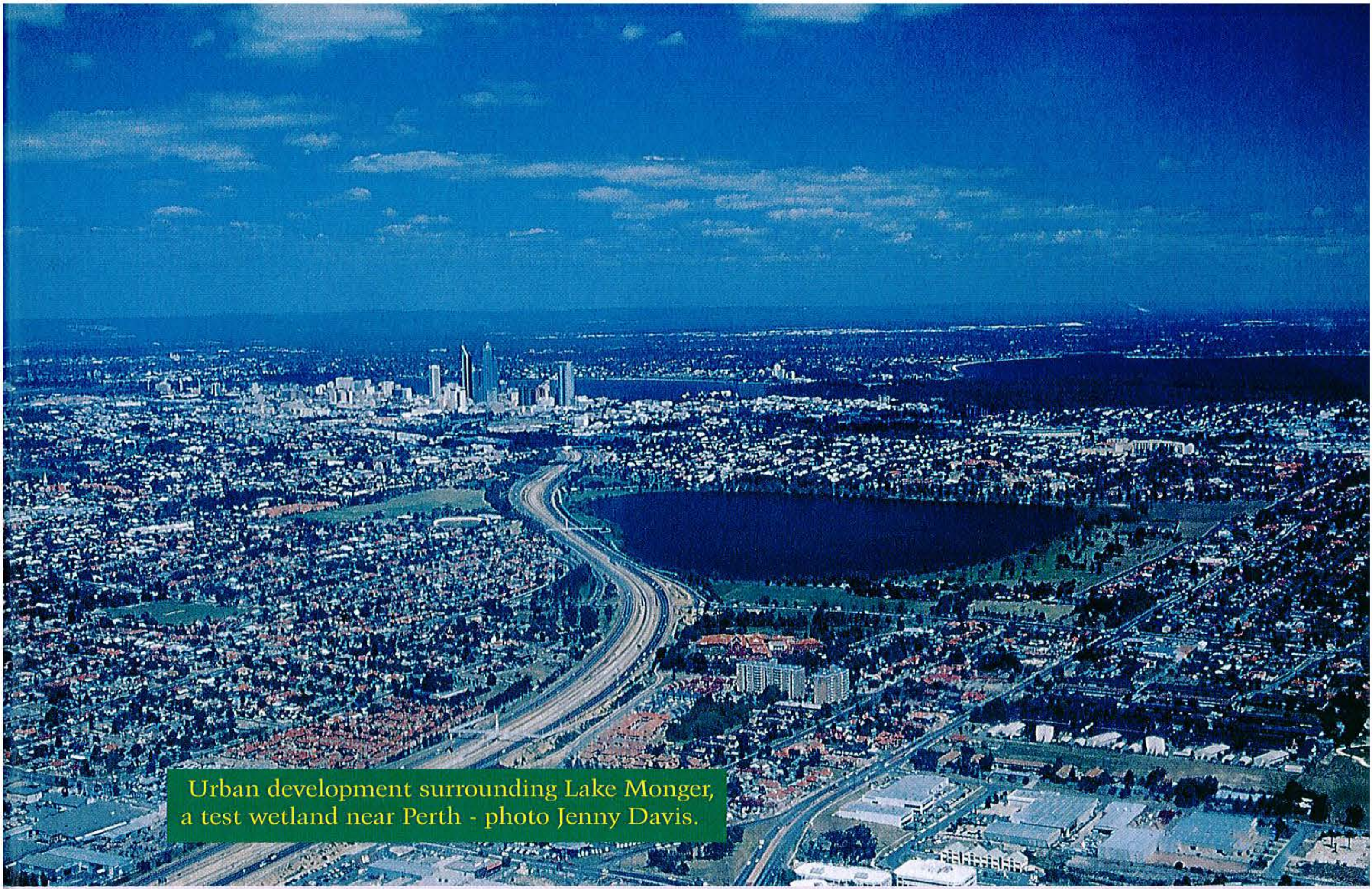
Are river bioassessment protocols applicable to wetlands ?

Dr Jenny Davis and Megan McGuire, School of Environmental Science, Murdoch University; Dr Pierre Horwitz and Bea Sommer, Centre for Environmental Management, Edith Cowan University; Associate Professor Richard Norris, CRCFE, University of Canberra; Dr Bruce Chessman, NSW Department of Land and Water Conservation

Live picking of invertebrates at a seasonal freshwater wetland near Perth, Western Australia - photo Jenny Davis.

Wetlands, worldwide, have only recently been recognised as areas of ecological complexity and conservation importance. Although some cultures have lived among and utilised wetlands in a sustainable way, for centuries, the modern history of wetlands in many regions of the world has been one of destruction and degradation. Globally, losses have been estimated at 50% of the original wetland area but in some areas of Australia estimated losses are even higher, for example, in Western Australia, an estimated 70% of the original wetlands have been drained, filled–in or otherwise lost as a consequence of land clearing for agriculture and urban development (Halse, 1988). The global importance of wetlands, and the scale and extent of disturbance, indicate that assessment and monitoring should be essential components of national, regional and local wetland management strategies. Finlayson (1996) stated that successful wetland monitoring programs must involve clear objectives, appropriate and cost-effective protocols, and well-defined processes for response to the information obtained, including both decision criteria for action and mechanisms for action. The objective of this study, which was supported by LWRRDC and Environment Australia through the National Wetlands Research and Development Program, was to develop appropriate and cost effective protocols for wetlands. Specifically, this project sought to test the applicability of AUSRIVAS, a predictive modelling protocol developed for Australian rivers, to the monitoring and assessment of Australian wetlands.

AUSRIVAS, a rapid bioassessment procedure, utilising macroinvertebrates and reference and test sites, similar to the British RIVPACS (River InVertebrate Prediction and Classification System) (Wright *et al.*, 1993), has been developed as part of the National River Health Program (Schofield and Davies, 1996). The AUSRIVAS procedure uses a suite of reference sites to predict the expected composition of families of invertebrates at a test site; if the test site has fewer families than expected based on the distribution of reference site values, then it is considered to



Urban development surrounding Lake Monger, a test wetland near Perth - photo Jenny Davis.

be degraded or affected in some way. This approach involves the identification of a large number of sites of high environmental quality across a wide variety of river types and ecosystems. At each site the macroinvertebrate communities are sampled and the habitats characterised by a standard set of physical and chemical variables that are largely unrelated to likely pollutants, or human impacts. This set of reference sites is then classified according to their biota to produce groups of sites containing similar fauna. Numerical analysis is used to identify the environmental attributes which best describe each group of reference sites. The environmental attributes of a test site are compared with those of the reference sites to determine which group or groups of reference sites it most closely resembles. The fauna of these corresponding reference sites is compared with the test site: if the test site supports fewer taxa than are predicted by the reference sites, it is judged to be degraded. The predicted taxa list also provides a 'target' invertebrate community which can be used to measure the success of remediation and restoration activities. Given the considerable resources and effort devoted to the development of AUSRIVAS it seemed both logical and cost efficient to examine whether this method could be applied to wetland assessment and monitoring.

The term 'wetland' is used here to describe shallow (depth < 3m), permanent or temporary non-flowing waters. Wetlands are considered unique (Mitsch & Gosselink, 1993) because of their hydrologic conditions and their role as ecotones between terrestrial and aquatic systems. The typically shallow standing waters, with seasonal regimes of wetting and drying, represent habitats that are very different to the well-oxygenated, cool, fast flowing waters of upland rocky rivers and streams. Such differences suggest that a bioassessment technique developed for rivers and streams may not be suitable for wetlands. However, the differences between rivers and wetlands become less distinct in the case of lowland, sandy rivers in arid and semi-arid regions of Australia (and presumably in similar climatic regions elsewhere in the world) which are often functionally equivalent to wetlands when flows cease during dry periods.

Objectives

This project specifically sought to test the following hypotheses :

1) that a predictive model, incorporating

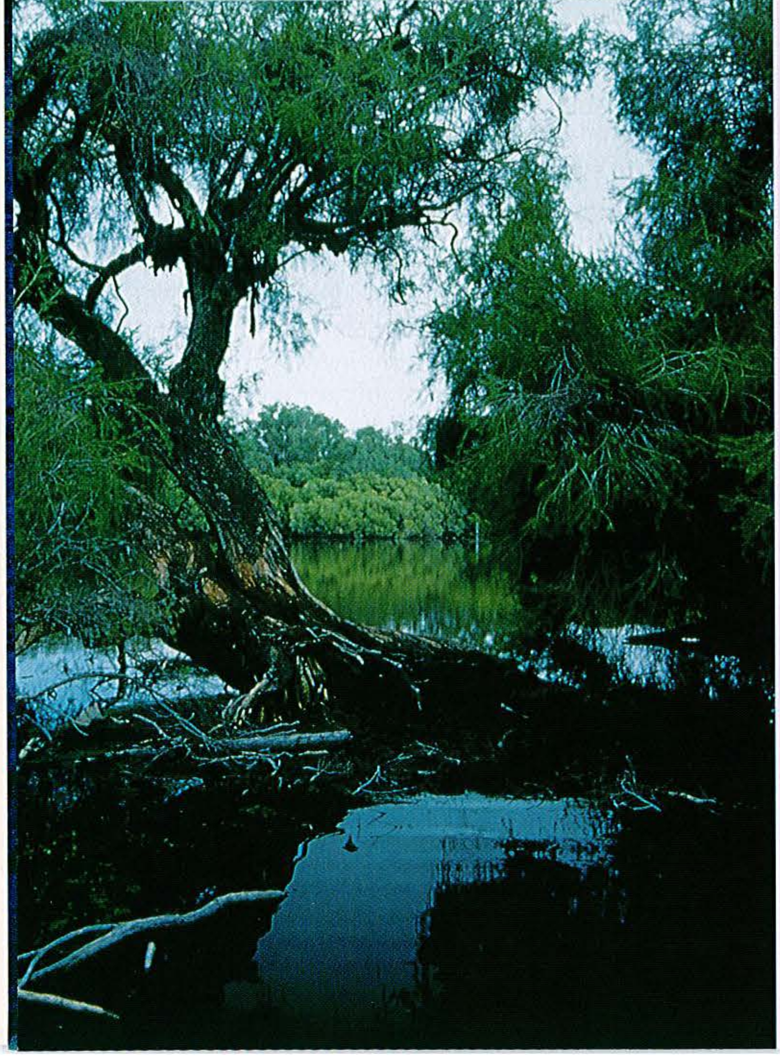
macroinvertebrate and environmental data, and reference and monitoring sites, could be developed for wetlands

2) that model outputs reflected wetland degradation or disturbance from human impacts

3) that model outputs for samples collected using a rapid bioassessment protocol (incorporating field processing of invertebrates collected from selected habitats) were not significantly different from those collected using a more quantitative protocol (incorporating randomly allocated sites and laboratory processing of invertebrates). Further hypotheses were constructed to act as a basis for evaluating and comparing output from the model against other information available for the test wetlands. These included:

4) that wetlands with the highest trophic status would receive the lowest rankings, in terms of the model output, if the model reflects poor water quality and ecological integrity arising from nutrient enrichment.

Undisturbed fringing vegetation typical of a reference wetland at Lake Chandala, Western Australia - photo Jenny Davis.



5) that model outputs were in agreement with the results of other bioassessment techniques applied to the same dataset.

Model Construction

A combined habitat and season model, similar to those developed for Australian rivers (AUSRIVAS), was constructed using a pre-existing dataset collected from 23 wetlands on the Swan Coastal Plain, sampled up to three times, in summer and spring,1989 and spring,1990. Four main groups of reference (least undisturbed) wetlands were identified by UPGMA classification (using the Bray-Curtis dissimilarity measure) as part of the model construction process. These groups comprised highly coloured (high gilvin) wetlands, saline wetlands and geographically-related groups. Predictor variables for these groups were identified by Multiple Discriminant Function Analysis as: calcium, colour (gilvin), latitude, longitude, sodium and organic carbon.

Findings

The model was tested by sampling 23 Swan Coastal Plain wetlands in spring (October) 1997. Two highly degraded wetlands (Yangebup Lake and Lake Gnangara) were correctly identified as well below reference condition due to human impacts. Some wetlands appeared to be below reference condition as a result of lower water levels. The test and reference wetlands sampled in spring 1997, were approximately 50 cm shallower than reference wetlands sampled in spring 1989 and spring 1990, mainly because of lower than average annual rainfall in 1997. The occurrence of fewer taxa than predicted in shallower systems indicated that wetland water levels have considerable influence on the composition of wetland invertebrate communities. These results indicated that modelling must involve sampling of sufficient wetlands, over sufficient time, to adequately characterise interannual variation in wetland water regimes.

Rapid bioassessment results were not significantly different from the results obtained with the original sampling method, which used random sampling and laboratory processing of invertebrates. This suggests that the former protocol could be used where quicker and cheaper bioassessment is required.

An algal bloom at a degraded wetland, Yangebup Lake, Western Australia, - photo Jenny Davis.

Comparison of modelling results with results of several other bioassessment techniques revealed different types of information on wetland condition. OE50 ratios were significantly correlated with pH and depth of sampling sites. The biotic index, SWAMPS, was significantly correlated with pH and log total P. One ordination axis was significantly correlated with log total P, total N nitrate/ nitrite and maximum wetland depth, whilst the other was correlated with pH, ammonia, total N and depth of sampling site. OE50 ratios were not significantly correlated with any indices of disturbance. SWAMPS values were significantly correlated with all disturbance indices except sediment contamination. Richness was significantly correlated with contamination and one ordination axis was significantly correlated with the presence of introduced fish. Consideration of mismatches, that is, wetlands that received high and low scores with different methods of bioassessment, provided additional insight into wetland condition. These results indicated that the use of a suite of bioassessment approaches, rather than modelling or the use of indices alone, is more informative.

The importance of different wetland habitats, particularly plant communities, in determining the composition and richness of invertebrate communities was demonstrated by this and other studies. Not only does this have implications for the design of bioassessment protocols it also indicates the need for some form of rapid assessment of wetland habitat condition based on the composition and abundance of submerged, emergent and fringing vegetation. Ideally, a rapid bioassessment protocol utilising macroinvertebrates should not be used in isolation but rather as part of a suite of monitoring tools including both a habitat or vegetation condition index and the measurement of specific water quality parameters. This would also enable conclusions to be drawn as to whether a low macroinvertebrate-based assessment reflected poor water quality or poor habitat condition, or both.

References

Finlayson, C.M. (1996) Framework for designing a monitoring programme. In Tomas Vives, P. (Ed.) (1996) *Monitoring Mediterranean Wetlands: A Methodological Guide*. MedWet Publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, pp.150.

Mitsch, W.J., & Gosselink, J.G. (1993) *Wetlands*. Van Nostrand Reinhold, New York.

Halse, S.A. (1988) *Wetlands of the Swan Coastal Plain – past and present*. Swan Coastal Plain Groundwater Management Conference, WA Water Research Council, Perth.

Schofield, N.J. and Davies, P.E (1996). Measuring the health of our rivers. *Water* 23:39-43.

Wright, J.F. Furse, M.T., and Armitage, P.D. (1993). RIVPACS - a technique for evaluating the biological quality of rivers in the U.K. *European Water Pollution Control* 3(4):15-25.

National Eutrophication Management Program Review of the first four years

Dr Peter Chudleigh,
Agtrans Research, Toowong, Brisbane

The National Eutrophication Management Program (NEMP) was established in 1995 by LWRRDC and the MDBC to further develop our understanding of the sources of nutrients and other factors contributing to the development of algal blooms. Algal blooms cost the Australian community more than $200m a year (LWRRDC 1999) and are a major environmental and water quality concern. As the Program draws to a close it is timely to assess what it has achieved and what the future directions might be after June 2000.

Consultants Agtrans Research, who were contracted by LWRRDC and MDBC to review the Program, concluded that NEMP has contributed significantly to our knowledge of this complex system and provides a sound platform for further applied research. They were particularly impressed with the quality of the science and the overall management of the Program. Importantly, implications for management are already being developed from the results of the research and further management guidelines will continue to emerge as projects are completed. Improved networking and communication between researchers and catchment and water managers has also been evident.

Three objectives were set for the Program. The first was concerned with gaining an improved understanding of processes leading to the initiation and development of algal blooms. The Program met this objective quite clearly. The second objective was associated with developing techniques, including predictive models and decision support systems to help prevent and manage the impacts of eutrophication. This objective is likely only to be partly met due to the balance of the Program being geared towards strategic research. The third objective, concerned with effective communication, was met.

NEMP has provided national leadership in a number of ways. Firstly, NEMP has incorporated other research and researchers outside of the Program into its workshops and general communications. Secondly, it has introduced stakeholders to a coordinated program in a structured manner, at least in those States in which Focus Catchments are located. By encouraging networks, NEMP has facilitated information exchange across Australia regarding matters of eutrophication which transcends the NEMP projects themselves.

What will NEMP achieve?

Cost of algal blooms to Australia

Although there have been one-off estimates of the costs of individual algal bloom events – eg Darling bloom, closure of North Pine dam – **there has not before been a national assessment of the cost that algal blooms**

impose on Australia. A recent NEMP consultancy has conservatively estimated the annual cost of freshwater algal blooms to be between $180 and $240 million, based on the community's willingness to pay for avoiding blooms. This cost does not include coastal and estuarine blooms such as the outbreak in Gippsland Lakes last Easter and the recent incident in the Swan River WA. This cost of blooms is borne about equally by urban water users, irrigated agriculture and dryland farmers illustrating the need for community action to tackle the problem. Although the consultants examined the records of algal blooms held by each State government agency, they were unable to detect trends in the frequency of blooms because of the recency of these records, the influence of confounding (particularly climate) factors and the incompleteness of the records.

Managing storages to minimise risk of algal outbreaks

Burrinjuck Storage near Canberra has a unique record of water quality stretching over 18 years including a period with nitrogen and phosphorus removal from the inflowing waters because of upgrades at the Canberra STP. A detailed study of these data has shown that the nutrients that fuel the blooms are most likely to come from the bottom sediments rather than directly from inflowing waters. It is the availability of nutrients that limit the biomass of the algae and not other factors such as light. Organic carbon coming from the upstream catchment appears to be driving the release of sediment nutrients. The overall algal biomass was definitely reduced after phosphorus was removed from Canberra effluent and there was a switch from harmful blue-green algae to more acceptable green algae. Using a workshop approach and collating information from other reservoir studies, the **researchers and storage managers have developed a flow chart and guide to the different management options – a first for reservoir managers and enthusiastically received by them.**

Biomanipulation is one technique for managing algal blooms in storages that has had success overseas but has been untried in Australia. The technique involves the introduction of predatory fish that manipulate the foodchain in such a way that nuisance algae are suppressed by zooplankton. NEMP is supporting a trial of this technique in a storage in Queensland with promising results so far.

Influence of N, P and light on blooms

Although it has been accepted for some time that algal blooms require access to a range of nutrients and light as well as minimal predation in order to develop to nuisance proportions, the accepted wisdom has been that phosphorus has been the critical factor in controlling their development in freshwaters. Many of the algal management policies are directed towards reducing phosphorus concentrations. **NEMP research has shown clearly that both phosphorus and nitrogen are about equally important nutrients and that access to light is even more important in controlling growth in turbid Australian rivers**. A recent workshop in Melbourne between researchers and managers explored the implications of these findings for management policies.

Influence of flow on blooms

Many of the rivers in south-east Australia are impounded behind weirs that control the flow for irrigation purposes. Researchers have shown that the algal blooms that form in these weirpools arise primarily because of the stratification of the water. Cyanobacteria, unlike other forms of algae, can regulate their buoyancy and so move up and down in the water column. This provides them with a competitive advantage in these weirpools where they can move between the nutrient enriched, anoxic bottom waters and the light zone in the top waters. The researchers have developed a number of flow management techniques that will break the stratification and so remove this advantage – these techniques are being trialled in NSW. These studies have been extended to a Queensland weirpool under NEMP. Here, it was found that there was a more complex interaction between stratification, light and nutrients. It is not possible to control the stratification through flow management in this large weirpool and the researchers are exploring methods to limit the penetration of light into the water and hence control cyanobacterial growth. **Flow management has been identified as an important strategy for controlling algal blooms in some rivers in Australia but the extent of its usefulness and how it is applied requires prior investigation.**

Sources of P in the landscape

When algal management plans were drawn up in the early 1990s, there was considerable emphasis on reducing the phosphorus entering rivers from fertilizer. NEMP funded research into radio-isotopic tracers that act as sensitive markers for fertilisers. The results showed that for a typical catchment in northern NSW fertilisers were a negligible contributor to the phosphorus attached to sediment particles. Most of the phosphorus comes from natural stores in soils and is liberated by soil erosion. These results are now becoming widely accepted for similar dryland farming areas and NEMP is sponsoring various workshops and expert panels to turn these results into practical management guidelines. However, in irrigated pastures areas such as in the Shepparton district of northern Victoria or on the sandy soils of Western Australia there is a significant contribution to the phosphorus load from applied fertilizers. **The best current understanding of the sources of phosphorus from Australian catchments is contained in the NEMP produced workshop proceedings 'Phosphorus in the Landscape', LWRRDC Occasional Paper No. 16/98,** and in a widely distributed brochure produced from these proceedings.

Role of bottom sediments and their need for management

Most of the phosphorus and nitrogen in rivers, storages and estuaries comes from bottom sediments that have been eroded over the decades since the catchments were cleared for agriculture. These nutrients are released into the water column, particularly when the bottom waters turn anoxic. NEMP has sponsored a project that has examined this source of nutrients in some detail through field and laboratory studies. A model has been developed to test our understanding of the factors that control the release of nutrients from sediments. When complete this model can be used to test various ways to control the anoxia and hence the nutrient release. A project in Wilson Inlet, WA has measured the flux of nutrients from the sediments of that estuary and shown that about seven times as much nitrogen comes from these sediments as from fresh river inflows. The project has also shown that the sediments act as a trap for the phosphorus entering the estuary from the rivers i.e. there is a steady build-up of phosphorus in the sediments each year. The research shows that if there was an extended period of anoxia in the estuary there would be a large release of nutrients from the sediments that would fuel a major algal bloom.

Bioavailability of different forms of P

For many years there has been a belief that phosphorus from sewage is more readily taken up by algae than phosphorus attached to soil particles originating from erosion of catchments. If true, then this would support arguments for upgrading sewage treatment plants since, pound for pound, this source of phosphorus is more potent. An earlier project in the Namoi area had shown that there was very little trace of the phosphorus from the Narrabri STP within 20 kms downstream of the outfall. That is, the discharged phosphorus may have had a local effect but was a very small contributor to the downstream phosphorus load in the river. A NEMP sponsored project is currently testing whether there are significant differences in the bio-availability of phosphorus coming from a dryland catchment, an STP outfall and an irrigation drain in the Goulburn Valley, Victoria. The project is not completed but early results show that about 50% of the total phosphorus is immediately available for algal growth from all three sources over the longterm. The remaining STP material is biological in origin and is likely to be more bio-available than the remaining material from the catchment and the irrigation area, but this is yet to be confirmed.

New and standardised techniques for algal & nutrient monitoring

Laboratories have long used the total phosphorus and total nitrogen concentrations in rivers as the standard measure for nutrient levels. An earlier project had shown very clearly that the same total phosphorus concentration in different rivers could lead to algal biomasses that differed by factors of three or more, even when all other factors were the same. The reason is that most of the phosphorus is bound to sediment particles and, depending on the sediment characteristics, the phosphorus can be more or less available to fuel algal growth. **That is, total phosphorus (and total nitrogen) are poor measures of the potential for algal blooms; bio-available phosphorus and nitrogen are much better measures.** NEMP has supported the dissemination of a technique – the iron strip method – for simply and cheaply measuring the bioavailable fraction of phosphorus. A number of laboratories have become interested in the technique and have assessed it through workshops funded by NEMP.

NEMP has also funded the development of a technique to determine whether nitrogen or phosphorus is controlling the growth of cyanobacteria in a particular waterway. The answer is important because it indicates whether managers should be trying to reduce phosphorus or nitrogen levels. This measurement has normally been slow, expensive and difficult to perform and the new technique promises to provide a rapid and cheap method although interpreting the output from the technique is difficult. NEMP has funded a workshop where the technique was assessed by managers, some of whom plan to trial the technique.

NEMP has also produced a manual for sampling algal blooms in both standing waters and flowing waters. Up until recently it had been very difficult to get a comprehensive picture of the extent of algal blooms because agency staff had sampled the water at different depths, at different distances from the shore, etc and had used different laboratory procedures to count the algal cells in these samples. The manual has been assessed by laboratory managers and is now in widespread use throughout Australia.

New approaches to managing eutrophication

As our understanding of algal blooms improves through NEMP projects, we have been able to develop a wider range of management techniques. Flow management, first developed outside the NEMP program, is being generalised for application in a wide range of rivers. Light is the factor that controls algal concentrations in many situations and NEMP researchers are trialling methods to control light penetration into the waterbody. Biomanipulation is showing promise as a method for controlling cyanobacterial concentrations in large storages. The importance of managing sediments in rivers, storages and estuaries so that they do not turn anoxic and release pulses of nutrients has been emphasised by a number of projects.

In some freshwaters, controlling nitrogen will lead to better management of cyanobacterial blooms and NEMP has developed one technique for quickly testing whether a particular waterbody is nitrogen or phosphorus limited. Nitrogen needs to be controlled either by reducing losses from catchment sources or by promotion of denitrification on land and in the water.

Overall, the complexity of the various factors operating in the development of algal blooms has been increasingly recognised in NEMP. Many projects are not yet completed and the final year of the Program will focus on the integration of all project outputs into management guidelines. In addition, there will be a review of the current understanding of algal blooms and the implications for management policy.

What impact has NEMP had?

Notwithstanding the contribution to knowledge that NEMP has made so far, it is too early to assess outcomes and overall impact on reducing algal bloom incidence and intensity. The Program is not due to be completed until June 2000, and a number of projects are still incomplete and the implications for management still to be determined. It is not likely that resulting specific management interventions to reduce the severity and frequency of algal blooms will be applied within the lifetime of the Program. The same conclusion is likely with respect to policy changes within catchments and more broadly within State agencies.

Nevertheless some of the outputs listed above may result in significant management changes in the future. For example, a fine clay will be trialled by Rockhampton City Council to artificially suppress growth when light reaches critical levels defined from the NEMP research. Also, the biomanipulation project using predatory fish has potential to make a significant impact if the lake trial is successful.

At the beginning of NEMP there was considerable uncertainty as to whether existing and proposed management actions would be effective in controlling algal blooms. This uncertainty arose from:

* conflicting views on the sources and bioavailability of phosphorus;
* little information on the role of nitrogen and micronutrients;
* limited understanding of stratification and related control measures;
* where and how flow strategies might be used;
* the role of in-stream sediment sources and their control; and
* the importance of episodic events.

All management plans emphasised phosphorus reduction; the MDBC algal management strategy also proposed flow management. Thus managers had few tools for algal management and new approaches needed to be developed. It was contended that such issues needed to be better understood in order for future management interventions to be soundly based. In this regard, NEMP has contributed to improved understanding of processes that will help resolve these uncertainties. There will need to be further investment in more applied research to translate much of this improved understanding to more specific management guidelines.

Although the Program has developed a number of alternative management techniques and guidelines, these have yet to be thoroughly tested in practice. There have been strenuous efforts to engage managers and community coordinators in this work, although there have been only a limited number of practical tools delivered to managers at this stage of the Program.

Any further funding by partners should focus on capitalising on the strategic understanding gained, and trialling and disseminating the new management techniques developed.

Has NEMP been money well spent?

An investment analysis for the whole Program carried out within this review, and using conservative assumptions, showed that the \$8.7 million investment in NEMP should provide a positive net present value of \$50m using a discount rate of 7% real. The internal rate of return was 27%, well above market interest rates, and the benefit-cost ratio was 5.6 to 1. This analysis assumed that some benefits would flow directly from NEMP in a few years time but also allowed for a further investment cost of \$1.5 million per year for four years to build on the results of the existing Program in order to achieve continuing reductions in algal outbreaks.

What have we learned about the Focus Catchment approach?

The Focus Catchment approach used in NEMP was aimed mainly at producing information that was transferable to other catchments. A secondary objective was to provide information for improved management within the catchment itself. The approach was largely successful in producing some synergy between researchers and providing interaction between the research effort and the community. Overall it has worked reasonably well.

One of the key potential benefits from the focus catchment approach is to engender ownership of the research and therefore the research findings to the decision makers in the catchment. For this to be achieved, more interaction with the catchment community and resource managers into priority setting for the catchment, including issue identification and project design should occur. If this is the case, an improved balance of strategic and management orientated research may be developed. The early involvement of catchment managers and water managers in any new program is essential. However, such an approach should be considered against the alternative of carrying out research in selected catchments (one or more) according to which catchments can provide the most information eventually transferable to the maximum number of catchments. Process type research carried out in various catchments may have greater prospects for extrapolation.

Where to from here?

NEMP is preparing a major summary document covering the latest understanding of the causes of eutrophication and algal blooms and the increased management opportunities that have arisen. This document will be disseminated widely and will be a major resource for water managers. The consultants suggested the following recommendations for the current Program:

* The development of guidelines and principles for management actions from projects should be a major activity in the remaining period of NEMP and should be encouraged by NEMP management.

* While the primary objective of the Focus Catchment approach was not to provide solutions to local catchment issues, there is an expectation by some communities that that this will be forthcoming and it is important that a significant effort is made in this endeavour.

* A stocktake, categorisation, and synthesis of models produced or refined under NEMP should be undertaken and how the models might be used in other research or by land and water managers, together with their data requirements, explored in detail.

* Integration of the outputs of NEMP regarding the implications for other programs would be useful and a small workshop across four or five other relevant programs and the NEMP should be considered. The following recommendations are for any continuing Program:

1) Any future program associated with eutrophication consider scoping studies focusing on management information needs as important inputs to the structure and priorities of the program. Such scoping studies should be carried out before any other projects are funded and should cover:
* the decisions currently being made by land and water managers that take into account the development of blue-green algal blooms;
* the scope for interventions at different locations along the water chain (eg. land use and practices, nutrient export, maintaining stream bank integrity, flow control, reservoir management interventions etc.);
* the potential for cost-effective solutions at different points along the water chain.

2) The balance between strategic and applied research be given more prominence in developing priorities and selecting projects for future research and development, with a bias in any future program towards more management orientated or applied research that capitalises on the opportunities provided by NEMP.

3) For all research projects funded in future, there should be stronger definition and expression of the linkages between the potential research outputs and how these outputs will be used by detailing the type of management and policy decisions that may be assisted by such outputs.

4) A higher level of interaction should be pursued between any future NEMP and other programs associated with interacting processes and strategies such as Riparian Lands, River Health and Irrigation. In addition various land use based programs of the Commodity R&D corporations (Dairy, Meat etc) should be consulted in order to determine where a program such as NEMP can best contribute in terms of information needs at the catchment level.

5) Consideration needs to be given to the argument that small reductions in nutrient exports from land use may not necessarily be effective for many years or perhaps never, given river sediment sources of P, and episodic events.

6) Careful consideration should be given as to whether to use a focus catchment approach in future. Such considerations should take into account the major purpose of the program (process understanding, localised case studies, producing management guidelines for all catchments), and the synergies expected (between researchers and between researchers and the community including personnel of State agencies). If a focus catchment approach is to be used in the future, sufficient numbers of projects within each catchment should be funded to provide sufficient scope for interaction and synergy. This may mean limiting the number of focus catchments.

The review of NEMP, LWRRDC Occasional Paper 05/00, will be available from the end of June from the AFFA shopfront (1800 020 157) or at the LWRRDC website <www.lwrrdc.gov.au> under 'Publications'.

Minimising the impact of pesticides on rivers:

The cotton industry model

Developed by LWRRDC, CRDC and MDBC

Figure 2 Spraying cotton with insecticides at Moree, NSW - Nicholas Woods.

Cotton, pesticides and river health

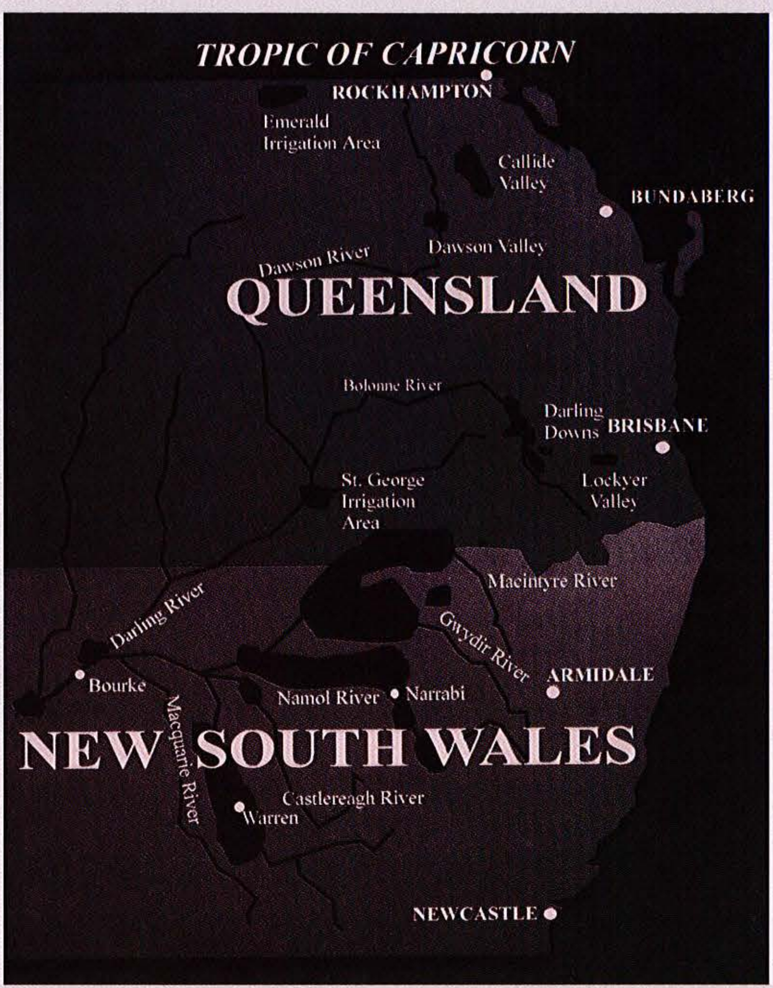
The cotton industry has grown since the 1960s to become the nation's fourth largest rural export earner and grossed around AUS $1.5 billion in 1998-99 with production reaching 3.22 million bales. In this year 403,000 ha of irrigated cotton and 131,000 ha of dry land cotton were grown, although the dry land component was unusually large. About 1,500 cotton growers operate in a belt that reaches from the Darling River in central New South Wales northwards into central Queensland. Australia's cotton crop is the highest yielding of the world's major cotton producers.

As with most of Australia's other rural industries, pests (insects, weeds, disease etc) are a major impediment to production. Without effective management programs, particularly for insects, crop damage would be such that the economic viability of cotton production would be threatened. Currently the cotton industry relies on a number of methods including the use of pesticides to control pests.

Caterpillars of two species of heliothis *(technically Helicoverpa)* moth (figure 1) are

Figure 1. A caterpillar of t heliothis moth, a major pest cotton in Australia - John Gre CSIRO.

the most significant pests and can devastate whole cotton crops if not controlled. Control of Helicoverpa involves the use of insecticides, such as endosulfan which is typically applied early in the growing season. Endosulfan and other pesticides used in cotton production have been detected in rivers in cotton growing areas and they have occasionally been implicated in fish kills. Cotton, however, is not the only source of pesticides in cotton growing areas. **Atrazine is the most frequently detected pesticide in rivers** in the pesticide monitoring component of the NSW Department of Land and Water Conservation's Central and North West Regions Water Quality Program but atrazine is not used in cotton production.



Australia's main cotton growing regions

Pesticide contamination is only one of a number of factors affecting river health in cotton-growing regions. Other impacts include land clearing, fertiliser use, effluent discharge, grazing, water extraction, river flow regulation and invasive exotic pests such as carp. These impacts can result in damage to riparian vegetation, riverbanks and stream habitats and biota, as well as increased sedimentation, turbidity and nutrient concentration. All contribute to outbreaks of algal blooms and other disturbances to river ecosystems. **It is therefore difficult to separate out the impact of pesticides used in cotton in this complex scenario.**

The cotton industry has long supported research into pest management strategies to reduce pesticide use, including transgenic (B.t.) cotton, disease and insect resistant cotton varieties, biological control agents, cultural practices and strategic use of insecticides. For example, the Cotton Research & Development Corporation (CRDC) invests in a broad range of research and development projects that seek to minimise the use and impact of pesticides in the cotton industry. These include projects aimed at:

* Reducing pesticide use through the development of alternative pest management practices and improved systems approaches such as integrated pest management and area wide management;

* Improving application techniques when pesticides are required; and

* Improving pesticide hazard analysis and risk management through the development and application of best management practices.

Over half of the CRDC's annual budget is spent on these projects. The introduction of transgenic cotton varieties has led to a reduction in pesticide use and there has been increasing adoption of non-chemical approaches to pest management, such as food sprays for predators, bio-pesticides, conservation of beneficial insects, crop compensation for pest damage, trap crops for pests and tillage to control pests during their dwelling stage which over time is expected to lead to a declining role for chemicals in crop protection. **Although it is expected that pesticide use will be reduced by 50% within five years, the cotton industry will still need to use chemical pesticides to maintain**

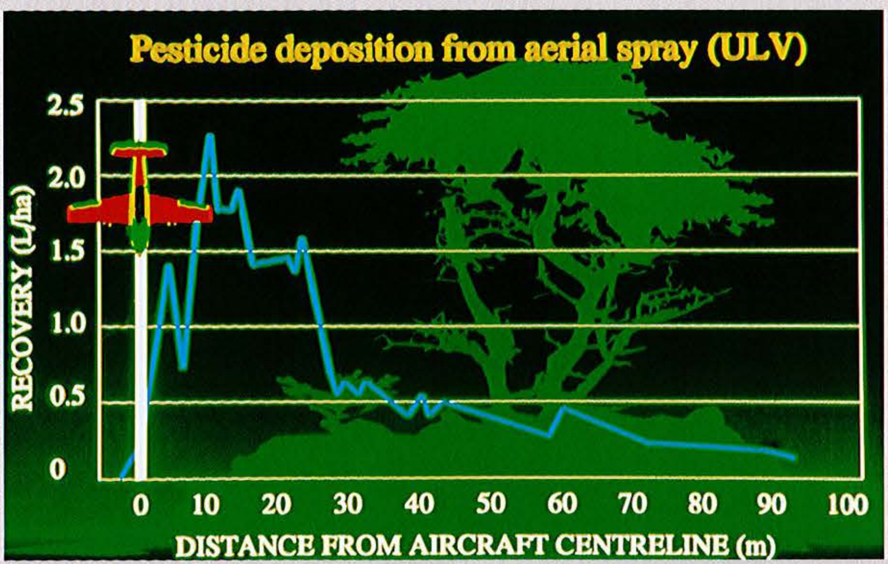


Figure 3
Wind-born drift of pesticide after aerial spraying - N.Woods.

economically viable production for the foreseeable future.

Research on Pesticides and the Riverine Environment

In response to concerns over the state of rivers in cotton growing regions LWRRDC, CRDC and MDBC commenced a $6 M cooperative research program in 1993 aimed at minimising the impact of pesticides on the riverine environment, using the cotton industry as a model.

The R&D program's goals were to:

* Assess the possible impact of current pesticide use on the riverine environment;

* Develop practical and economic methods to reduce the transport of pesticides from application sites, and minimise effects on the riverine environment; and

* Provide a scientific basis for the development of management guidelines and regulatory codes.

The program had three overlapping phases:

1) Investigate the major pathways of pesticide movement to rivers and the impact of pesticides on river biota;

2) Identify and test potential methods for ameliorating problems associated with pesticides; and

3) Develop and implement best management practices to minimise pesticide contamination.

Findings from the research

Pesticide transport and impact

The research in Phase 1, involved 10 different research agencies and focussed on identifying the transport mechanisms and the fate of pesticides, particularly endosulfan, on cotton farms and during transport off-farm. **Endosulfan may be transported by droplet drift after spraying, as vapour following volatilisation, on wind borne dust particles, and by soil and water movement during storms and tailwater runoff.**

Figure 4
Collecting soil from tail drains on a cotton farm.- B. Simpson.

Spray Drift

Pesticides are usually applied to cotton as sprays from low flying aircraft (figure 2). The need for aerial spraying is related to the large operational scale of many cotton farms and problems associated with ground based spraying, such as the inability to access the cotton fields with ground equipment after irrigation or rainfall, reduced options regarding the timing of spray applications and the potential for soil compaction.

The following four factors most significantly affect the movement of pesticide droplets after aerial spraying:

* Droplet size - smaller droplets (<100 μm) are more likely to be affected by wind and air turbulence than larger droplets around 250μm;
* Weather conditions, particularly wind strength and direction. Other phenomena such as surface temperature inversions contribute to spray drift;
* The height of release of the pesticide affects the spread of spray droplets away from the crop, as do aerial vortices generated by the aircraft wings; and
* Droplet deposition, particularly of small droplets, is affected by turbulence that can increase pesticide deposition on crops, compared with bare soil.

Increasing the size of spray droplets and using spray buffer zones both reduce the impact of spray drift. **The study showed that spray drift is potentially a significant contributor to riverine contamination and improved application practices are essential to reduce the off-farm movement on pesticides in sensitive areas** (figure 3).

Volatilisation

Pesticides can volatilise from plant and soil surfaces, within the soil pore spaces and from pesticides adsorbed onto soil particles. This is affected by the saturation vapour pressure of the pesticide, its adsorption to substrates, wind velocity, temperature, soil water content, pesticide diffusion and advection through the soil and application methods. The research established the limited potential of volatilised endosulfan to contaminate nearby rivers. Its contribution is likely to be less than either spray drift or runoff, but **volatilisation can create diffuse contamination over large areas and may be a primary component of "background" endosulfan levels observed in rivers in cotton growing areas.**

Airborne Dust

Soil particles on which pesticides are deposited are subject to suspension in the atmosphere from air disturbances and activities such as tillage and traffic. The research also indicated that dust movement on farms can relocate pesticides. This pathway, however, is far less significant than spray drift in the off-farm aerial transport of pesticides.

Surface Water and Suspended Sediment

Pesticides can be transported off farm in solution or attached to suspended sediments (figure 4). Both of these pathways are major factors in pesticide contamination of rivers, particularly in storm runoff (figure 5). Even modern farms, which can fully recycle irrigation drainage water on-farm, are not always designed to contain large storms. The major issue with storm events is their unpredictability in time, space and size/ severity. Thus **it is difficult to design a system that could handle every single storm event**, particularly if there is a second storm within a short period of time. Farms that do not have adequate recycling and on-farm storage facilities may even release contaminated tailwater to rivers and lagoons during minor storms.

Percolation to Groundwater

Groundwater can be contaminated by pesticide percolation through the soil. Although this is unlikely to occur to any significant extent in the clay soils typical of Australian cotton farms, the Australian Geological Survey Organisation has identified herbicide contamination of groundwater beneath some other irrigated systems.

Pesticide degradation and fate

The mechanism of pesticide breakdown in the environment involves complex chemical, photochemical and microbiological processes. For example, endosulfan can be transformed in soil and on the plant from the parent alpha and beta isomers into the equally toxic breakdown product, endosulfan sulfate. However, this only occurs to a limited degree in water where hydrolysis to the non-toxic endosulfan diol is the major degradation pathway.

The research showed that neither endosulfan nor endosulfan sulfate accumulates in soil from year to year (figure 6). Peak concentrations occur during the spraying season, initially as alpha and beta

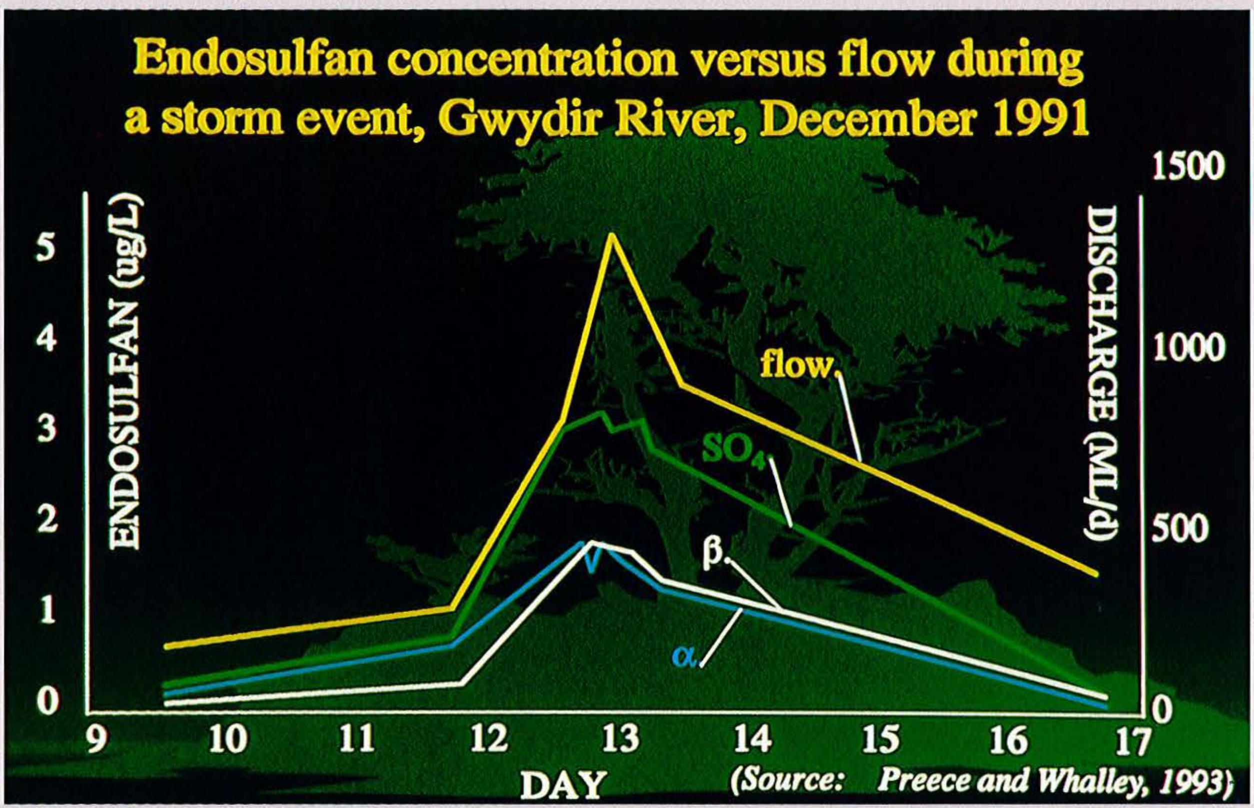


Figure 5
Pesticides are transported into rivers during storm events - Dept of Land and Water Conservation,

endosulfan and subsequently as the sulfate. The concentration of pesticide in runoff is closely related to the concentration of pesticide in the soil at the time. Once in the river system, endosulfan either remains in the water column, volatilises or binds to bottom sediments, and subsequently degrades. **There is also no evidence that endosulfan accumulates in river systems from year to year.**

River bio-monitoring and ecological impacts

The research program studied the impact of pesticides on aquatic ecosystems, principally by monitoring changes in populations of macroinvertebrates in rivers and by laboratory and mesocosm (replicated, artificial, field-based) experiments to assess dose-toxicity responses. These studies showed that pulses of endosulfan at concentrations towards the highest levels measured in rivers could have significant ecological effects (see Rivers for the Future Issue 10, pp38-40).

Chemical Monitoring

Pesticide monitoring over five growing seasons (1991 to 1996) in the Central & North West Regions of NSW found that the detection of endosulfan in rivers is closely tied to its use in cotton (figure 7). **During the cotton spraying season, endosulfan concentrations in the river water samples tested frequently exceeded the ANZECC guideline value for protection of the aquatic environment.** However, atrazine, which is not used in cotton, was the most widely detected pesticide in rivers in the study area.

Phases II and III - Applying the research

The 'Best Practice' method of management was identified as the most effective means of ensuring that the cotton industry adopted new or improved farming practices to reduce the risk of pesticide contamination of the environment. Best Practice involves thorough analysis of known practices and rigorous screening to ensure that practices recommended are viable. **Modern agricultural industries use a combination of scientific research and advances in technology, Best Practice and compliance with the legislation to achieve improved environmental performance.**

Phase II of the program involved the development, testing and evaluation of prospective practices that emerged from the research and other sources. A workshop held in March 1996 identified and ranked potential practices requiring further study.

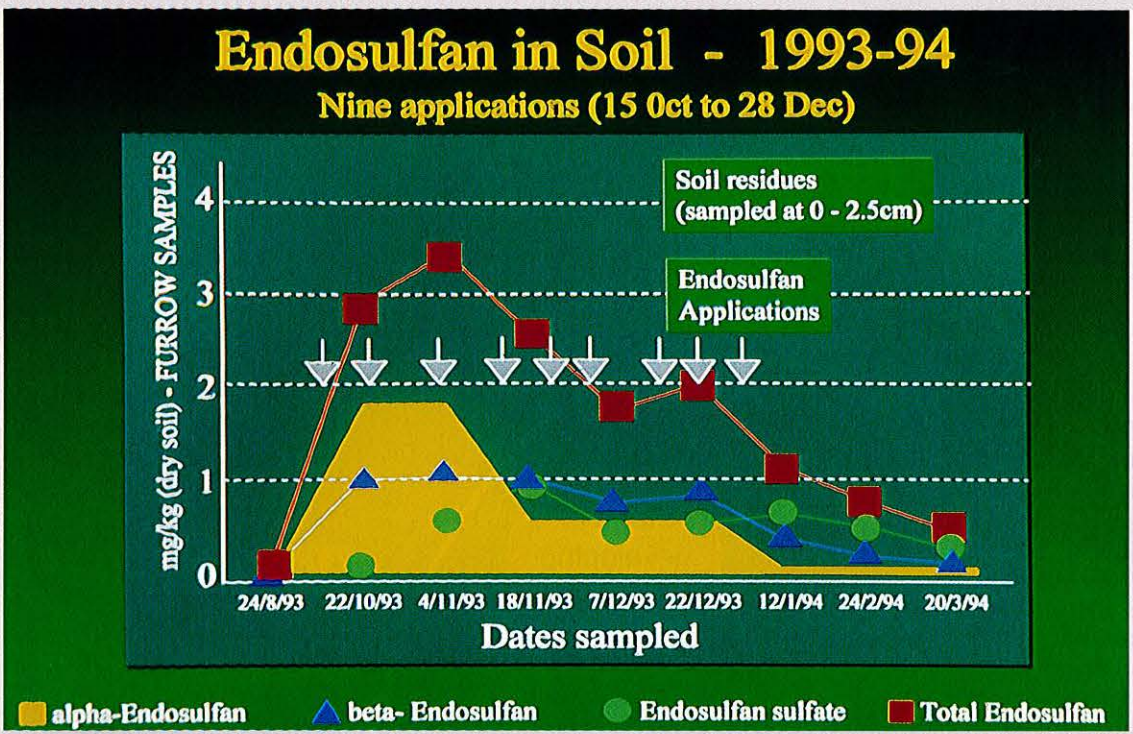


Figure 6
The degradation of endosulfan in soil over time - B. Simpson.

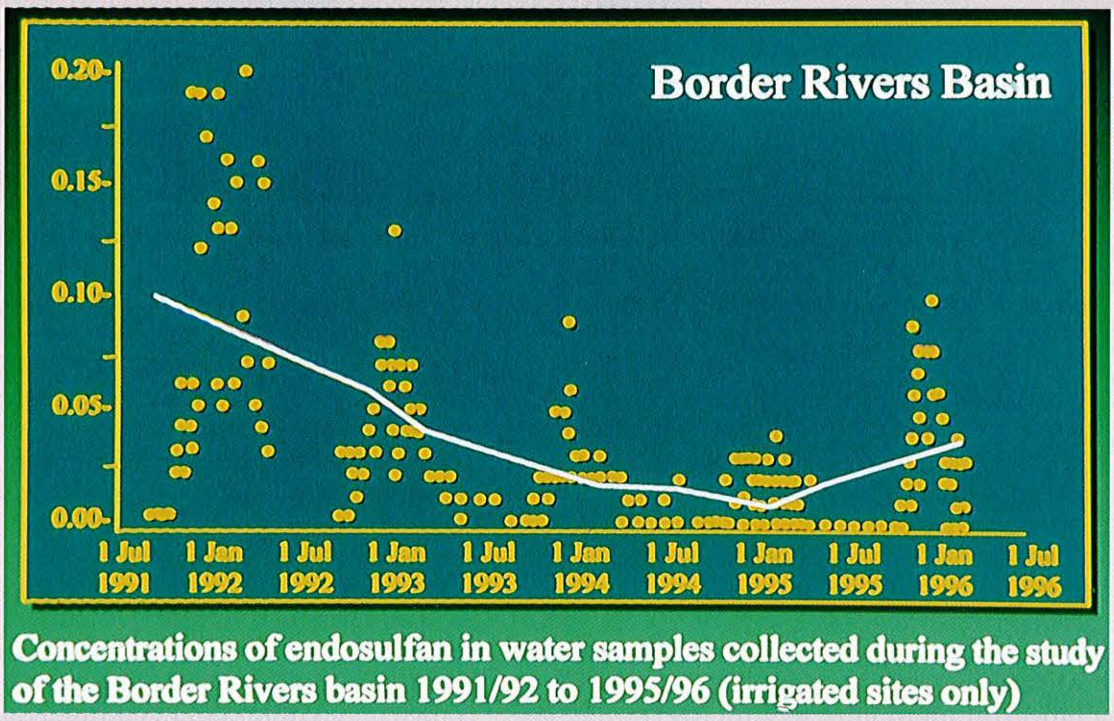
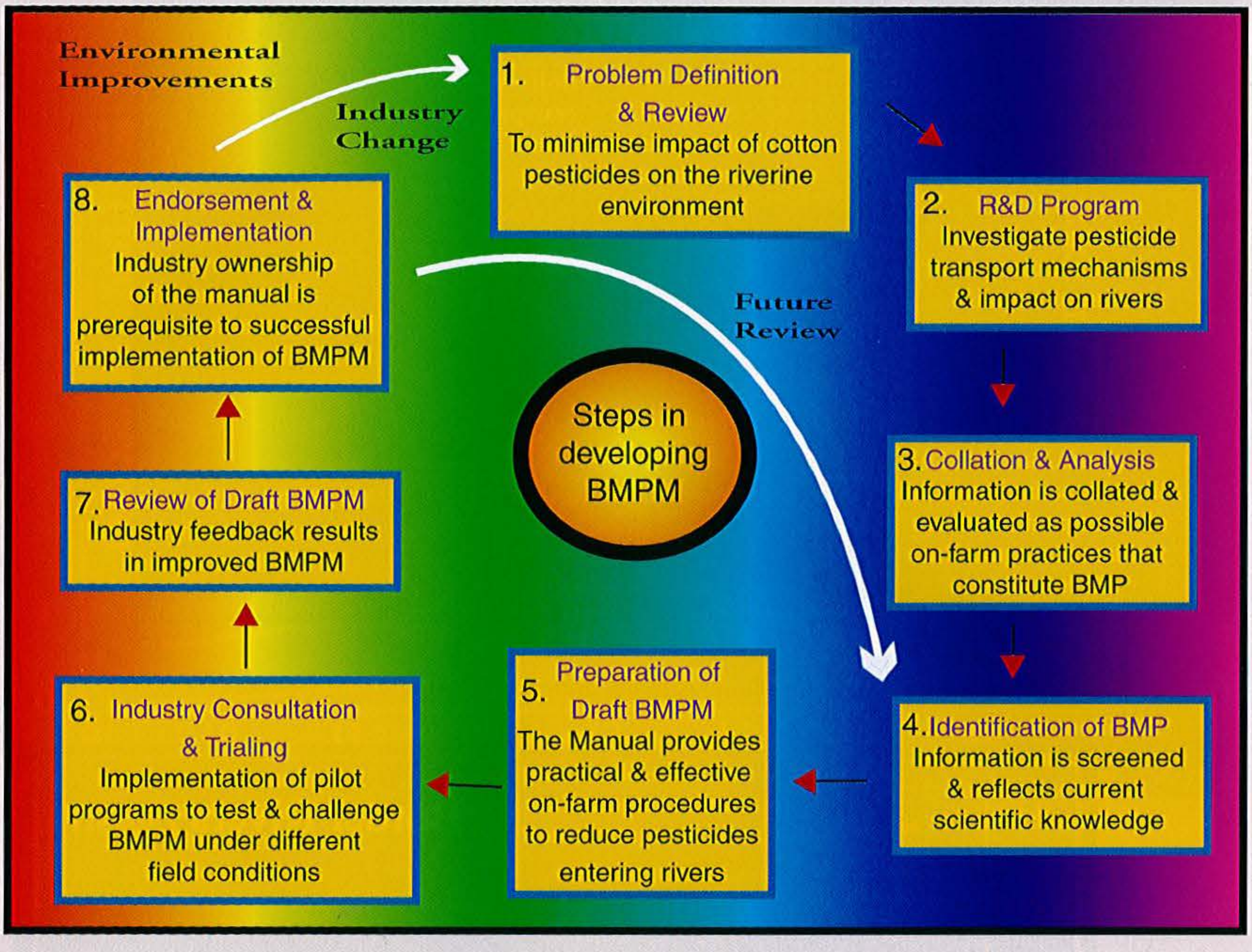


Figure 7
Endosulfan in rivers is linked to its use on cotton. - Dept. of Land and Water Conservation, NSW.

Further studies developed these potential 'solutions' to the point of being recommended Best Practices.

In Phase III, an interdisciplinary team of specialists, practitioners, other researchers and advisers from industry and grower organisations came together to workshop the issues. Proven research findings and common sense approaches to better pesticide management were identified for inclusion in a Best Practices Manual.



BMPM - Best Management Practice Manual   BMP - Best management Practice

A Best Practices Manual for the cotton industry

The Best Practices Manual has been developed as the main delivery/technology transfer mechanism for achieving the research program's goals. It advocates practices that help minimise the amount of pesticide transported off farms in order to reduce their impact on the riverine environment.

The format of the Manual, which leads cotton farmers down a planning pathway, is a powerful method of having R&D outcomes adopted by farmers, as the critical issues that the research focuses on can be highlighted in the self assessment work sheets. These self-assessment work sheets form the core of the Manual and enable farmers to assess and document their own operation, based on the best practice guidelines and against a series of risk rated examples. These work sheets then lead to the development of action plans designed to minimise the risk in areas highlighted as being of high risk during the self-assessment process.

A strong case is made for the adoption of a practice (ie. the risk sought to be managed is identified) and for the practice (ie. the solution to managing the risk). Solutions are identified on an as need basis, ie. **the research outcomes can be focused very specifically on the needs of the individual farmer.**

The Manual provides a flexible framework for cotton farmers to improve their environmental management. It recognises that cotton farming takes place in a wide range of environmental, commercial and social conditions. Cotton farmers can develop practical farm-specific plans that minimise the impacts of cotton on the environment, as well as demonstrating their commitment to responsible resource management.

Key Benefits of the manual

Encouraging farmers to develop plans on their own initiative is more effective in environmental management than government regulation and public-sector controlled planning - self directed initiatives are more likely to work than command and control mechanisms of change. Allowing the users of agricultural chemicals to (in a sense) self regulate their activities provides a valuable adjunct, or alternative, to government regulation.

The manual complements the current trend in environmental legislation that focuses on a general environmental duty of care and the need for due diligence requirements. This requires that risks be assessed, planned for and managed (eg. Queensland's Environment Code of Practice and the recommendations from the Industry Commission's Inquiry into Ecologically Sustainable Land Management, September 1997).

New Tools and Best Practices

PIRI

PIRI (Pesticide Impact Ranking Index) is a useful tool in designing pesticide-monitoring programs and in setting the R&D priorities to minimise the off-site impact of pesticides. The index has been developed to (1) rank pesticides in terms of their relative potential to contaminate groundwater or surface water, and (2) to compare different land uses in a catchment or at a regional scale in terms of their relative impact on water quality.

PIRI is based on a quantitative risk assessment approach and identifies three essential components; the value of the asset (threatened water resources), the source of the threat to the asset (pesticide use) and the pathway through which the threat is released to the asset. Each component is quantified using pesticide characteristics (toxicity, amount used, sorption and persistence) and soil and other site conditions (water input, erodibility and vulnerability to soil loss, recharge rate, depth of watertable etc). Research is continuing into evaluating and validating PIRI as an on-farm pesticide management tool (see Rivers for the Future Issue 10, pp5-8).

Reducing off-target spray drift

Use of a range of integrated strategies can reduce the off-target, downwind transport of pesticides by spray drift. Field experiments found that the off-target droplet movement of sprays can be reduced by selecting appropriate wind vectors, adopting large droplet placement (LDP) application techniques (although this technique can lead to a decrease in efficacy of the pesticide) and creating in-crop buffer distances on the downwind sides of sprayed areas. Off-target downwind deposition of endosulfan falls to about 1-2% of the applied dose within 250 metres for LDP spraying, compared to 500 metres for ULV (ultra low volume) spraying.

Modelling farm design

The GLEAMS model has been developed to evaluate the effectiveness of a range of farm design and management options aimed at reducing endosulfan in runoff. Retaining stubble on the soil surface (increasing infiltration and reducing the amount of soil erosion) is the most effective field management practice for reducing endosulfan transport off-field.

Improved irrigation techniques and reduced sprays can each reduce pesticide transport when compared to conventional practice. On farm storage has the potential to capture most of the endosulfan transported in runoff from the field, particularly when runoff from the field is minimised by other practices.
The rainfall environment influences runoff, with more intense daily rainfall leading to larger runoff events and more endosulfan being transported. Interactions between climate and site characteristics need to be considered when evaluating management strategies to minimise pesticide movement in runoff.

Stabilising soil erosion on cotton farms

Soil loss from cotton farms can be substantially reduced by reducing tailwater from irrigation, retaining anchored crop stubble under cotton and by using flocculants in irrigation water. Farm trials have shown that these practices can be incorporated into profitable irrigated cotton systems at a commercial farm scale and provide the expected benefits in reduced soil losses and pesticide transport. Off-field practices, involving trapping sediment in taildrains and silt traps, also reduces sediment movement off the farm.

There is still a lot of work to be done to incorporate this area into conventional farming systems-this system is only being used at Emerald, which has two distinct features, steep slopes, and a climate that allows a wheat crop grown for stubble to be harvested for grain (once you go south, the wheat has to be sprayed out).

Pesticide Application

Growers are responsible for all pesticide spray application decisions and protocols, and need to keep neighbouring properties informed about these matters.

Pesticides should be applied in a way so as not to cause damage to adjacent areas, taking account of weather and environmental conditions, and by using buffer zones when appropriate. Growers are responsible for minimising the amount of pesticide applied to crops by taking account of seasonal and weather conditions, and by using the most appropriate application method for their properties.

Farm Design

Furrow length and gradients should be designed to reduce erosion from water runoff, and tailwater drains should have low gradients to reduce water runoff velocities. Storm water management plans can be used to reduce water runoff. This involves maximising the capacity of farms to retain stormwater, and preventing this water from reaching natural water courses, wetlands and billabongs.

Integrated Pest Management

Pest management strategies that can be used include transgenic cotton, preserving beneficial insects, managing the development of pesticide resistance, the destruction of overwintering Helicoverpa pupae by cultivation, use of food sprays to attract predators, bio-pesticides, crop compensation for pest damage and trap crops for pests.

Soil and Water Management

Growers can minimise soil erosion by retaining stubble, reducing in-crop cultivation, maintaining soil organic matter and by adopting minimum tillage farming systems which are compatible with pupal destruction to maximise soil surface cover. The runoff of pesticide contaminated water should be minimised by controlling and scheduling irrigation to take account of soil and weather conditions.

Future Developments

The cotton industry is firmly committed to the management of the risks associated with pesticide use. The Manual helps cotton farmers to better understand the risks of using a pesticide so that they are therefore better able to manage and minimise those risks. The Manual takes into account the varied environmental, commercial and social conditions under which different farmers operate, and therefore establishes a flexible system of risk assessment and control that can be used in all cotton farming operations. The cotton industry has set itself the goal of 100% implementation by June 2001.
In addition, the cotton industry and regulators have already agreed that endosulfan levels in rivers will be reduced by 20% in three years and 50% in six years.

"This research program should produce real benefits for both the Australian environment and the cotton industry. It is unique in evaluating all aspects of an environmental problem by combining expertise from diverse backgrounds, pursuing a participative approach with the industry, and continuously briefing resource managers and regulators of progress. This holistic approach can serve as a model for other research involving complex agricultural ecosystems" (Harrison and Tisdell, 1996).

For more information contact Dr Nick Schofield, Program Manager Water Resources, LWRRDC, GPO Box 2182, Canberra, ACT 2601, Phone (02) 6257 3379, Fax (02) 6257 3420, email <nick.schofield@lwrrdc.gov.au>.

References and further reading

The 1998 Pesticides Conference, 'Minimising the impact of pesticides on the riverine environment: key findings from the cotton industry – 1998 conference'. LWRRDC Occasional Paper 23/98, 118pp.

Australian Cotton Industry Best Management Practices Manual, Cotton Research and Development Corporation, 1997.

The Cotton Model – A Model for Minimising the Impact of Pesticides on the Riverine Environment. LWRRDC/CRDC/MDBC (available from LWRRDC).

Legislating for River Management

Mary Maher, Peter Nichols, Susanne Cooper

Teembura Creek, Qld - photo Satish Choy

Sustainable river management requires integrated resource management, replacing the present fragmented, frequently reactive sectoral and monodisciplinary approaches with more flexible and integrated approaches that seek to reflect the complexity and interconnectedness of society and natural resource management systems.

An analysis of legislation for managing Australia's rivers deals with key questions, including:

* How effective is present legislation, and is its potential used?

* What are the critical river management targets, short and long term?

* How can legislation assist, drive or deliver, or empower others to deliver, the necessary 'grunt' for rivers and ensure:

- 'joined up thinking' from the various government agencies;

- governments taking an active role in 'engineering' of markets for achieving sustainable rivers;

- better reporting on non-compliance by the private sector and on policy performance by government?

* How is an holistic approach to river management to be crafted from the present single-issue, single agency approach?

* What role can legislation play in a context where flexible processes and adaptive management must prevail?

* How can legislation move river management from being government-driven to being driven by the private and community sectors including legislative provisions for:

- self-reliance;

- self - or co-regulation; and

- community empowerment through improved transparency in face of executive discretion; independent review mechanisms; monitoring and reporting?

In the LWRRDC 1999 project, *River Restoration and Management Legislative Frameworks: an Analysis of Australia and International Experience*, the task was to define criteria for a world's best practice legislative framework for all Australian jurisdictions for the 21st century. The aim was to provide the opportunity for healthier rivers in Australia by using an agreed nationally consistent legislative framework model.

Our approach to the task involved:

- a focus on four themes considered central to river management;

- reviewing a range of Australian legislation at all three levels of government, as well as legal provisions in selected relevant countries; and

- analysing and documenting critical success factors for a best practice legislative framework.

The four themes - water flows, water quality, riparian areas and administrative arrangements for integrated catchment management (ICM) - were chosen on the basis that:

- they represent a cross section of the major missing river management issues (protection of ecosystem values, governance and community empowerment);

- they deal with discrete yet overlapping aspects of river management including resource allocation, pollution, land development and institutional arrangements; and

- all four are presently experiencing legislative reviews.

The definition of a best practice legislative framework is one which:

defends rivers as a vital part of our natural capital and defines ecological 'bottom-lines' or thresholds for their use. This requires pre-stated measurable performance indicators, arrived at throughcommunity involvement;

- manages conflicts between users, and between users and non-users;

- facilitates change and requires continuous improvement in performance;

- enables adaptive management, through policy, institutions, and management, in response to changes in perceptions, knowledge, technologies and management regimes; and

- protects the public interest.

The legislative framework encompasses all instruments having a statutory basis. These fall into two broad areas:

- those affecting land and water users impacting on rivers and their restoration; and

- those affecting governmental structures and inter-governmental and inter-agency relations and operations.

Components of legislation involved in river management include:

- responsibilities for river management;

- structures for implementing policies, involving stakeholders and operation and service delivery aspects;

- definition of the outcomes required in terms of desired ecological and resource use outcomes, such as water entitlements, risk assessment, community consultation, setting of water quality objectives, and catchment-specific outcomes;

- permitting, enforcement and compliance requirements in statutory plans as well as licences, permits and approvals;

- 'checks and balances' found in monitoring and reporting legislation as well as community empowerment, including generic and specific statutory review and appeal provisions, whether of public agencies or otherwise.

The 1994 COAG Agreement for water industry reforms is arguably the most significant catalyst for legislative change to river management in Australia and its impacts are not yet complete, much less critically evaluated. Most apparent examples of legislative initiatives are still just good ideas at present; they are not yet critically evaluated; locally, nationally or internationally. In Australia, no jurisdiction has specific legislation or a legislative framework that manages rivers or their ecological processes in a systematic, integrated manner.

> In Australia, no jurisdiction has specific legislation or a legislative framework that manages rivers or their ecological processes in a systematic, integrated manner.

Circumstances in most jurisdictions are changing rapidly in response to the COAG initiatives and other responses to the crises in our rivers. There is widespread acknowledgment of the need for change and a more sustainable approach. Some States have prepared ESD, catchment management and integrated resource management legislation, mainly focused on administration processes by government agencies. Greater emphasis has been placed on increasing the legislative status and achieving greater coherence / reconciliation amongst various statutory planning mechanisms; for example, integrated coastal plans, some catchment plans, some river plans.

Most jurisdictions are presently incorporating performance needs for ecological protection in matters of:

⇒ resource use and access legislation, for example:

⇒ land development and industry operations for example requirements for:

⇒ public land and water administration, construction including:

⇒ infrastructure provision for example water allocation management plans.

Existing legislation, trends and legislative needs were examined across the four themes of water flows, quality, riparian and ICM.

In water flows, the assessment, identification and delivery of environmental flows to our river systems have received recent extensive attention across Australia. This essentially stems from the COAG process aimed at better administration of our water resources, and incorporating environmental flows as an integral part of their reformed management.

Increasing demands for a limited and often scarce resource, and conflict between extractive and other water uses, have resulted in the development of broadly accepted principles and parameters for environment flow objectives. In addition, there has been rapid development of State legislation and policies to provide the statutory framework for their implementation.

A critical question which emerges is how to set the objectives for environmental flows? Should they maintain or slightly improve existing conditions, or seek restoration to some future desired state?

In theme two, the quality of Australian waters continues to deteriorate, due to factors arising mainly from consumptive and discharge uses not incorporating parameters for environmental protection and sustainability.

> A critical question which emerges is how to set the objectives for environmental flows? Should they maintain or slightly improve existing conditions, or seek restoration to some future desired state?

Existing legislation for water quality is delivered:

- directly through specific water quality protection legislation, focused until recently on prescriptive licences for point-source water quality discharges and largely ignoring non-point sources and enforcement;

- indirectly through a range of statutory mechanisms including town planning, coastal and other land use planning which paid little regard to water quality protection needs; and

- more recently, through catchment management strategies for land and water management, across all tenures.

Recent key legislative developments include a national approach to the definition of water quality objectives and associated performance criteria (ANZECC guidelines 1992); extension of statutory requirements to address water quality needs through stormwater plans, catchment plans and even planning schemes; and the move to incentive-based licensing and regulatory negotiation between industries and protection agencies.

Protection policies for specific water bodies (wetlands, estuaries, lakes, dams), given legal status, have the potential to integrate water quality, water quantity and stream condition objectives and to drive high energy reforms into many agency and private sector plans

Protection policies for specific water bodies (wetlands, estuaries, lakes, dams), given legal status, have the potential to integrate water quality, water quantity and stream condition objectives and to drive high energy reforms into many agency and private sector plans. At the waterbody level however, the scale of the planning task is sizeable and some States have adopted a 'stressed rivers' approach to set the priorities in their river systems. Another feature in some States has been the devolution of management responsibilities to local and catchment authorities. Devolution however has not necessarily been accompanied by adequate resourcing, greater coordination, integration or clarity of policy, leading to risks of inconsistency, institutional failure (the catch-cry) and at the local level, a culture of 'consent with conditions'.

Existing legislation does not deliver the degree of protection, rehabilitation or active management needed to match the ecological significance of the role riparian areas play in river functioning and restoration

In theme three, riparian areas, existing legislation does not deliver the degree of protection, rehabilitation or active management needed to match the ecological significance of the role riparian areas play in river functioning and restoration. A systematic approach has proven difficult in the face of differing tenures. Legislation has not delivered active management in any systematic way and riparian areas are addressed indirectly through legislation for planning, or for leasing of lands, or through specific ecological regulations for example, for vegetation or species protection.

Riparian areas are attracting attention in a range of river and catchment related plans, statutory and non-statutory. However this has to be combined with legislation for prevention of and intervention in the event of damage to the river system, and more specifically, to its riparian areas.

In theme four, institutional arrangements for ICM, legislation specifically for catchment management exists in New South Wales, South Australia and Victoria. In these three States, legislation has devolved powers for planning and management to varying degrees to the catchment / regional level. Other States and Territories have policy commitments to integrated catchment management and have made organisational changes to implement catchment management. Several have recently proposed introducing specific catchment management legislation.

Cullen (1997) argues that it is the lack of integration - between governments, between agencies, between disciplines and between

Cullen (1997) argues that it is the lack of integration - between governments, between agencies, between disciplines and between knowledge providers and knowledge users - which forms the basis of water/ catchment management problems

knowledge providers and knowledge users - which forms the basis of water / catchment management problems. Those State governments with institutional arrangements for catchment management have recognised this and established structures and processes to facilitate integration; indeed, to require it. Catchment Plans in SA and Victoria now have legal status. Catchment managers must have the ability to generate the necessary funding for operations and services. Independence is one aspect of funding, the other is ensuring the funding is adequate for the priorities, priorities decided at catchment level though using criteria from local, regional and state policies.

Young (1997) argues that catchment management plans in the future must constitute target-based, legally binding documents for water rights and other resource access arrangements; we agree.

From the analysis of existing laws, it is evident that NSW, SA and Victoria have moved decisively towards a catchment management model, with key institutional and operating arrangements stipulated in legislation. Other States and Territories, most with critical river problems of protection and degradation, have informal arrangements for catchment management, generally being delivered through informal working arrangements between water, land and environment protection agencies.

The case studies were not of great assistance in assessing the capacity of present laws to bring about river management, because practices in place appeared rarely to utilise all legal opportunities available. Also, even a best-practice legal framework will not guarantee maximal outcomes.

Dovers (1997) summarises the daunting requirements of truly adaptive management as "informational; intellectual; statutory; ecological / substantive; participatory; political and institutional". The challenges of the administrative structures for river management are not peculiar to Australia; they exist throughout the world in both technologically advanced and developing countries.

From in-depth review of legislation for four topics - environmental flows, water quality, riparian areas and institutional arrangements for catchment management - the following conclusions were drawn:

- rivers are receiving greater attention. No national, binding standards have been set for their protection or management. Surrogate standards are proposed through Ministerial or council agreements, or Commonwealth 'bribery'. Overseas river achievements in federal systems indicate the need for stronger Commonwealth lead, in partnership with States and Territories. There is limited application of Commonwealth powers to protect rivers.

- there is confusing terminology across jurisdictions for most aspects of river / resource management.

- water resource issues are the main focus of attention; some degree of recognition of environmental flow needs; narrow focus on river water, not the total water cycle. There is strong opposition to security of environmental flows in water allocation.

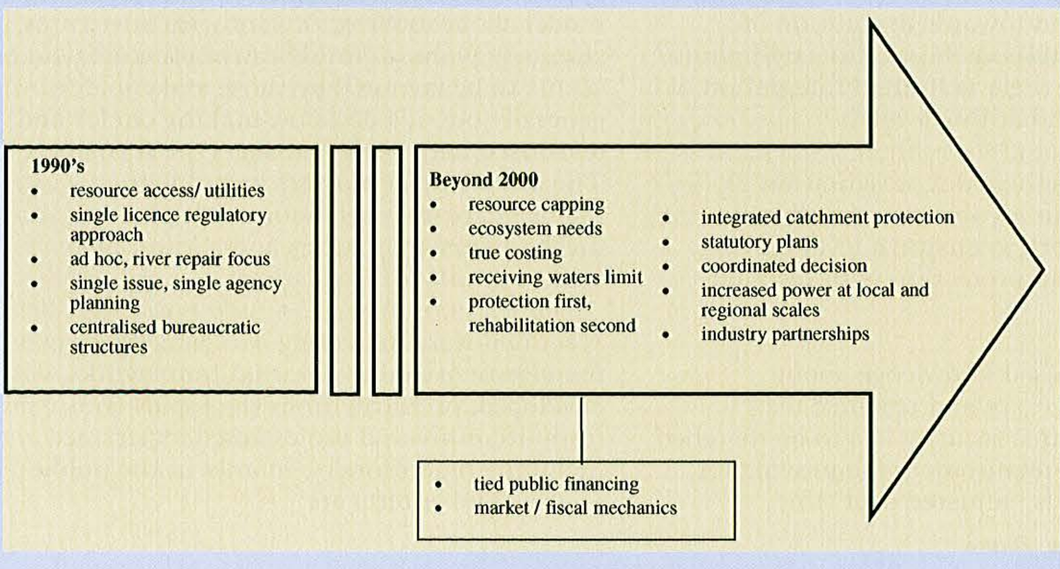


Figure 1. Legislation's role in Ecologically Sustainable Water Management


Liffy Creek, Tasmania

- the Commonwealth's commitment to NSESD (National Strategy for Ecologically Sustainable Development) has not been borne out in reality (Productivity Commission's 1999 study).

- commitment has been given by all States to Integrated Natural Resource Management / Integrated Catchment Management. In most States, problems arise because major resource agencies are distant from the integrated planning process; outside the cooperative arrangements for planning and service delivery.

- evolution towards catchment-based planning. However these plans remain non-statutory or advisory only in most jurisdictions. Catchment legislation is added to the plethora of other legislation relating to resource management or ecosystem protection.

- there is a trend towards devolution of functions and responsibilities to catchment / local level, but there is limited integration of statutory powers at this level.

- there is strengthened representation of stakeholders but an absence of national / state policy framework to ensure a level playing field - ecosystem protection with resource management.

- there is increased knowledge about ecosystem processes and resource use impacts. Resource security has to be matched with emerging requirements to provide for ecosystem needs, adjusted over time.

The big directions of the future appear to be:

- ecologically sustainable water management (ESWM, similar to ESForestM), where equity and ecological interests are represented alongside economic and sectoral interests in water management decisions.

- development of new administrative arrangements at regional / catchment level.

- nationally-agreed binding framework for rivers (ie. where to after COAG?).

- development of companion mechanisms in the package (tax reform, industry adjustment, environmental accounting) in a compatible and comprehensive way; potentially decreasing role for legislation if these mechanisms perform for river management.

The nature of the legislative framework appears to be at a crossroads. The regulatory model about moving forward with structures, statutory plans, administrative processes etc., seems to be favoured by those stakeholders generally outside decision-making circles and disabused with river managers' performance. The other model moves forward with inclusive, co-management, multiple mechanisms approaches and a lower but critical profile for legislation.

A set of criteria reflecting best practice river management and restoration frameworks was developed, primarily from the topics; and from literature and professional experience including practitioners, mainly in the public sector. The criteria are:

* setting binding, measurable river management standards should be a national function, requiring a strong leading role by the Commonwealth.

* a general duty-of-care should be legislated for all landholders and all others to manage all aspects of surface water and groundwater resources sustainably, and to achieve ESD as the primary object (not just as one of several) of their activities.

* a statutory definition of 'river' is needed, founded in the total water cycle and including floodplains, all related wetlands, surface and groundwater etc.

* there needs to be a single, multi-functional agency for a river's management and rehabilitation river management agencies need a catchment-wide spatial characteristic.

* river management agencies need a statutorily-based set of powers commensurate with their responsibilities, that is, for planning, funding, educating, regulating and achieving all components of river management.

* river management agencies need to include all stakeholders in an open, equitable and adequately resourced manner.

* given the previous three principles, and the extent to which local government is already involved in some environmental and other aspects of river management, there need to be close links between river management agencies and local governments.

* river management agencies need a statutory, comprehensive river management plan.

* there needs to be a statutorily required regular, publicly available audit of river management and rehabilitation, independent from the restoring / rehabilitating agency.

* the legislative framework for administrative components of river management should contain a requirement for specified periodic reviews; and

* all legislation with a direct or indirect effect on river management needs to have and maintain primacy over all other legislation, including that applying to utilities and emergencies.

It has taken some 200 years to bring Australian rivers to their present unsatisfactory state; it may take a not dissimilar period to restore our rivers to a sustainable level. Legislation has a critical role to play. The imperative now is to further examine the gap between the scope and mechanisms for river management contained within existing legislation and that of a preferred legislative framework, and then to work with the drivers promoting legislative strategies for holistic river management in each jurisdiction.

For more information contact
Mary Maher & Associates, 17 Katrine Street, West End. QLD 4101.
Email: <mmaher@squirrel.com.au>.

The full report 'River restoration and Management Legislative Frameworks : an Analysis of Australian and International Experience' is available as LWRRDC Occasional Paper No. 02/00 and website <www.lwrrdc.gov.au> under 'Publications'.

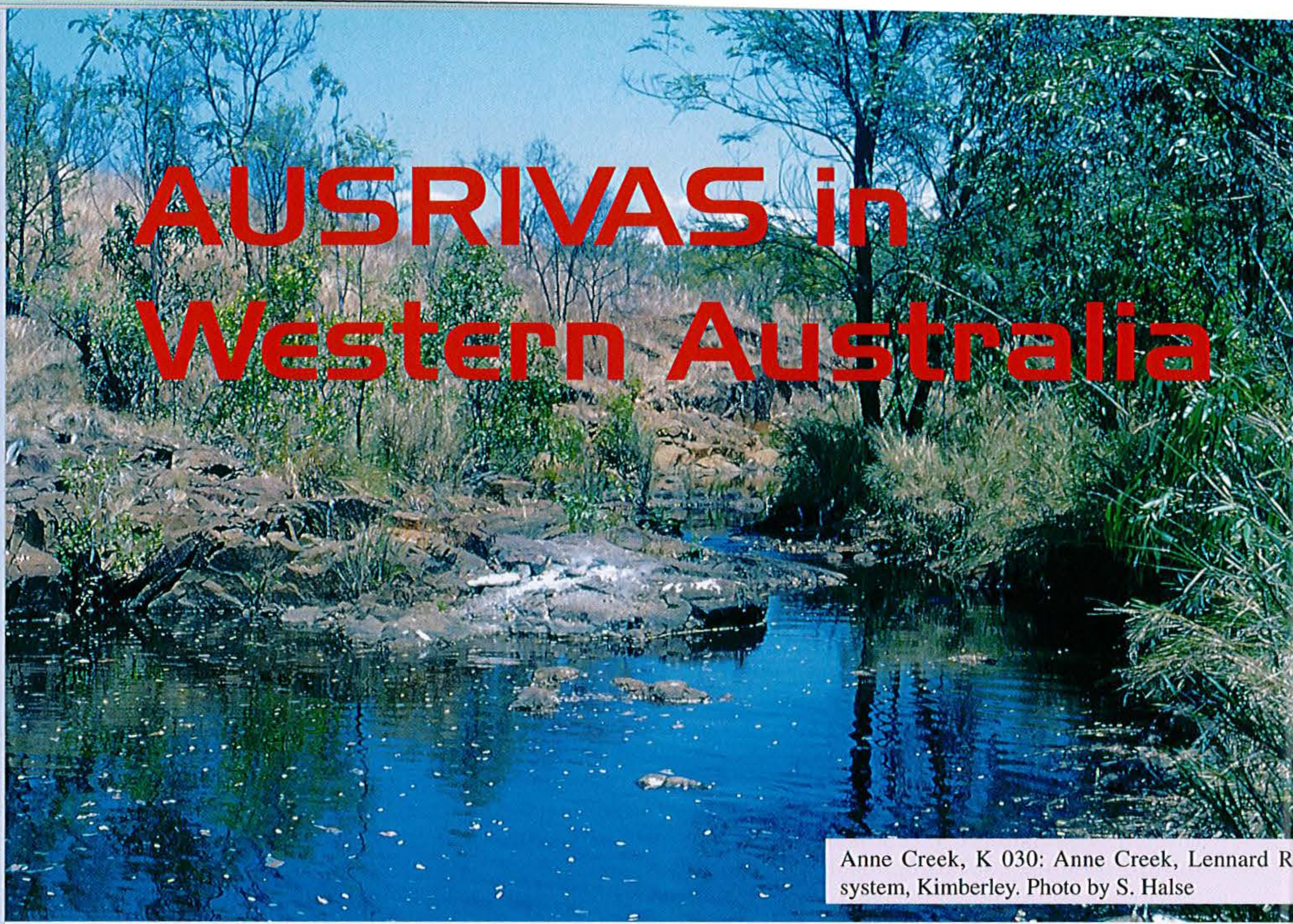
ANZECC (1992). National Water Quality Management Strategy, Australian Water Resources Council: Canberra.

Cullen, P. W. (1997). The Australian Scene: Visions for Integrating Catchment Management. In Proceedings of the Second National Workshop on Integrated Catchment Management, Australian National University, Canberra, 29 September – 1 October.

Dovers, S ' Public Policy and institutional R&D for Natural Resource Management' in Mobbs C., Dovers S (1999) 'Social, Economic, Legal, Policy and Institutional R&D for Natural Resource Management – Issues and Directions', LWRRDC Occasional Paper No.01/99.

Young, M. (1997). ICM in 2020: conditions that will make Australian ICM exemplary. In Proceedings of the Second National Workshop on Integrated Catchment Management: Melbourne.

AUSRIVAS in Western Australia



Anne Creek, K 030: Anne Creek, Lennard R
system, Kimberley. Photo by S. Halse

Winston Kay, Michael Scanlon and Stuart Halse
Department of Conservation and Land Management, WA

The Monitoring River Health Initiative (MRHI) was established in 1994 by the Federal Government through EA and LWRRDC because of growing concern about the condition of Australia's waterways. The primary objective was to develop a standardised tool for evaluating condition of rivers and streams. The lead agency responsible for implementing the MRHI in Western Australia is the Department of Conservation and Land Management (CALM).

During Phase I of the MRHI, from 1994-96, 184 reference (or minimally disturbed) sites were sampled on rivers and streams throughout WA to collect baseline data about which macroinvertebrate families occurred in different parts of the State and how stream type affected their occurrence. Because of the enormous area involved, a collaborative effort between CALM and three WA universities – Edith Cowan University, Murdoch University and the University of Western Australia was required. Sites were sampled four times over the two years (twice in autumn and twice in spring). Computer models were then developed in collaboration with Richard Norris at the University of Canberra (Smith *et al.* 1999). These models are known as AusRivAS models (Australian River Assessment System) and are accessible via the internet at: <http:/enterprise.canberra.edu.au/Databases/AusRivAS.nsf>. Using a small suite of environmental variables such as latitude, longitude and stream discharge, the models determine the macroinvertebrate families most likely to occur in a river or stream in the absence of any disturbance (*E*). The families collected from a test site (*O*) are compared with the families predicted to occur if it is not disturbed and the ratio of observed to expected families (*O/E*) provides a measure of ecological condition (or health) of the river.

Phase II of the MRHI, also called the First National Assessment of River Health (FNARH), commenced in 1997. Its aim was to evaluate Australia's rivers, using AusRivAS models, for state of the environment reporting. To date, over 2,100 macroinvertebrate samples have been processed in WA and 545 sites have been assessed. A total of 138 macroinvertebrate

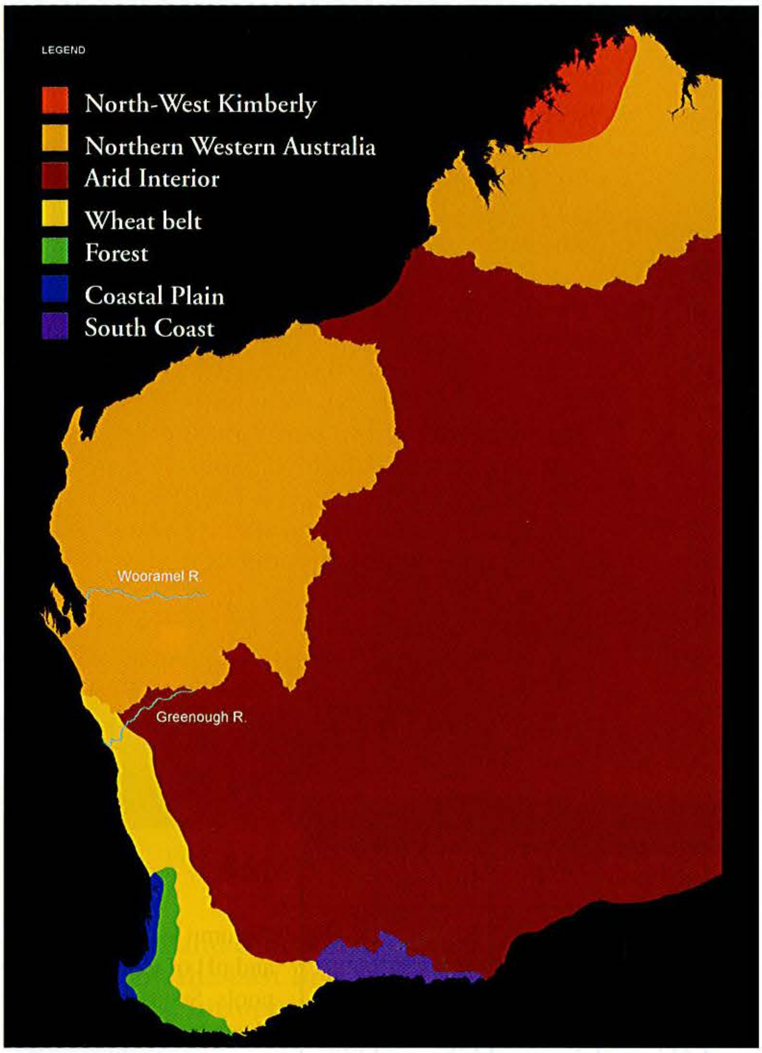


Figure 1.
Preliminary riverine macroinvertebrate bio-regions in WA.

families have been collected and 280,000 animals identified. By the end of Phase II, over 600 sites in WA will have been evaluated.

In addition to building AusRivAS models and using these to assess river condition, there have been several important spin-offs from the MRHI. Previously, there had been no large-scale surveys of aquatic macroinvertebrates in WA and almost no information was available from the northern part of the State. There are now excellent collections for taxonomic and biogeographic studies. Despite only a small proportion of these having being examined by taxonomists, undescribed species from fourteen different families have been found, including at least one new genus (Knott & Halse 1999). There have also been considerable range extensions for some animals identified to species level.

Analyses at family level have revealed the broad patterns of distribution of macroinvertebrate communities in WA (Figure 1). There is a strong distinction between communities of the north and south with the transition occurring between the Wooramel and Greenough Rivers. Northern WA is largely homogeneous in terms of its aquatic macroinvertebrates, despite its large size, but the north-west Kimberley appears to be richer than elsewhere in the north (Kay *et al.* 1999).

South-Western WA contains four regions. The Forest comprises catchments that are largely forested, where macroinvertebrate communities are characterised by moderate richness and low abundance, whereas the Coastal Plain is characterized by moderate richness and high abundance. The Wheatbelt is an extensively modified landscape where rivers have been heavily impacted by agriculture. Its macroinvertebrate communities are characterized by low richness and high abundance. The communities of the South Coast, where some rivers are naturally saline and acidic, are more depauperate than those of the Wheatbelt.

Case study: The Collie Basin

This study was initiated by the Collie Basin Research Steering Committee, as part of water resource planning to ensure environmental and social values of the Collie River are maintained. The aim was to assess ecological condition of the larger pools on the South and East Branches of the Collie River. Extensive coal mining occurs in the Collie Basin. As a result of sulphur-rich material being exposed to air during mining and associated de-watering operations, groundwater has become locally acidic. While mining continues, de-watering operations will continue to lower the surrounding water table, which has reduced river flow in summer and lead to a scheme to supplement river flow in the South and, to a lesser extent, East Branches with acidic groundwater. After mining ceases, groundwater levels will rise and maintain river flow through summer, as occurred pre-mining.

However, some groundwater will be acidic. Information about condition of pools currently being supplemented will enable predictions about likely effects of the rise of an acidic watertable.

River pool condition was assessed in three ways and a pool was classified as ecologically degraded only if two (or more) assessments suggested it was impacted. AusRivAS models were used for the first assessment. The models are still being refined, however, and many families of macroinvertebrates in WA have very broad ecological tolerances (unpublished data), which reduces sensitivity of the models. Therefore, a second assessment was made by comparing the number of families collected in Collie River pools with the average number collected from all Jarrah forest and Swan Coastal Plain reference sites. When the ratio of number of families in a pool to average number in reference sites was < 1.0, the pool was classed as disturbed. A third assessment was derived by counting number of families belonging to the insect orders Ephemeroptera, Plecoptera and Trichoptera (EPT). Up to nine such families can occur in jarrah forest pools and if all families are absent, or only one occurs, it is likely the pool is ecologically degraded.

Fifteen river pools on the Collie River were sampled in April (autumn) 1999; most had already been sampled in August (spring) 1998 (Figure 2). River flows were natural in spring and supplemented in summer and autumn upstream of COL14 on the South Branch and upstream of COL10 on the East Branch. In most cases, there was no surface water in river sections between pools in autumn.

Results

Groundwater supplementation caused large reductions in pH of South and East Branch pools near the point of inflow. Water became

Location of pool	Pool	Assessments				pH
		ARS	Rich	EPT	Impact	
South Branch	COL14	B*	1.0*	0*	Yes	2.9
	COL15	B*	0.9*	0*	Yes	2.9
	COL16	A	1.4	1*	No	3.3
	COL25	A	0.8*	0*	Yes	3.0
	COL26	B*	1.0*	1*	Yes	3.4
	COL27	A	0.9*	2	No	4.4
	COL17	C*	1.8	4	No	6.4
East Branch	COL10	A	1.4	2	No	3.8
	COL06	A	1.7	1*	No	3.4
	COL28	A	1.4	2	No	3.8
	COL29	A	1.6	1*	No	3.8
Upstream East Branch	COL11	C*	0.5*	0*	Yes	8.4
Downstream pools	COL30	A	1.4	1*	No	7.6
	COL08	A	1.4	2	No	6.9
	COL31	B*	1.9	5	No	7.1

Table 1.

Autumn assessments and pH of Collie River pools. Scores suggesting impairment are marked with an asterisk:

ARS = AusRivAS score (A, reference;

B, mild impairment;

C, substantial impairment);

Rich = ratio of number of families to average for reference sites in same region;

EPT = number of families of Ephemeroptera, Plecoptera, Trichoptera;

Impact = overall assessment.

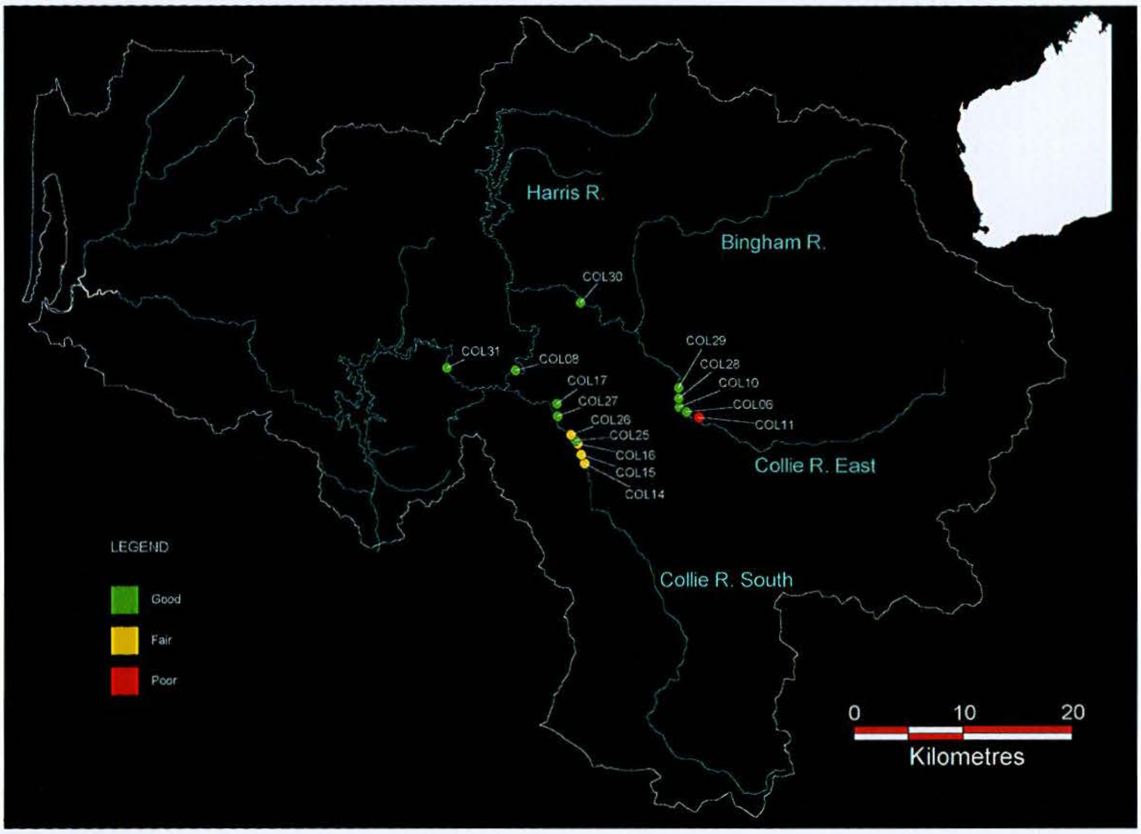


Figure 2. Ecological condition of Collie River pools in Autumn 1999

less coloured and conductivity decreased, especially on the East Branch. In South Branch pools, nitrogen was converted from organic forms to ammonia.

In Spring 1998, prior to supplementation, all pools were assessed as undisturbed except COL11, the most upstream pool on the East Branch, which was saline and eutrophic as a result of agriculture. The generally good condition of pools in spring was not surprising because the river was flowing strongly, with comparatively good quality runoff from most of the catchment.

Assessments in Autumn, after several months of supplementation, showed river condition had declined markedly on the South Branch (Table 1, Figure 2). Four of the five pools closest to the point of supplementation were ecologically impaired (COL16 was the exception, though it was rated as disturbed by EPT score). The two more downstream South Branch pools, which had higher pHs, appeared to be unimpacted.

With the exception of COL11, which was upstream of supplementation, all pools on the East Branch and all pools downstream of the junction of the two Branches were assessed as undisturbed in autumn. COL11 had a salinity close to that of seawater and high nitrogen content.

Discussion

Assessments based on AusRivAs methodology produced strong evidence of declining river condition in the Collie River South Branch over summer. There were insufficient chemical and habitat data to identify the cause with certainty but ecological damage started to become apparent at pH < 3.5. All sites with pH < 3.0 were impaired (Table 1). It is possible, however, that high ammonia level, or some other factor, was the cause of impairment rather than pH.

Based on northern hemisphere studies, it is surprising that the low pH values on the East Branch (3.4 - 3.5) did not also impact macroinvertebrate communities. However, macroinvertebrate families in WA have broad environmental tolerances and it is likely that they are tolerant of low pH. Studies in the Northern Territory have found that many Australian midge larvae are unaffected by acidic mine discharge. Vegetation around low-pH pools on the South and East Branches was in good condition, suggesting riparian communities were not impacted by low pH.

Miner's Pool, Drysdale River, Kimberley. Photo by S. Halse

Metals were measured in spring but did little to explain the pattern of disturbance exhibited in Autumn. Iron levels were high on the South Branch but were equally high in some control pools.

The Collie Basin study is an example of the many uses of AusRivAs as a tool for river assessment in WA. Results will be used to guide future decisions about supplementing river flows and managing rising groundwater after mining ceases. Although AusRivAS has already produced useful results in WA, accuracy of assessments could be improved by small changes to current AusRivAS protocols. Some disturbances have a strong abundance signal, which cannot be utilised at present. Greater quantification and standardisation in sampling methodology would enable abundance information to be incorporated in assessments.

For more information contact Stuart Halse, CALM, Phone (08) 94055135, Fax (08) 9306 1641, email <stuarth@calm.wa.gov.au>.

References

Kay W. R., Smith M. J., Pinder A. M., McRae J. M., Davis J. A. & Halse S. A. (1999) Patterns of distribution of macroinvertebrate families in rivers of north-western Australia. *Freshwater Biology*, **41**, 299-316.

Knott B. & Halse S. A. (1999) *Pilbarophreatoicus platyarthricus* n. gen., n. sp. (Isopoda: Phreatoicidea: Amphisopodidae) from the Pilbara region of Western Australia. *Records of the Australian Museum*, **51**, 33-42.

Smith M. J., Kay W. R., Edward D. H. D., Papas P. J., Richardson K. St J., Simpson J. C., Pinder A. M., Cale D. J., Horwitz P. H. J., Davis J. A., Yung F. H., Norris R. H. & Halse S. A. (1999) AusRivAS: using macroinvertebrates to assess ecological condition of rivers in Western Australia. *Freshwater Biology*, **41**, 269-282.

Taxonomy and Identification of Aquatic Macroinvertebrates

John Dean and Ros St Clair
Environment Protection Authority, Victoria

Notalina bifaria (Leptoceridae) from south-eastern Australia. Photograph: J.Gooderham, E.Tsyrlin.

The value of aquatic macroinvertebrates for environmental monitoring of running waters is widely recognised. While identification to family level is often adequate for broad brush surveys, the detection of more subtle changes in water quality or changes on a local scale will usually require species level identifications. Furthermore, to facilitate transfer of ecological information between studies, the accurate and consistent identification of animals to species is paramount.

One of the major impediments to Australian studies on running water ecology has been the inadequate taxonomy of many groups of aquatic macroinvertebrates. Many species remain undescribed, and even if a species has been described the taxonomic description is often restricted to aerial adults. Immature larvae and nymphs, the stages most often collected in aquatic surveys, usually cannot be associated with the named adult.

A recently completed study has investigated the aquatic stages of certain families of mayflies and caddisflies, two of the most common insect groups in Australian running waters. The aims of the study were to:
- develop a standard system for the designation of unidentified taxa.
- identify morphological characters of taxonomic value, and publish fully illustrated identification keys.
- establish National and State Voucher Collections for reference purposes.
- produce taxa/character matrices which could be used for the development of electronic interactive identification keys.

The bulk of the material examined was from the aquatic insect collection held by the Museum of Victoria, which has been accumulated over many years and includes material from all Australian states. In addition, some material collected during the MRHI program (Monitoring River Health Initiative) was examined, and also voucher collections held by various groups undertaking aquatic macroinvertebrate studies in Australia.

Australian National Voucher Collection

The 'Australian National Voucher Collection of Aquatic Insects' has been lodged in the Museum of Victoria, and includes immature stages of presumptive species of Australian mayflies and caddisflies. Lodgement in Victoria was necessary because many of the

	Known Genera Descr.	Known Genera Undescr.	Known Species Descr.	Known Species Undescr.	# immature taxa included in keys
EPHEMEROPTERA					
Ameletopsidae	1	0	3	0	2
Coloburiscidae	1	0	3	0	2
Ephemerellidae	1	0	1	0	1
Leptophlebiidae	16	8	60+	50+	99
Oniscigastridae	1	0	3	0	3
Prosopistomatidae	1	0	1	0	1
Siphlonuridae	1	0	1	1	2
TRICHOPTERA					
Antipodoeciidae	1	0	1	2	3
Atriplectididae	1	0	2	0	2
Calamoceratidae	1	0	9	0	1
Helicopsychidae	1	0	14	0	12
Hydrobiosidae	15	0	64	5	42
Hydropsychidae	8	3+	27	25+	46
Kokiriidae	3	0	5	0	2
Leptoceridae	15	1	129	50+	81
Limnephilidae	1	0	3	0	2
Odontoceridae	2	1	4	4	4
Oeconesidae	1	0	1	0	1
Philorheithridae	5	3	14	7+	14
Plectrotarsidae	3	0	5	0	3
Stenopsychidae	1	0	9	0	1?

Taxonomic status of selected Families of Australian Mayflies and Caddisflies.

voucher specimens were from the museum's collection and could not have been transferred elsewhere. The collection is intended as a source of reference material, although to maintain collection integrity some access restrictions will have to be applied.

In the absence of formal names, standardised designations have been applied to taxa in the collection. Unidentified taxa have been designated by the prefix AV (Australian Voucher) and a number, eg *Nousia* sp.AV3, which will serve to distinguish them from taxa held in pre-existing voucher collections. This will overcome difficulties experienced in the past, where in many cases different voucher collections have used the same designation for what have been different species.

Taxonomic status of Families investigated

Taxonomic status of the families investigated is summarised in the adjacent table. The caddisfly families Hydropsychidae, Leptoceridae and Philorheithridae, and the mayfly family Leptophlebiidae contain many undescribed species and some undescribed genera, and are the families most in need of taxonomic revision. For most families, the number of immature taxa included in the identification keys is less than the number of species known. Obviously there will be additional larvae and nymphs in Australia which were not examined during the project, and it is also expected that future taxonomic research will reveal some voucher taxa in the keys actually represent two or more valid species. One of the big gaps in current knowledge is the absence of larval keys to the leptocerid genera *Oecetis* and *Triaenodes*. These genera account for more than 100 of the known species in the family Leptoceridae.

The project has established a foundation for future studies. Advances in adult taxonomy, in conjunction with the rearing and association of immatures, will ultimately enable the replacement of voucher designations with species names.

Dissemination of identification keys

Identification keys have been presented at a series of taxonomic workshops held at the Murray-Darling Freshwater Research Centre and published in the CRCFE/MDFRC Identification Guide Series (see references below). Keys for additional Trichoptera families will be published and presented at the taxonomic workshop in February 2000. Taxa-character matrices for identifications to family and genus were developed and forwarded to CSIRO Entomology for use in a CD-ROM interactive identification key.

Undescribed species of leptophlebiid mayfly from the Northern Territory, *Jappa* sp.AV1. Photograph: J.Gooderham, E.Tsyrlin.

This project was funded by LWRRDC and EA and supported by the Victorian EPA.
For more information contact John Dean, phone (03) 9616 2366, email <john.dean@epa.vic.gov.au>

Further reading:

Dean, J.C. (1997) *Larvae of the Australian Hydrobiosidae (Insecta: Trichoptera).* 53 pp, 138 figs. Identification Guide No.11, Cooperative Research Centre for Freshwater Ecology.

Dean, J.C. (1999) *Preliminary Keys for the identification of Australian mayfly nymphs of the Family Leptophlebiidae.* 91 pp, 247 figs. Identification Guide No.20, Cooperative Research Centre for Freshwater Ecology.

Dean, J.C. (1999) *Preliminary Keys for the Identification of Australian Trichoptera Larvae of the Family Hydropsychidae.* 40 pp, 91 figs. Identification Guide No.22, Cooperative Research Centre for Freshwater Ecology.

Dean, J.C. & Suter, P.J. (1996) *Mayfly nymphs of Australia. A guide to Genera..* 82 pp, 133 figs. Identification Guide No.7, Cooperative Research Centre for Freshwater Ecology.

St Clair, R. (1997) *Preliminary Guide to the identification of late instar larvae of Australian Philorheithridae, Calamoceratidae and Helicopsychidae (Insecta: Trichoptera).* 42 pp, 95 figs. Identification Guide No.12, Cooperative Research Centre for Freshwater Ecology.

Other LWRRDC Newsletters

* *'FOCUS' - National Dryland Salinity Program newsletter*

* *'Intersect' - LWRRDC general newsletter*

* *'RIPRAP' - Riparian Lands Management newsletter*

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Rivers for the Future welcomes contributions from river researchers and managers. A copy of this Guide for Authors can be requested from Russell Moran c/o LWRRDC (see below).

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The magazine 'Rivers for the Future' is published by the Land and Water Resources R&D Corporation (LWRRDC) to provide an update and discussion of river-related research funded by the Corporation. Contributions from river researchers and river managers are welcome, as are submissions from private individuals, organisations, institutions, corporate bodies and government on river related research issues. The magazine, through the Editorial Committee, reserves the right to accept or reject any submission.

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Rivers for the Future
Magazine Coordinator
c/o LWRRDC
GPO Box 2182,
CANBERRA, ACT 2601.
Phone: (02) 6257 3379
Fax: (02) 6257 3420

Russell Moran can be contacted directly on:
Phone (02) 6251 6794
Fax (02) 6251 8177.
Mobile 0418 647 927
Email <rzzz@dynamite.com.au>

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