CATCHING UP
on contaminants

The Australian community is increasingly aware of the importance of our water resources and riverine environments to the future sustainability of agriculture and the environment. Contaminants and pollutants are central to river management because they influence the quality of irrigation and drinking water, and the condition of aquatic habitats for riverine plants and animals.

Australian Government
Land & Water Australia

CON*t*ents

RIP*A*rian lands:
WHERE LAND AND WATER MEET

From the Editor

Welcome to another edition of *RipRap*. This edition is focusing on the research being funded through the National River Contaminants Program, a joint initiative of Land & Water Australia and the Murray-Darling Basin Commission. This Program is now into its second year, and the research being funded covers a range of different issues related to understanding and managing contaminants in our river systems. We have also included a large range of new products for you to access, for example climate prediction tools groundwater models and two new irrigation insights reports that make interesting reading. I hope you enjoy this edition, and on behalf of the Rivers Arena at Land & Water Australia, I would like to wish you a very Happy Christmas and New Year.

Season's greetings
FROM THE RIVERS ARENA

CATCHING UP on contaminants

By Brendan Edgar
and David Nicholls

The Murray Darling Basin Commission and Land & Water Australia commissioned the **National River Contaminants Program** to improve our understanding and management of river contamination issues, help reduce associated costs, and better manage the risk of river contamination. The Program is providing practical technical information to directly support the development of an integrated approach to managing river contaminants at national and catchment scales. This edition of *RipRap* features the research projects being funded by the Program.

Taking a whole-of-ecosystem approach, the Program focuses on the combined impacts of major riverine contaminants — salt, nutrients and sediments — and their role in ecosystem processes. Though these contaminants occur naturally, large increases in the amounts present can damage the environment. To better manage these contaminants in rivers we need to understand:

~ where contaminants are coming from in the landscape?
~ how they are transported to the river system? and,
~ what transformations occur as contaminants interact within the water column and with other potentially harmful contaminants?

Salt as a contaminant

Research has demonstrated the seriousness of the salinity problem in Australia. Much is now known about the causes of increased salinity, and a number of effective strategies have been demonstrated to reduce the problem. However, little research has been conducted on the specific environmental impacts of salinisation.

In particular, few investigations have examined biological changes in salinised rivers or wetlands and the different levels of damage. There is a lack of information on the sensitivity of Australian freshwater biota to increases in salinity, particularly sub-lethal or long-term effects, synergistic/antagonistic relationships, or on potentially more sensitive life stages. There is only limited understanding of how salinity impinges on ecosystem functioning and associated processes, or how key drivers of ecosystems are affected. Some research suggests that exposure to salinities of between 1000 and 2000 mg/L^{-1} for even short periods is likely to have significant effects on lowland river ecology. In general, current knowledge concerning the effects of increasing salinity on aquatic ecosystems is inadequate to guide decision making.

Research projects on this topic:
~ What happens when you add salt? Davis, page 6
~ Predicting salinity induced loss of aquatic faunal biodiversity. Kefford et al., page 8

Nutrients as contaminants

Increased river nutrient loads do not generally constitute a serious issue for irrigation or drinking water quality. Rather, it is the ecological effects of nutrient enrichment (eutrophication) and associated changes in water chemistry such as oxygen depletion, that are the problems. By stimulating primary production, nutrient enrichment often results in excessive plant growth — sometimes aquatic plant growth, but more commonly excessive algal growth.

Excessive algal growth (e.g. algal blooms), are of concern to water supply authorities because both phytoplankton and attached algae can block filters and delivery equipment, and the high organic load leads to increased water treatment costs. Blooms of many cyanobacterial species are additionally problematic because of the toxins they produce.

To date, much of the Australian eutrophication research on inland river systems has focused on phytoplankton blooms, and understanding the roles of phosphorus supply and flow conditions. This research continues to progress, providing improved understanding of the complex relationship between algal blooms, light, nutrients and flow, identification of river flow management options and reservoir destratification techniques, and improvements in catchment scale techniques for identifying phosphorus sources. Much of this work was carried out in rivers and estuaries as part of the National Eutrophication Management Program.

Information on the way that nutrients are sourced and move in catchment river systems and are transformed by instream biogeochemical processes is accumulating, and the ability to model these processes is improving. Recently, it has been demonstrated that nitrogen is an important nutrient that limits phytoplankton growth in a number of inland waters, and the National River Contaminants Program is investing in key research on nitrogen in both rivers and riparian environments.

Research related to this topic:
~ Avoiding the "fat" of the land — case studies of agricultural nutrient balance. Neville & Weaver, page 10
~ In-stream and riparian zone nitrogen dynamics. Fellows, page 14

Sediment as a contaminant

Sediments are one of the most common river contaminants. Increased input of coarse sediments can degrade river habitats by infilling bed spaces. Widespread sediment deposition can even bury entire riffle-pool morphologies, creating sand slugs that replace diverse river habitats with uniform sand beds and wide shallow flow. Fine sediments that are carried in suspension interfere with the respiration and feeding of many river animals, for example, favouring fish (such as carp) that are not visual feeders.

By increasing turbidity and reducing light penetration, increased loads of suspended sediments may also alter patterns of productivity in river systems. Photosynthesis in submerged plants may be reduced and algal species such as some toxic cyanobacteria may be favoured due to their ability to regulate buoyancy.

Many agrochemicals, heavy metals and nutrients chemically bind to sediments, and managers need to consider both the direct contamination by sediment, as well as the role of sediment in transporting and transforming other contaminants.

Recovery of a large proportion of Australian streams will not occur unless sediment is better managed and sediment transport processes are better understood. The National Land and Water Resources Audit investigated large-scale patterns of sediment transport and the potential affects on river ecology. However catchment and river managers also need tools to predict the hazard of sediment delivery to streams; to identify the major river reaches that are impacted by sediment; and to prioritise where in catchments remediation work will be most effective.

Research related to this topic:
~ Catchment nutrients and sediment budgets: identification of knowledge gaps. Bormans, page 21

Interactions between contaminants

The largest gaps in our understanding of river contaminants are those related to the interactions between contaminants, both in terms of how they interact biologically, physically and chemically in transport or in storage, and in terms of the complex responses of aquatic biota to mixtures of contaminants.

While relatively simple experiments can reveal the tolerances and responses of individual organisms to particular contaminants or even combinations of contaminants, scaling these results up to predict ecosystem level response is extremely difficult. The combination of detailed experimental work with medium scale field testing and large-scale system modelling is likely to be the best way to advance our understanding of these issues.

Research related to this topic
~ Managing wetlands subjected to multiple environmental threats. Boon et al., page 22
~ Integrated impacts of contaminants and flow on riverine ecosystem production. Ryder et al., page 26

~ Developing capacity in catchment contaminant cycle modelling. Newham & Cuddy, page 28
~ Development of risk-based approaches for improved management of contaminants in catchments. Pollino & Hart, page 30

CATCHING UP on contaminants

Summary

The recognition of both the threats that river contaminants pose to sustainability, and our limited knowledge of some river contaminant processes, particularly contaminant interactions and ecological responses, have led to the establishment of the National River Contaminants Program. The program is providing a focus to fund and coordinate river contaminant research with the prime objective of improving the way in which river contaminants are managed, and thus reduce their associated environmental, social and economic costs.
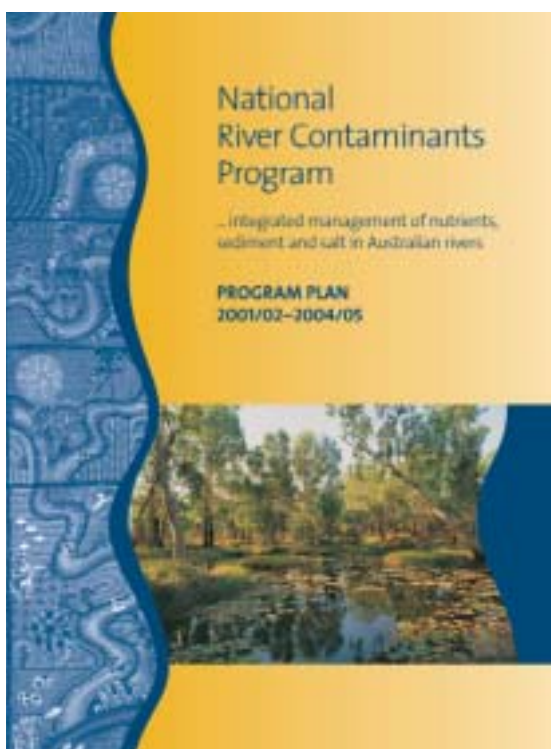
The National River Contaminants Program Plan can be downloaded off the website www.rivers.gov.au or is freely available from CanPrint Communications 1800 776 616

For further information

Brendan Edgar
Program Coordinator
Lamd & Water Australia
Tel: 02 6257 3198
brendan.edgar@lwa.gov.au

David Nicholls
Rivers Program Officer
Murray-Darling Basin Commission
Tel: 02 6279 0511
david.nicholls@mdbc.gov.au

CONTAMINANTS ~ CONTAMINANTS ~ CONTAMINANTS ~

INTERNATIONAL
River Restoration Survey

Have you have ever been involved in river restoration, sustainable river management or similar activities? Why not share your experiences and opinions with the international restoration community? A web based survey has been prepared as part of some background research into uncertainties in river restoration by Joseph Wheaton at the University of Southampton School of Geography. The survey only takes between five and fifteen minutes of your time and results will be made available in spring of 2004. Just follow the link below to take the anonymous survey:

www.geog.soton.ac.uk/users/WheatonJ/RestorationSurvey_Cover.asp

Full details about the survey are provided at the front page of the site. Please respond before 20 December, 2003.

Land & Water Australia
Annual Report 2002–03

The Annual Report gives an overview of Land & Water Australia's research and development achievements during 2002–03. It is available for downloading from the Land & Water Australia website: http://www.lwa.gov.au/downloads/publications_pdf/PR030565.pdf or to order your free copy from CanPrint Communications 1800 776 616, quote product code PR030565.

WHAT H*A*PPENS when you add

By Jenny Davis

The aim of this research project is to apply the *state and transition* models of landscape and vegetation ecology, and the *alternative stable states* model for shallow lakes, to inland rivers and wetlands that are undergoing salinisation. We hope that this approach will enable us to predict the consequences of increasing salinisation on inland aquatic systems, and guide the development of restoration principles and practices for secondary saline ecosystems. The project is collaborative, bringing together researchers from three universities and a state conservation agency.

dominated by submerged macrophytes and charophytes (see Figure 3), and one dominated by benthic microbial communities at higher salinities.

We are now undertaking a field sampling program at seven waterbodies, which includes both primary and saline systems, to determine the influence of seasonal climatic and hydrological changes on the development of these different states. Experimental work is being undertaken to determine the thresholds in salinity, and other factors, which might trigger a change in state.

State and transition model: Usually applied to rangelands or woodlands, where vegetation can exist in multiple states and changes in environmental factors, or management, drive the transition from one state to another.

Alternative stable states: The existence of two or more alternative states over a range of intermediate environmental conditions. The states can arise from positive feedback in a system. A rapid transition may occur between states and represents a non-linear or threshold response to environmental or management factors. The shift in shallow lakes from a clearwater, macrophyte dominated to a turbid, algal dominated state is often considered to be an example of a shift between alternative states.

Hysteresis: a system does not move forwards and backwards along the same path.

Secondary salinisation of rivers, streams and wetlands, often accompanied by altered water regimes and nutrient enrichment, is a major environmental issue in both south-western and south-eastern Australia. The history of secondary salinisation spans 30–50 years in some regions in south-western Australia. Data provided on waterbodies in south-western Australia by Brock and Lane (1983), Davis et al. (1993), Froend and McComb (1990), Halse et al. (1993) and Pinder et al. (2003) has been re-examined with the new objective of determining the presence of alternative states. The most extensive dataset was provided by Pinder et al. (2003) who had undertaken a biodiversity survey of 232 waterbodies in the wheat belt region of south-western Australia (see Figure 1).

From this information, we have developed a preliminary model (see Figure 2) which proposes that wetlands may exist in two alternative states, one with maximum salinities below 70 g/L Total Dissolved Solids (TDS) and

- ■ greater than 30 pptTDS
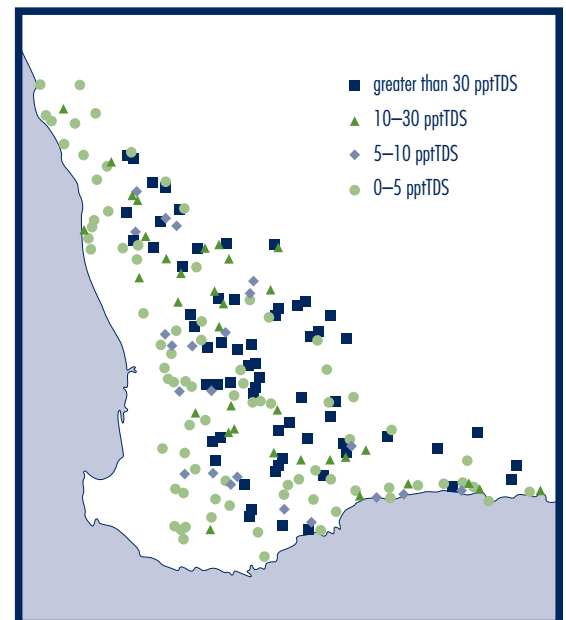- ▲ 10–30 pptTDS
- ◆ 5–10 pptTDS
- ● 0–5 pptTDS

Figure 1: *Salinities of sites surveyed by Pinder et al. (2003) in the wheatbelt region of Western Australia.*
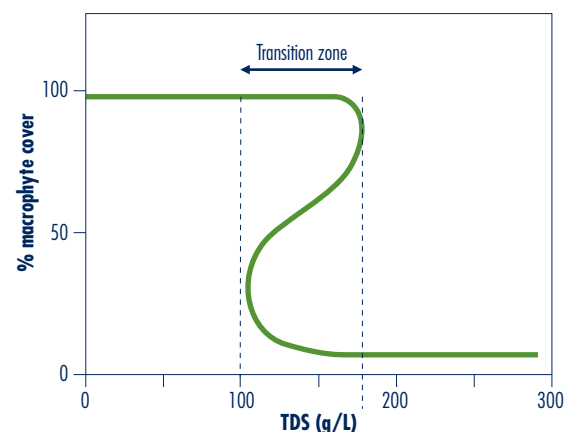

Figure 2: *Proposed alternative states model for saline wetlands in Western Australia.*

salt?

Stands of submerged macrophytes are important, with respect to biodiversity, because they usually support a richer aquatic fauna than benthic mats. However, it must also be noted that primary saline wetlands may naturally support benthic microbial communities throughout much of their drying phase. Naturally saline systems are extremely dynamic and receive episodic pulses of freshwater after major rainfall events. As a consequence they may contain submerged plants for part of a wet-dry cycle and benthic mats for the remainder.

In addition to recognising the presence of different states, we need to determine if hysteresis occurs. While a shift from submerged macrophytes to benthic microbial communities appears to be fairly closely linked to salinities increasing beyond 70 g/L TDS, will a shift from benthic microbial communities back to submerged macrophytes occur if salinities decrease? We also need to determine what role a seasonally fluctuating or episodic water regime plays in the formation of different states?

Information obtained to date suggests that although many waterbodies in south-western WA have increased in salinity, the shift from fresh-water to saline systems does not mean that all ecological values are completely or irretrievably lost. The simplistic, but perhaps widely held view, that saline systems have little ecological value, is clearly wrong. Many saline systems still support a range of plants and animals and maintain a number of valuable ecological processes. For saline systems experiencing less than 70 g/L TDS
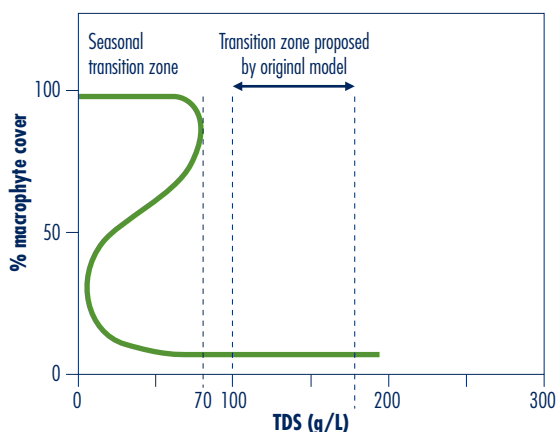
Submerged macrophytes: Aquatic plants growing on the bed, and in the water column, of shallow wetlands, river channels and the littoral regions of lakes.

Benthic microbial communities — comprise mostly blue-green algae but diatoms, unicellular and filamentous green algae and bacteria may also be present. They form mats across the bed of wetlands and salt lakes, and can range from loose aggregations of algae and bacteria, to mucilaginous films to hard, lithified crusts.

maximum salinity, the management goal may be to ensure that they do not move from macrophyte dominance to benthic microbial communities dominance, rather than to return to a freshwater state. In practical terms, it may be much easier to prevent a system from moving to a saline to hypersaline state than it is to return a saline system to a freshwater one. Valuable biodiversity will be maintained and options for future restoration remain. The development of this approach in south-western Australia will have relevance to systems in eastern Australia where there is a shorter history of salinisation, but a similar sense of urgency to deal with the problem.

For further information

Associate Professor
Jenny Davis
School of
Environmental Science
Murdoch University
Tel: 08 9360 2939
Email:
davis@essun1.murdoch.edu.au

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Figure 3: Modified model resulting from the application of the field data.

The simplistic, but perhaps widely held view, that saline systems have little ecological value, is clearly wrong.

PREDI*C*TING salinity induced loss of aquatic faunal

By Ben Kefford,
Dayanthi Nugegoda
and Satish Choy

Salinity levels in many Australian rivers are increasing, and it is likely that this trend will continue over the next 100 years. There are also many management practices that influence the salinity of rivers. With the current lack of knowledge on the impact of increasing salinity on freshwater organisms, it is difficult to manage salinity rises in a way that minimises harm to freshwater biodiversity. Predictions of the effect of rises in salinity on freshwater organisms are, therefore, essential for the management of freshwater biodiversity. Such predictions can be used in conjunction with risk assessments, setting catchment targets and evaluating management options.

There are a very large number of species that inhabit Australian freshwaters, and it is impossible to study all of their salinity tolerances. There are also many attributes of salinity tolerance: lethal tolerance, sub-lethal tolerance (levels of salinity too low to kill but cause other effects such as reduced growth or reproduction) and the tolerance of species at different life stages. Although salinity may not affect some salt tolerant organisms directly, they may still be affected indirectly through salinity effecting their predators, prey or competitors. Additionally, salinity often occurs in conjunction with other changes in the environment, so the effect of salinity may be modified by these other changes. As a result of this complexity, this project is investigating the salinity tolerance of sub-sets of species and evaluating the importance of different effects of salinity on their environment.

We have assessed the relative salinity tolerance of macro-invertebrates (animals without a backbone visible with the naked eye, e.g. insects and snails) from the Barwon River in south-west Victoria. It is not known whether salinity tolerance information from one location will be relevant to other places, so we are also assessing the relative salinity tolerance of a sample of macro-invertebrates from the southern and northern Murray-Darling Basin, as well as from tropical Queensland. By comparing the relative salinity tolerance of macro-invertebrates from these five places, we can assess the degree to which salinity tolerance varies spatially.

Results to date show that two micro-invertebrate (animals without backbone and not visible with the naked eye, e.g. water fleas) species were more salt sensitive than macro-invertebrates. This is important, because micro-invertebrates form a critical part of freshwater food chains and, therefore, if salinity effects micro-invertebrates at low levels there may be indirect effects on macro-invertebrates and fish. To explore this further, we are continuing to examine the salt tolerance of different micro-invertebrates.

We are also extending the work that has been done on the salt tolerance of adult fish, to collect new data on the tolerance of early-life stages where gaps in our knowledge have been identified. We are not investigating all invertebrate species to the same degree. For all, we are considering their short-term lethal tolerance. However, for one sub-set (chosen to represent members from major taxonomic groups) we are

Some of the species being examined in this study (from left): Coenagrionidae, Cura sp., Glyptophysa sp., Austrochiltonia sp. Photos Colin Clay.

THEME   RESEARCH   RAPT IN RIVERS   IT'S A WRAP   INFORMATION

biodiversity

investigating what levels of salinity cause reductions in factors such as growth or reproduction, but which do not kill the organism outright (or sub-lethal tolerance). We will also evaluate the degree to which key water quality variables influence the effect of salinity. This will be done by conducting experiments that vary salinity and other variables in combination.
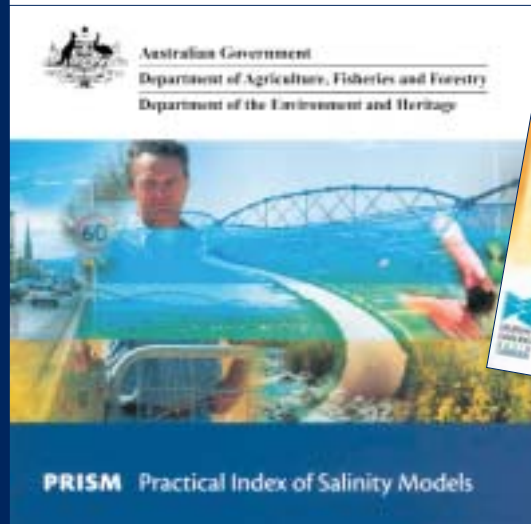
There are many reasons why our laboratory experiments might not represent the real world. Because of this, we are also conducting *in situ* experiments and monitoring natural populations at sites with different salinities to validate our laboratory experiments. We will also construct a model that predicts the effect of salinity changes on freshwater fauna. The predictions of this model will then be tested against macro-invertebrates living along a salinity gradient. If the predictions match the real world, then the model will be of great benefit to the management of freshwater biodiversity against rising salinity levels. If, however, predictions do not correspond well with the real world, we will identify possible reasons for these results and suggest further research to improve the model.

For further information

Ben J. Kefford
Department of Biotechnology and Environmental Biology
RMIT University
Tel: 03 9925 7126
Email: ben.kefford@rmit.edu.au

GROUNDWATER Models:
A community guide to better understanding

PRISM   Practical Index of Salinity Models

This compact handbook is designed specifically for catchment communities and natural resource managers as a guide to understanding and development groundwater models. The handbook is distributed with the **PRISM — Practical Index of Salinity Models** CD that provides information on over 90 tools, models and frameworks that can assist natural resource management planning. The CD has been prepared by the National Dryland Salinity Program and Land & Water Australia for the Department of Agriculture, Fisheries and Forestry and the Department of the Environment and Heritage. Product code EC030616.

Land & Water Australia is also distributing:

Groundwater Flow Systems Framework — Essential Tools for Planning Salinity Management (product code PR030628). This framework interprets the vital relationships between landscapes and groundwater systems leading to dryland salinity, taking into account the different geologies and landforms found throughout the Murray-Darling Basin. The framework assesses the salinity risk faced by catchments, defines how each groundwater flow system is likely to respond to interventions, and designs the most appropriate and cost effective salinity management options. For a copy of the full report contact CanPrint Communications. A Summary Report is also available (product code PK030627).

All these products: CanPrint Communications 1800 776 616

AVOI*D*ING the "fat" of the land:
case studies of agricultural nutrient balance

By Simon Neville
and Dave Weaver

Let's start with a simple analogy: if a person eats more than they need, they gain weight. That is: if our feed inputs (kilojoules in) are greater than our outputs (exercise — kilojoules out) then we will gain weight (kilojoules in storage). That's our fat.

If, on the other hand, our feed inputs are less than our outputs, then we will lose weight. And if our inputs are the same as our outputs, our weight will remain constant.

In general, the further away you are from an 'ideal' weight, the greater the health risks. And yes, other aspects of your body management — smoking, drinking, too many late nights and B grade movies will also impact on your health — but the excess weight is important. It's all about balance.

An agricultural enterprise is very similar: if inputs of feed and fertiliser (nutrient in) exceed the sum of the products sold or exported from the property (nutrients out), then there will be nutrients for storage in the soil or loss. The immediate nutrient losses can cause eutrophication of waterways, and the stored nutrients represent a potential for loss in the future when stored in the soil. So this is the environmental risk — too much "fat" in the agricultural system!

In many agricultural systems a large proportion of the difference between inputs and outputs can be stored in soils. But soils have finite storage capacities, and the remainder will be lost through a range of pathways, including leaching and runoff (phosphorus P and nitrogen N), and through losses to the atmosphere (nitrogen).

A recent set of case studies on the south coast of Western Australia has examined how much nutrient ("fat") is accumulating in three intensive agricultural enterprises. The Nutrient Balance Case Studies were part of a research program conducted in the Watershed Torbay project funded through the National Rivers Consortium. It examined nutrient inputs and outputs in a piggery, a dairy and in an annual horticultural operation. The three case studies are located in the Torbay catchment, on the south coast of Western Australia, 20 kilometres west of Albany. They are all reasonably small, viable enterprises. The piggery has 100 sows, and an additional 80–200 cattle grazed on effluent-watered pasture; the dairy has 200 milking cows, and the horticultural enterprise has 22 hectares of annual crops including cauliflower, broccoli, sweet corn, pumpkins, capsicum and lettuce.

These case studies were carried out largely through a simple survey to collect data on the feed and fertiliser inputs, along with the products sold, with the difference being represented as production and environmental losses (Figure 1 opposite).

Our approach was to multiply the mass of various inputs and outputs by their nutrient content to arrive at yearly quantities of N and P inputs and outputs in a simplified framework for each of the three operations.

The range of possible inputs and outputs for a farm included fertiliser inputs based on fertiliser purchases; non-fertiliser inputs such as feed, animals, nitrogen fixation, rainfall; and nutrient removed off-farm in products, based on sales of product and animals. The difference between inputs and outputs can be considered as the sum of production and environmental losses for that year.

Table 1 (opposite) summarises the inputs and outputs and provides P input : output ratios for the three case studies. The "production and environmental loss rates" shown, are gross loss rates from the production system, and include environmental losses from the farm. A significant amount of the nutrient lost from the businesses will be retained on site for future production use, but this also increases the risk of environmental loss through time.
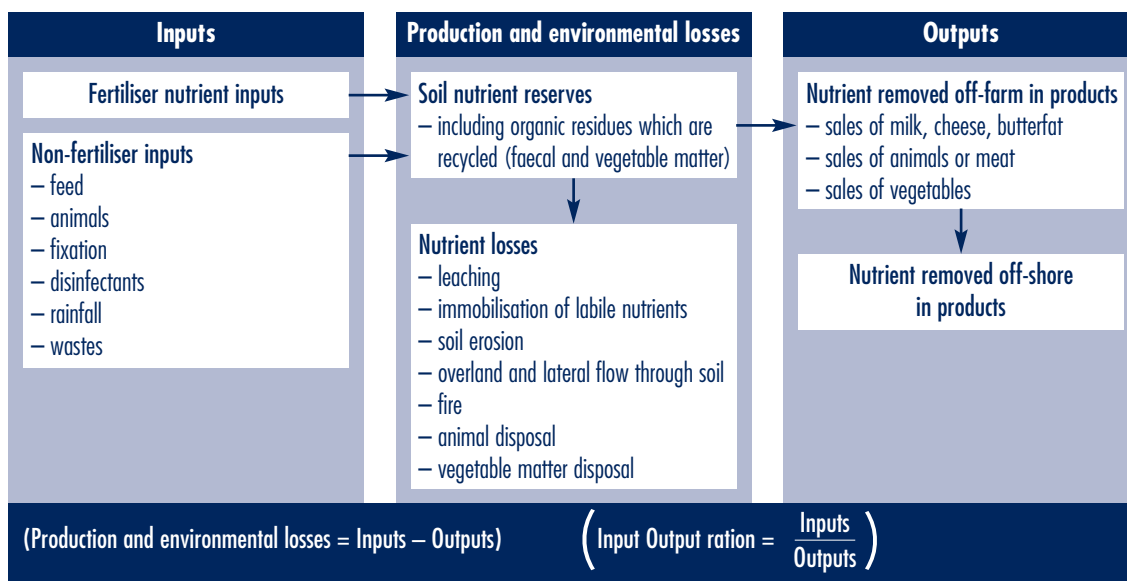
AVOI*l*ING the "fat" of the land

Inputs	Production and environmental losses	Outputs
Fertiliser nutrient inputs	**Soil nutrient reserves** — including organic residues which are recycled (faecal and vegetable matter)	**Nutrient removed off-farm in products** — sales of milk, cheese, butterfat — sales of animals or meat — sales of vegetables
Non-fertiliser inputs — feed — animals — fixation — disinfectants — rainfall — wastes	**Nutrient losses** — leaching — immobilisation of labile nutrients — soil erosion — overland and lateral flow through soil — fire — animal disposal — vegetable matter disposal	**Nutrient removed off-shore in products**

(Production and environmental losses = Inputs – Outputs) $\left(\text{Input Output ration} = \dfrac{\text{Inputs}}{\text{Outputs}}\right)$

Figure 1: Nutrient Balance Framework (adapted from Reuter, 1999)

The higher intensity land uses (piggery and horticulture) clearly show higher production and environmental loss rates per ha; although the loss was highest for the dairy. The piggery input output ratio is appreciably lower, probably as a result of nutrient replacement through the use of effluent as a nutrient source for cattle grazing.

Table 2 (below) summarises the inputs and outputs and provides N input: output ratios for the three case studies. Again, the "production and environmental loss rates" shown, are the loss rates from the production system, and include environmental losses.

These imports and exports are ties to regional and global economies that are necessary to maintain the agricultural, urban and forestry economies of the watershed and to supply the P and N in foodstuffs and consumer products wanted and needed by the human population (modified from Cassell et al. 1998).

A number of questions arise from this study: What opportunities do Best Management Practices (BMPs) provide to address problems of nutrient balance? Where in the nutrient balance framework do BMPs operate? How high are the potential environmental losses from these case studies, and do these potential losses match losses estimated in monitoring and used in recent modelling of the nutrient loss in the region?

This research suggests that intensive land uses have very high production and environmental losses of nutrients. With such large differences between nutrient inputs and outputs, nutrient accumulation in soils with finite capacity would be rapid, and that capacity exhausted quickly in comparison to situations where the differences are small. We were surprised at the large differences between inputs and outputs, especially as none of the operators involved considered themselves to be profligate fertilisers or feeders of stock — far from it!

Table 1: Phosphorus loss rates and ratios	Dairy Kg per ha	Piggery Kg per ha	Horticulture Kg per ha
Fertiliser nutrient inputs	22.6	0.0	64.3
Non-fertiliser nutrient inputs	6.1	81.5	1.7
Total imports	28.7	81.5	65.0
Total exports	5.3	21.9	11.5
Production and environmental losses	23.5	59.6	54.6
Input : output ratio	5.5:1	3.7:1	5.8:1

Table 2: Nitrogen loss rates and ratios	Dairy Kg per ha	Piggery Kg per ha	Horticulture Kg per ha
Fertiliser nutrient inputs	14.5	0.0	266.6
Non-fertiliser nutrient inputs	123.3	409.0	114.1
Total imports	137.8	409.0	380.7
Total exports	27.1	118.5	59.7
Production and environmental losses	110.6	290.5	321.0

According to Koelsch and Franzen (2002):

> "A desirable Phosphorus Input to Managed Output target is 1 to 1. A ratio of less than 1.5 to 1 for phosphorus is likely to be acceptable. If a ratio is greater than 1.5 to 1, you may want to explore options that reduce this imbalance."

Managing nutrient loss

So how can we achieve an acceptable input : output ratio and reduce the rates of nutrient accumulation? And can we conceivably *reduce* current excessive nutrient stores through input:output ratios less than 1? The Nutrient Balance Case Studies project has examined a number of different BMPs and, in particular, what opportunity they offer to address the fundamental problem identified by the nutrient balances: too much input for what we get out.

A subjective assessment of how individual BMPs impact upon nutrient balance in a farming system is shown in Table 2. While it is simplistic, it does illustrate how likely the conventional tools available for nutrient management will impact upon nutrient balance by reducing inputs, increasing outputs or whether they act outside the nutrient balance sphere and simply delay losses.

The selection and prioritisation of management practices needs to consider how the practices address the issue of "nutrient balance". Some actions will delay nutrient loss, or move the problem from one location to another, rather than reducing inputs, increasing outputs or depleting stores of nutrients.

In terms of nutrient balance, effective fertiliser use assists by reducing inputs, through targeting actual nutrient requirements, and timing of application to both avoid direct losses through rainfall and to coincide with periods of greatest plant need. It is the major BMP for reducing nutrient inputs.
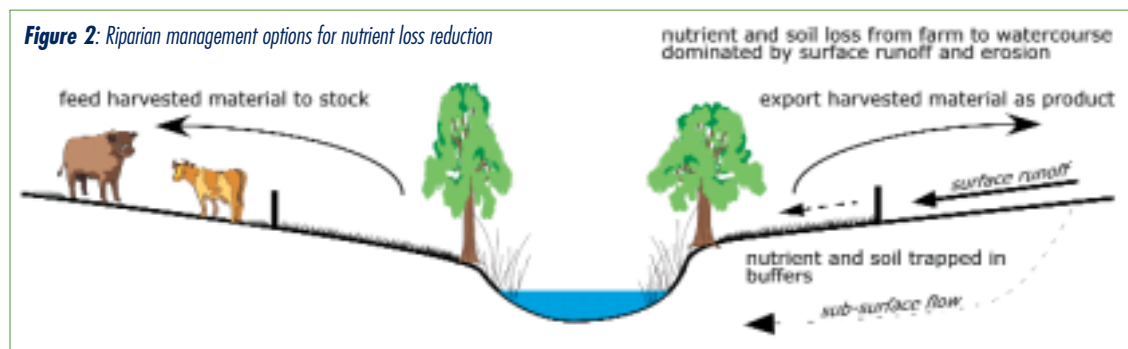
The replacement of annual pasture with perennials will increase utilisation of nutrients, thus improving outputs. Deep-rooted perennials can use water when annual pastures are dead, recover leached nitrate and phosphate, and provide cover to restrict wind and water erosion. Whilst perennials may potentially store more nutrients in biomass, nutrient balance benefits accrue from increased production and increased product outputs.

Riparian fencing and revegetation — which may provide a short term increase in nutrient stored in biomass — and stock exclusion from streams may only delay nutrient delivery, rather

Table 2: Probable BMP effectiveness

BMP	Does it reduce nutrient inputs to enterprise?	Does it increase product outputs from enterprise?	Does it improve the Nutrient Balance in the enterprise?	Does it just delay losses?
Fertiliser management	YES	No	YES	No
Perennial pasture	No	YES	YES	No
Riparian management	No	No	No	Probably
Stock exclusion from waterways	No	Possibly	No	Probably
Harvested buffers	No	YES	YES	No
Fertiliser replacement by irrigated effluent	YES	YES	YES	Possibly

Figure 2: Riparian management options for nutrient loss reduction

feed harvested material to stock

nutrient and soil loss from farm to watercourse dominated by surface runoff and erosion

export harvested material as product

surface runoff

nutrient and soil trapped in buffers

sub-surface flow

AVOI*N*ING the "fat" of the land

than acting specifically on nutrient balance. For riparian management to impact on nutrient balance it will need to consider the harvesting of plant material within the buffer to minimise nutrient accumulation in these areas. This harvested material could then be fed to stock on the farm (improving utilisation), or exported in product. This is shown in Figure 2.

Effluent management and spray irrigation can act as an input replacement, where effluent that would otherwise be lost is used as fertiliser for pasture growth. In the piggery case study for example, no fertiliser was purchased, and cattle were reared on effluent-fertilised pasture. Hence the cattle represented output that would otherwise have been lost from production.

So where to from here?

For sustainable nutrient use in agriculture to be achieved, nutrient inputs should match outputs. We need also to be mindful that the current stores of nutrients are too high, and that matching inputs and outputs under current conditions of high nutrient storage will still lead to problems of nutrient loss. Fundamentally, if we want to reduce nutrient losses to the environment, we need to examine the farming systems and their utilisation of nutrients, rather than simply arresting the loss of nutrients from current systems. We also need to implement management practices that deal directly with the problems relating to nutrient balance and loss, rather than just limiting or delaying them.

For further information

Simon Neville
Ecotones & Associates
Tel: 08 9840 9231
ecotones@westnet.com.au

Dave Weaver
WA Agriculture Department
Tel: 08 9892 8429
dweaver@agric.wa.gov.au

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IN-STREAM and riparian zone nitrogen dynamics

By Christie Fellows

Recent research in Australian waterways highlights the importance of nitrogen as the nutrient limiting primary production in some coastal (e.g. Moreton Bay: Dennison and Abal 1999; Port Phillip Bay: Murray and Parslow 1999) and riverine systems (Mosisch et al. 2001). In systems where nitrogen is the limiting nutrient, an increased delivery of nitrogen is likely to boost algal growth, to the detriment of ecosystem health (Bunn et al. 1999). Increased stream loadings of nitrogen are now recognised as a significant impact of upstream land use in many catchments, both in Australia and overseas. There is growing interest in identifying and quantifying processes which may serve to reduce the delivery of excess nitrogen to surface water and to remove nitrogen that has reached surface water environments.

Nitrogen and carbon cycling are tightly linked in aquatic ecosystems and there are significant gaps in our understanding of the transport, uptake, and transformations of both of these elements, especially in riparian zones. Significantly, there is presently no quantitative information on the relative importance of these processes, and their interactions, in the variety of climatic, hydrologic, and geologic settings typical of Australian catchments. This lack of understanding hinders the development and refinement of both surface water quality models and guidelines for riparian zone and stream management. As part of the National River Contaminants Program, this project will investigate in-stream and riparian zone nitrogen and carbon cycling in three distinct bioregions (southeast Queensland, southwestern Australia and southern Victoria) to address important knowledge gaps and to test current conceptual models of stream and riparian zone functioning.

Research objectives and approach

The overall aim of this project is to increase our understanding of nitrogen and carbon cycling processes in streams and their adjacent riparian zones to enhance our ability to manage these ecosystems. Specific project objectives are:

1. Use existing data and information to refine conceptual models of nitrogen and carbon cycling in streams and their adjacent riparian zones and identify key knowledge gaps.
2. Conduct focused fieldwork to address these gaps and test the conceptual models.
3. Determine the relative importance of riparian versus in-stream nitrogen removal.
4. Provide estimates of riparian and in-stream process rates for catchment water quality models.
5. Enhance guidelines for riparian and stream restoration in terms of nitrogen management.

Three geographic regions were chosen for study because of their contrasting climates and soil types, as well as the fact that conceptual model development could draw on data from past and ongoing research in each of these regions. The members of the research team from each region are: southeast Queensland —Professor Stuart Bunn, Dr Christine Fellows (GU) and Dr Heather Hunter (QNR&M); southwestern Australia — Professor Peter M. Davies and Dr Craig Russel (UWA); and southern Victoria — Professor Barry Hart and Dr Mike Grace (Monash University).

This research focuses primarily on small streams (orders 1–3) because the dynamics of low-order streams are particularly critical to the overall cycling and transport observed at a catchment scale. Small streams are important because most of the stream length in a catchment is in its headwaters (Dunne and Leopold 1978) and the degree of interaction between surface waters and groundwater is greatest here.

Conceptual model development

Our current conceptual models of nitrogen cycling focus on differences in the relative importance of riparian zone and stream channel processes under varying hydrologic conditions, and include the influence of riparian vegetation cover and catchment landuse (Figure 1 opposite). The contrasting environments of southeast Queensland, southwestern Australia,

IN-STREAM and riparian zone nitrogen dynamics

− Well-vegetated riparian zone − High levels of soil organic carbon	− Poorly-vegetated riparian zone − Low levels of soil organic carbon

Wet conditions / High baseflow

− Organic-rich zone saturated
− High rates of nitrate removal in riparian zone
− Riparian zone and in-stream processes important

− No organic-rich zone
− In-stream processes more important than riparian zone processes

Organic carbon rich zone

Water table height

Dry conditions / Low baseflow

− Organic-rich zone dry
− In-stream processes more important than riparian zone processes

− No organic-rich zone
− In-stream processes more important than riparian zone processes
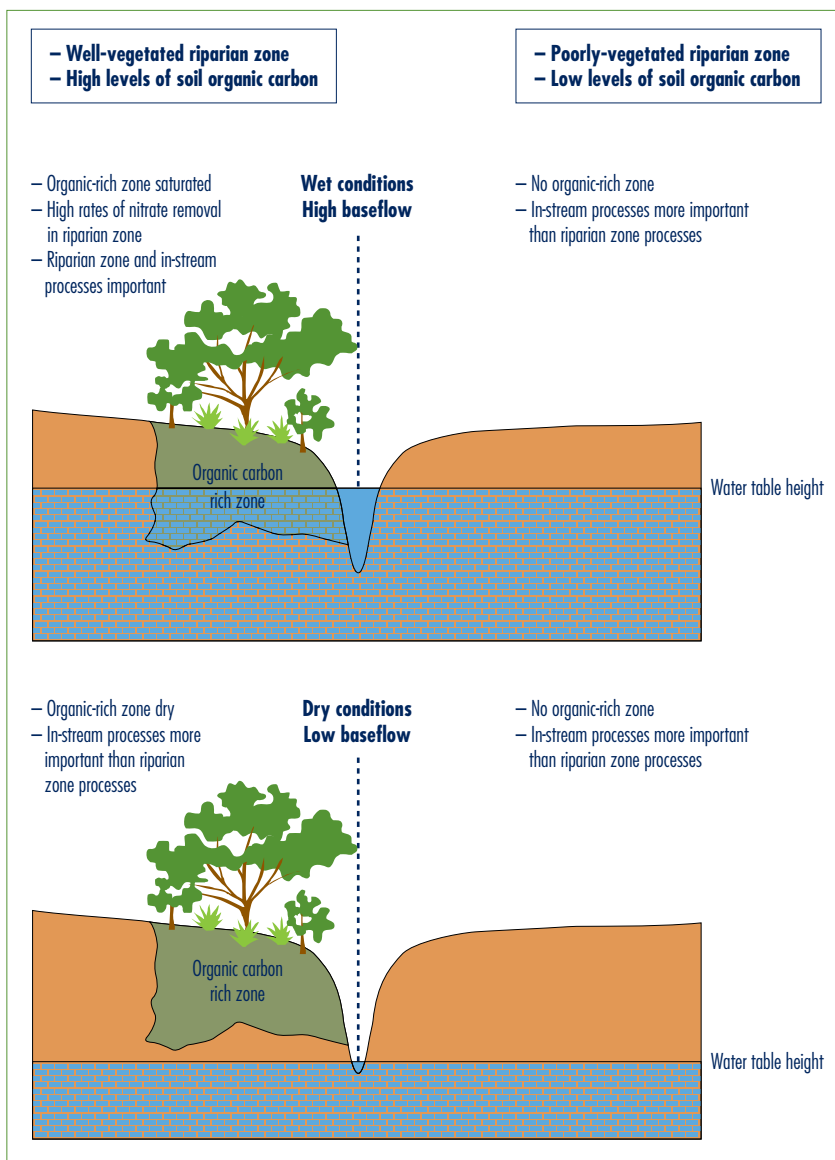
Organic carbon rich zone

Water table height

Figure 1: Excerpt from conceptual models portraying the interactions between hydrology, riparian zone vegetation, and carbon and nitrogen cycling processes in a catchment with high-nitrogen land use and two levels of riparian zone vegetation. Well-vegetated riparian zones typically have higher levels of soil organic carbon. When these areas become saturated, they can support high rates of nitrate removal through the process of denitrification (conversion of nitrate to nitrogen gas).

Filling knowledge gaps and testing conceptual models

Fieldwork at multiple sites in each region will be conducted to test and refine these conceptual models. Sites are being chosen with guidance from local managers, catchment groups, and land holders to encompass a range of catchment nitrogen inputs and riparian zone condition. We are also drawing on existing data by including suitable sites at which we or others have previously conducted research. The four main components of the fieldwork are:

1. Groundwater hydrology and chemistry

One of the primary beneficial roles attributed to riparian buffer zones is removal of pollutants from groundwater en route to surface water bodies. The underlying assumption is that groundwater flows through the riparian zone to the stream, presumably with some component of flow perpendicular to the stream. Near-stream groundwater flow varies greatly across systems, and the direction and magnitude of groundwater flow will determine the potential impact of the riparian zone on surface water. At the chosen study sites, groundwater hydrology and chemistry will be investigated using groundwater wells.

2. Effect of shade on in-stream primary production and nutrient uptake

A conceptual model of how small streams may respond to changes in riparian zone vegetation and catchment land use presented by Bunn et al. (1999) predicts that algal primary production will be low and light limited due to shading by riparian vegetation at minimally disturbed sites. When riparian vegetation is cleared, light availability increases and subsequently, algal production will increase. An increase in production is presumably accompanied by an increase in the rate of nutrient uptake by algae. We will examine the relationship between shade, algal production, and nutrient uptake by making *in situ* measurements across a gradient of riparian shade conditions. Results from this study will provide information about decreases in production and nutrient uptake that might be expected in response to riparian revegetation efforts or other changes in shading.

and southern Victoria are expected to lead to very different surface water and groundwater hydrology and nutrient cycling. For example, soils in the WA study region are predominately duplex soils, in which water moves much more rapidly through the surface soil than the less permeable subsoils. Precipitation moves rapidly to streams through this shallow surface soil, and therefore the potential influence of the riparian zone on subsurface processes may be limited in comparison to southeast Queensland and Victoria, where subsurface water residence times are longer.

3. Rate measurements for key nitrogen cycling processes

Nitrogen cycling in most environments is relatively complex, involving many forms of nitrogen and numerous biological and physical processes. One key nitrogen cycling process that takes place in streams and riparian zones is denitrification, the conversion of nitrate to nitrogen gas. Denitrification is the focus of many riparian buffer studies because it is a pathway for permanent removal of nitrogen from the system. The feature most frequently cited as leading to high rates of denitrification in riparian zones is increased availability of organic carbon due to the presence of riparian vegetation. This organic carbon serves as a potential source of energy for the microbes carrying out denitrification, and so high rates of denitrification are expected to occur where high levels of organic carbon are present. Rates of in-stream and riparian zone denitrification will be measured under contrasting hydrologic conditions (low baseflow/no flow and high baseflow) in each region to determine the importance of this process in mediating downstream nitrogen delivery.

4. Stable isotopes as an integrated signal of nitrogen cycling

Recent research in southeastern Queensland has found that the stable isotope signature of nitrogen in stream organisms and submerged plants is related to catchment land use and nitrogen loading (Udy and Bunn 2001), with more enriched isotope values associated with greater catchment loading rates. This relationship may provide a relatively easy and inexpensive method for assessing nitrogen loading at different places within a catchment. In addition, simultaneously assessing the stable isotope signatures of riparian plants, groundwater and surface water, and aquatic plants may help provide evidence as to what mechanism generates these more enriched values and whether or not groundwater inputs of nitrogen are significant at different sites.

For further information
Christy Fellows
Centre for Riverine Landscapes
Griffith University,
Tel: 07 3875 3840
Email:
c.fellows@griffith.edu.au

Stable isotopes

Isotopes are atoms of the same element that have different numbers of neutrons and, therefore, different atomic masses. For example, a carbon atom has 6 protons and can have 6, 7, or 8 neutrons, resulting in atomic masses of 12, 13 or 14. A carbon atom with 7 neutrons is referred to as carbon-14 or ^{14}C. ^{14}C undergoes radioactive decay to an isotope of nitrogen, and is therefore termed an "unstable" or radiogenic isotope. In contrast, ^{12}C and ^{13}C do not radioactively decay, and are called stable isotopes. In addition to carbon, several other elements that are also important in biological and chemical processes in the environment have more than one stable isotope, including oxygen, hydrogen, sulphur, and nitrogen. The isotopes with lower atomic mass (^{12}C, ^{14}N, ^{16}O, etc.) are much more abundant in the environment than their counterparts with higher atomic mass (^{13}C, ^{15}N, ^{18}O, etc.). The relative amounts of two isotopes of the same element can be measured using a mass spectrometer.

Stable isotope analysis is a tool that can be used to answer many questions in the environmental sciences because concentrations of stable isotopes in a substance reflect the source of the element as well as processes that the element has undergone. In the study of aquatic ecosystems, carbon and nitrogen stable isotopes in animals and their potential food sources have been used to identify foodwebs (what animals are eating). Stable nitrogen isotopes in plants and animals have also been used to trace anthropogenic sources of nitrogen in aquatic systems, such as sewage, which has a higher $^{15}N/^{14}N$ ratio than most natural sources of nitrogen.

$$^{12}C \quad ^{14}N \quad ^{16}O \quad ^{13}C \quad ^{15}N \quad ^{18}O$$

IN-STREAM nitrogen dynamics

Future work

Over the next year and a half, fieldwork will be conducted to test the applicability of our conceptual models. On the basis of our findings, we will refine the conceptual models and assess the implications for stream and riparian management guidelines. Research outputs will include:

1. Refined conceptual models of nitrogen transport and cycling for riparian zone/stream channel environments for three regions of contrasting climate and geomorphic setting.
2. Description of near-stream groundwater hydrology and chemistry for multiple streams in each region.
3. Assessment of the implications of the research findings for riparian zone and stream management/restoration.
4. Quantitative information on riparian zone and in-stream processes for use in the refinement of catchment water quality models.

The overall outcome of this project will be an improved understanding of key ecological and hydrologic links between riparian zones and their associated streams and how these links influence nitrogen and carbon cycling. This information is essential to the ecologically (and economically) sustainable management of these important ecosystems.

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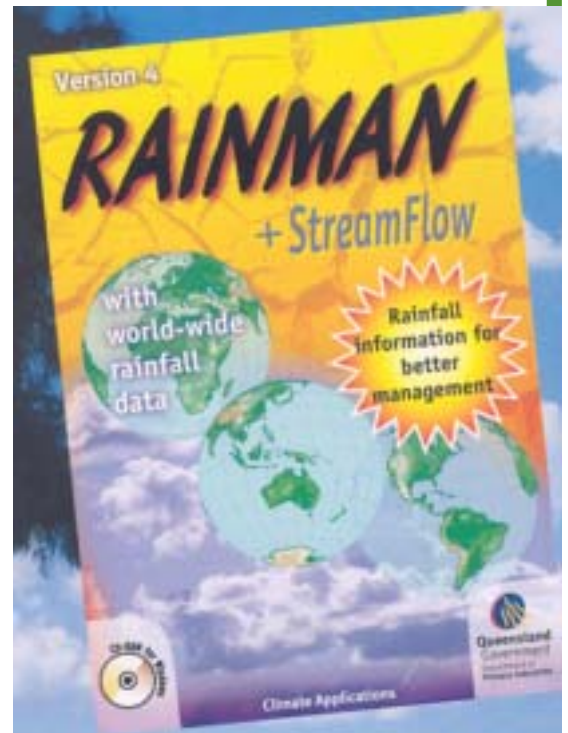
RAP*t* in rivers

WELCOME TO IAN PROSSER

Ian Prosser has joined Land & Water Australia as the manager of the rivers and water R&D programs. He replaces Colin Creighton who is now working on the Healthy Country Flagship Program initiated by CSIRO. Ian has been involved with rivers programs in Land and Water Australia and the National Land & Water Resources Audit for the last nine years. He started by leading the erosion and water quality aspects of the National Riparian Lands R&D Program. A major role followed in the National Land & Water Resources Audit, leading a project on sediment and nutrient transport in catchments with Chris Moran, and one on assessing river condition with Richard Norris. This work has influenced regional management planning for sediment and nutrient control and revealed the catchment scale nature of these problems. Now he has moved from being a research leader at CSIRO Land & Water to managing a broader portfolio of research but with similar goals of promoting research that makes a difference to catchment and river management.

RECLAMATION NATION

A major new collaborative project is aiming to remove some of the barriers to the use of reclaimed effluent water in Australia's horticultural industries. While re-use of water has doubled during the last four years, approximately 86 per cent of Australia's effluent is still sent to waste. Australia's horticultural industries could make use of this resource to substitute for existing sources of irrigation water and also to expand into new production areas where market opportunities exist. In conjunction with Horticulture Australia Limited, CSIRO, the Western Australian Departments of Agriculture and Environment and the Water Corporation, the Victorian Department of Primary Industries, and South Australia's Arris Pty Ltd, the Sustainable Irrigation Program is investing in the three-year, $1 million research project.

Earlier this year, the Sustainable Irrigation Program called for expressions of interest from research providers to undertake priority research and development work. A large number of applications about the use of recycled water were received. By working at the national level the Sustainable Irrigation Program has been able to bring a number of researchers into a single project that crosses state borders, and scientific disciplines. This research will provide benefits to all horticultural industries, including viticulture. The first stage of the two-stage project will gain an understanding of the issues facing horticultural industries for the sustainable use of recycled water, and identify gaps and barriers to implementation. This stage will also identify high priority research to be undertaken in stage 2.

For further information
Tim Lester
Land & Water Australia
Tel: 02 6257 3379
Email: tim.lester@lwa.gov.au

NATIONAL PROGRAM FOR
Sustainable Irrigation

NATIONAL RIVERS CONSORTIUM

Catchment assessment techniques to help determine priorities in river restoration

Focussing on water quality and riparian health, this CSIRO Land & Water project is demonstrating practical methods that can be used to assess where in a particular catchment river restoration works are likely to have the greatest impact on riverine health. Three focus regions have been selected for the project including the Upper Murrumbidgee in NSW, the Goulburn-Broken region in Victoria and the Mt Lofty Ranges region in South Australia. A range of GIS analyses have been undertaken with preliminary results generated. These are currently being evaluated in close consultation with catchment management agencies.

For further information
Scott Wilkinson
CSIRO Land & Water
Tel: 02 6246 5774
Email: scott.wilkinson@csiro.au

Quantifying health of ephemeral rivers

Ephemeral rivers and streams are widespread throughout the inland regions of Australia. There is increasing interest by governments, industry and communities in monitoring changes to the health of ephemeral rivers. However, assessment methods currently used in Australia have largely been developed and evaluated on coastal or permanent streams that carry year round flows. The National Rivers Consortium is funding this joint CRC for Catchment Hydrology and CRC for Freshwater Ecology project to evaluate and compare a range of river health assessment methods for 'ephemeral streams,' defined for the project as "*streams and rivers that cease to flow for some period of time on an annual basis under their natural flow regime. During this period there is also a loss of surface-water connection along at least part of the river channel*". Field trials of indicators and assessment techniques are being undertaken on ephemeral streams within South Australia, as many of South Australia's rivers are ephemeral, carrying significant flow only during the wet season (winter) or during infrequent but intense rainfall events in other seasons.

For further information
Dr Fran Sheldon, CRC for Freshwater Ecology
Tel: 07 3875 3914
Email: F.Sheldon@griffith.edu.au

PROTECTION OF RIVERS, RIVER REACHES AND ESTUARIES OF HIGH CONSERVATION VALUE

With funding provided from the Natural Heritage Trust, this project is seeking to develop broad, Australia-wide support for a coordinated and national approach to protecting and managing rivers, river reaches and estuaries. The project tender was awarded to NSW National Parks and Wildlife Service, leading a diverse team drawn from across Australia. Support for the project has been received by State and Territory agencies and an Australia-wide national forum is proposed in early 2004 to bring together representatives from all the States and Territories and non-government organisations to build consensus and generate a consolidated approach. A final discussion paper will then be prepared that outlines opportunities to build on existing activities to implement a coordinated and Australia-wide approach to protecting and managing key rivers, river reaches and estuaries. This project is part of the National Rivers Consortium.

For further information
Richard Kingsford, NSW National Parks and Wildlife Service
Tel: 02 9585 6488 Email: richard.kingsford@npws.nsw.gov.au

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* Identifying and managing values associated with river landscapes
* Education and change — putting ideas into practice
* River management — grass roots level

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Tuesday 19 October — Registration and Welcome Reception (evening)
Wednesday 20 October — Conference Sessions
Thursday 21 October — Conference Sessions and Field Trips
Friday 22 October — Conference Sessions and Close (mid-afternoon)

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CATCHMENT NUTRIENTS and sediment budgets: Identification of knowledge gaps

By Myriam Bormans

The quantification of suspended sediment sources, transport and deposition through catchments has improved significantly over the last few years with the use of budget models like SedNet (initially developed for the National Land & Water Resources Audit). That approach also identified the erosion processes responsible for sediment generation, whether they be streambank erosion, gully or hillslope erosion. These models have allowed predictions of annual sediment budgets at large scales, but data for verification has been limited.

Nutrient inputs to rivers come from point and diffuse sources. Diffuse sources include soil erosion, drainage of groundwater, wash-off of plant litter and livestock manure. Nutrients can be found — dissolved in the water, attached to suspended sediments, incorporated into biota (i.e. algae, aquatic plants, bacteria) and within bed sediments. Our ability to model nutrient sources, transport and transformations at catchment scale, has been limited to annual loads, smoothing out the shorter time scale variability driving a number of processes affecting ecological responses. Even at these longer time scales, nutrient predictions are even more poorly constrained than sediment loads.

Catchment scale nutrient budgets that assess the variation in the sources and pool sizes along the river network and under different flow conditions were identified as a research priority in order to predict the ecological consequences of varying the supply of nutrients to river systems.

This project is determining the dominant processes of nutrient transformations under different flow conditions by:

~ concentrating on catchments with sufficient measurements to derive budgets from actual data across a range of flows;

~ assessing the extent of denitrification within the river channel versus the riparian zone (in the Brisbane and Johnstone catchments);

~ determining how the ratio between phosphorus dissolved in water and attached to suspended sediment varies between catchments; and

~ including nutrient uptake by algae and aquatic plants.

These analyses will provide the necessary parameterisation of mathematical formulae to calculate nutrient transformations within catchments that are required to assess the ecological impact of current and future land management, and to underpin the development of predictive models.

For further information

Myriam Bormans
CSIRO Land & Water
Tel: 02 6246 5610
Email: Myriam.Bormans@csiro.au

MAN*A*GING wetlands subjected

By Paul Boon, Paul Bailey and Elisa Raulings

Wetlands are often the terminal water body in an aquatic system. They are located at the ends of rivers (e.g. many coastal wetlands on riverine deltas) or in floodplain depressions, where they form after a river experiences overbank flows during large floods. Some other wetlands — called lacustrine wetlands — are associated with shallow fringes of lakes, whilst others are associated with the banks of rivers and streams, and are known as riparian wetlands. In all cases, the wetlands are situated in depositional environments, meaning that they tend to accumulate material brought into them with floodwaters or flows into the lake or stream.

The materials wetlands accumulate are often associated with pollutants, such as nutrients, pesticides and heavy metals. Because they commonly experience wet and dry cycles, wetlands are also highly susceptible to salinisation, with salt coming into the wetland during the wet phase and being concentrated as the wetland dries out, sometimes to lethal amounts. Many coastal wetlands are situated on acid-sulfate soils, which release large amounts of sulphuric acid as they dry. This acid can poison estuaries and destroy coastal fisheries. Almost all wetlands in Australia have had their natural water regime interfered with as a result of abstraction for irrigation or urban use, being used for storm or floodwater retention, or having artificially high levels for aesthetic benefits and recreational opportunities.

In terms of management, those responsible usually have access to detailed wetland inventories, good information on the natural assets of the key wetlands (e.g. plant and animal species present, water quality data, etc), and an appreciation of threatening processes that affect these natural assets (e.g. salinisation, inappropriate water regimes). However, what they do not have is knowledge about the condition of the wetland and its ability to withstand environmental stress. This means that little is known about whether a wetland can support organisms and perform key ecological processes. Knowing the condition of the wetland would help managers understand whether or not management actions are effective in maintaining or improving wetland condition.

Another problem is that most research on wetland ecology has addressed the impact of threatening processes in isolation, yet in nature, wetlands are subjected to a multitude of threats over a wide range of spatial and temporal scales. This project addresses this shortcoming by examining how a high-value wetland responds to *multiple* environmental threats, and how natural resource managers can best manage these wetlands in a sustainable way.

Determining wetland condition and the impact of threatening processes on condition is limited by the absence of 'condition indicators' (see Figure 1). Development of appropriate condition indicators at multiple scales will help managers understand the condition of their wetland, and how threatening processes adversely affect wetland condition. Once condition indicators have been developed, managers can establish benchmarks and set realistic objectives based on condition. A key output of our project will be the development and trialling of general indicator tools that can be used in wetlands across the continent.

A key output of our project will be the development and trialling of general indicator tools that can be used in wetlands across the continent.
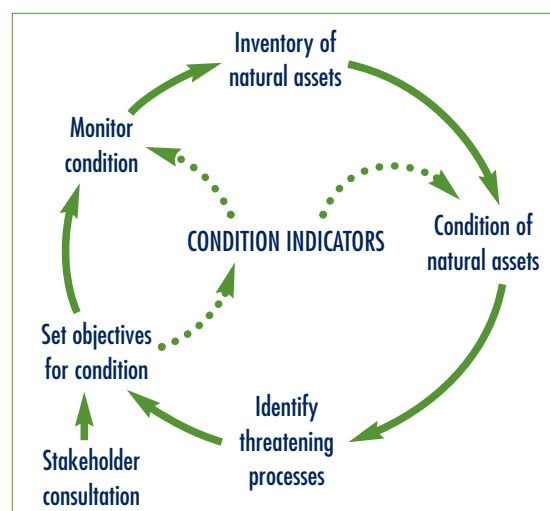
to multiple environmental threats

Project detail

The wetland system we are studying is situated on the south-western shore of Lake Wellington, on the Gippsland Lakes in eastern Victoria. The Gippsland Lakes are listed under the Ramsar Convention, and occupy an area of over 60,000 hectares. They comprise a number of State Game Reserves, Crown Land Reserves, a Coastal Park and a National Park. The area is heavily used for tourism and recreation — with 11% of the local population employed in tourism, twice the statewide average. The wetlands are largely brackish coastal swamps, dominated by Swamp Paperbark (*Melaleuca ericifolia*). Almost all of these wetlands have highly modified water regimes, having been artificially flooded or drained for much of the past two to three decades. Salinity is also rising, due mainly to the opening of the entrance to the sea at Lakes Entrance in the late 19th century, and also reduced flows down the rivers that flow into the Lakes systems. The reduced flows are primarily a result of abstraction for irrigated pasture. The underlying sediments are also potentially acid-sulfate soils. Carp have been present since at least the 1960s.

These threatening processes have degraded the Swamp Paperbark communities in the fringing wetlands of the Gippsland Lakes. The photos on this and the following page illustrate a typical scene showing the death of the paperbarks and their possible replacement by less desirable species such as reeds. As such, this wetland typifies the state of most similar coastal wetlands throughout Australia.

Our project has three main aims:

1. To determine how the condition of the wetlands changes in response to key environmental threats in isolation, and in combination with each other.
2. To determine the best way to rehabilitate wetlands, especially in terms of restoring healthy vegetation communities.
3. To assess the value of the wetlands to local communities, their conservation status and the best way in which they can be sustainably managed and improved.

Dowd Morass, one of the key wetlands of the Gippsland Lakes, is subject to several threatening processes, including an altered water regime, salt water intrusion, low pH and the presence of carp. These threats have reduced the ecological condition of Dowd Morass. We have started experiments to artificially drain a large area (~300 hectares) of this wetland over the forthcoming summer, in order to monitor the effect of a return to a more natural water regime on the condition of the wetland. Field-based methods, including vegetation transects and bird counts, will be complemented with remote sensing data, including aerial photographs and satellite imagery. We have used field-based methods to identify condition indicators, and have completed a condition assessment of Dowd Morass under permanently flooded conditions using these indicators. The indicators we have identified include the cover, health and regeneration of the dominant species, and the type and number of species in the understorey. These generic condition indicators may be transferable for use in other wetlands dominated by woody species, including Swamp Paperbark.

While the wetland is being drained, we will undertake glasshouse and pond experiments to determine the optimal salt and water regime for ecologically significant water plants to recruit, both from seed and as clonal reproduction. We have also undertaken a number of meetings with key stakeholder community groups, including hunting organisations and conservation bodies.

MAN∕GING wetlands subjected to environmental threats

For further information

Paul Boon
Sustainability Group
Victoria University
Tel: 03 9365 2210
Email: paul.boon@vu.edu.au

or

Paul Bailey
School of Biological Sciences
Monash University
Tel: 03 9905 1422
Email:
paul.bailey@sci.monash.edu.au

An interesting finding from these studies is that the community values their wetlands highly, and that they have observed a slow deterioration in wetland health. They believe many factors are responsible for this deterioration, but these do not necessarily correlate well with scientific and community assessment of threatened processes. The discrepancy between the scientific and community assessment of wetlands is a topic we will continue to investigate over the coming months. The community is participating in the research project, assisting with water quality monitoring, bird counts, repairs to the levees that allow us to selectivity drain the wetlands, and watching out for vandalism on our sites.

At the end of the project, we will have determined how multiple environmental factors interact to degrade high-value wetlands and how such sites can be rehabilitated. We will have a robust data set behind our work that will allow us to quantify what approaches worked and what ones did not. The research is being undertaken in close collaboration with community groups and with key management agencies, including the West Gippsland Catchment Management Authority, Department of Primary Industries, Department of Sustainability and Environment, and the Gippsland Coastal Board.

At the end of the project, we will have determined how multiple environmental factors interact to degrade high-value wetlands and how such sites can be rehabilitated.

NEW
RIPARIAN MANAGEMENT GUIDELINE
for the cotton industry

The Cotton Research and Development Corporation, CRC for Cotton, Land & Water Australia and cotton growers have worked together to produce a new riparian management guideline for the cotton industry. The guideline covers a range of topics, with case studies demonstrating how the management practices recommended in the guideline can be applied on farm. For your free copy of the guideline either contact the CRDC or CanPrint Communications.

Cotton Research and Development Corporation
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Managing riparian lands in the cotton industry

Rivers Arena

Linking science with practice to produce useful management tools
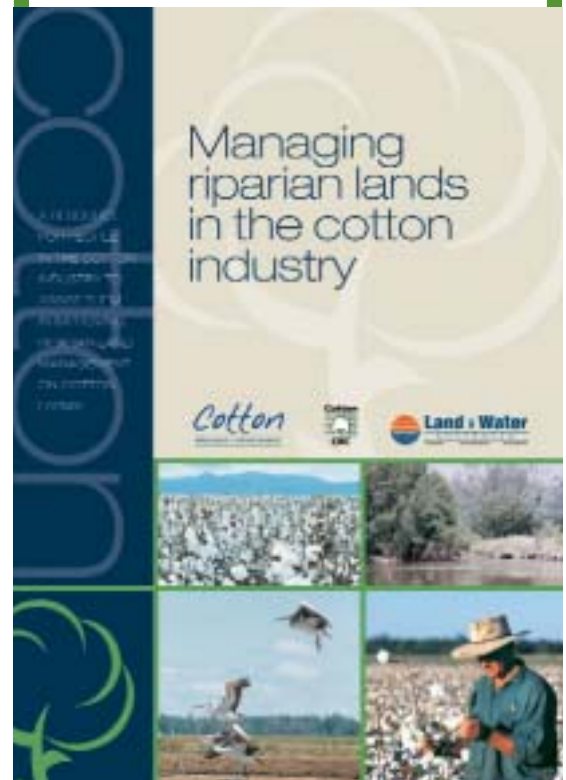
Land & Water Australia's Rivers Arena is committed to producing information that assists groups and individuals to better manage rivers and riparian areas. Our products are based on scientific research and practical experience to ensure that the information we provide is relevant, accessible and able to be implemented 'on-the ground' and 'in-the river'.

Fact Sheets

These Fact Sheets are grouped according to whether they deal with riparian land, in-stream issues, river contaminants or other management issues. They aim to set out the general principles and practices for sound management of rivers and riparian lands.

Guidelines and Manuals

These guidelines and manuals are aimed at a more technical audience and provide detailed information about the science underpinning recommended best practice in river and riparian management. They have become central reference documents for most catchment management organisations in Australia, as well as providing up to date river and riparian science for researchers working in the area.

Industry Specific Guidelines

These guidelines provide different commodity based industries with river and riparian management information specific to their needs. Two guidelines — 'Managing riparian lands in the sugar industry' and 'Managing riparian lands in the cotton industry' have already been produced. We are now working with the wool industry to develop guidelines that match science with experience to produce useful management approaches that integrate river and riparian management into farming systems.

RipRap

Each edition of *RipRap* focuses on a river and riparian management theme. In case you have forgotten what we have covered, here they are: Edition **10**: Streambank stability, **11**: Riparian zones: what are they?, **12**: Managing the riparian zone within a total farm system, **13**: Benefiting from overseas knowledge and experience, **14**: Managing and rehabilitating riparian vegetation, **15**: Seeing is believing: the value of demonstration sites, **16**: Managing snags and Large Woody Debris, **17**: Monitoring and evaluation ★, **18**: Inland rivers and riparian zones ★, **19**: River and riparian habitat for fish ★, **20:** River contaminants ★, **21**: What are ecosystem services? ★, **22**: Riparian research ★, **23**: Managing riparian land to achieve multiple objectives ★, **24**: Building capacity for river and riparian restoration ★

★ indicates back issues available in hard copy.

All these products are available (mostly free) from CanPrint Communications on 1800 776 616
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INTEGRATED IMPACTS
of contaminants and flow

By Darren Ryder, Sue
Vink and Rob Cawley

Environmental flows are assuming a central role in the management of many Australian rivers to ensure a sustainable resource both for the environment and water users. These flows are intended to mimic the natural flow regimes and habitats that existed before the damming of many rivers and, consequently, promote the return of natural habitat conditions. However, this approach is confounded because of the assumption that reinstating natural flow regimes alone will restore river health. The reality is that catchment degradation and altered flow regimes have resulted in many Australian rivers containing highly modified sources and concentrations of contaminants such as nutrients, salts and sediments, all of which can have individual and synergistic effects on river ecosystems. Just how these contaminants influence fundamental processes in rivers, such as the cycling of energy and nutrients critical to the functioning of floodplain rivers, are poorly understood.

Nutrients such as nitrogen (N), phosphorus (P), and carbon (C), can play an integral role in regulating rates of primary production in floodplain rivers. However, these nutrients can originate from diffuse sources such as catchment and riparian runoff, and are often accompanied by increased amounts of suspended sediment and salts.

Unravelling the interactions between flow, contaminants and energy cycles in regulated floodplain rivers is the central task of a joint project between researchers at the University of New England, CSIRO Land and Water, and the NSW Department of Infrastructure, Planning, and Natural Resources. Understanding ecosystem level processes such as primary production and food web structure, and their integrated response to present day contaminant and flow regimes is critical for the management of regulated floodplain rivers to sustain processes vital to improve river health.

This new research project is based in the highly regulated Murrumbidgee and Macquarie Rivers in NSW. It centres on the construction of contaminant budgets for the large-scale reaches (>100 kilometres) by high frequency observations of water column inorganic and organic C, N, P, suspended solids and salts, as well as measuring ecosystem productivity at a whole of river, reach and site scale.

Both ecosystem production and contaminant transformation will take place through organisms fixed in space such as biofilms (slime attached to logs, rocks, and sediment), and by water column primary producers such as algae which are transported with flow. This approach allows us to sample the same 'parcel' of water as it passes a series of sites along the river. In combination with field and laboratory experiments, this will allow an understanding of the interplay between flow, contaminants, and primary production, and how these relationships vary along the length of the river and with season.

Biofilms (attached slime containing algae and bacteria) on snags are an important site for the transformation of many riverine contaminants.

on riverine ecosystem production

Chambers used to measure the production and consumption of nutrients and energy in riverine systems.

Whole of river and reach scale productivity and respiration will be determined using measurements of diurnal changes in water column dissolved oxygen, pH and alkalinity. At the site scale, productivity within three major compartments (water column, sediment, and biofilms attached to logs and rocks) will be measured as the change in oxygen production or consumption within sealed chambers. Fully automated, recirculating chambers have been developed that alleviate many of the problems associated with chamber studies of metabolism in running waters. The chambers vent at regular intervals to prevent deoxygenation, provide variable flow rates across biofilm surfaces to mimic *in situ* velocities, and float at set depths to avoid problems associated with changing water levels.

Preliminary results from the Murrumbidgee River indicate that at the reach scale, ecosystem production can vary in response to the supply of available nutrients. However at the site scale, productivity appears to be regulated primarily by local flow regime and the suspended sediment load, and dominated by biofilms attached to woody debris. Similar measurements from the Macquarie River and its tributaries with substantially higher concentrations of salts will help tease apart the role of individual contaminants on ecosystem production.

Outcomes from this project will contribute to improved policy formulation and the better on-ground management of rivers by developing:
~ simple, effective and robust techniques for the monitoring and evaluation of ecosystem productivity,
~ protocols for integrated ecosystem management of rivers, and
~ conceptual and quantitative models of the interactions between flow, diffuse natural contaminants and ecosystem processes.

For further information

Darren Ryder
Ecosystem Management
University of New England
Tel: 02 6773 5226
Email: dryder2@pobox.une.edu.au

DEVELO*p*ING CAPA*C*ITY
in catchment

By Lachlan Newham
and Susan Cuddy

The ability to describe and explore the relationships between management activities and land and water conditions, is critical to maintaining and restoring the ecological health of stream and catchment systems. In this context, land and water managers are increasing their reliance on tools such as computer models to support their decision making. Accordingly, for the management of river contaminants, appropriately constructed models are needed to assist end-users identify sources, pathways, interactions and impacts of contaminants through a catchment landscape and its waterways.

The ambitious goal of this project is the development of a contaminant cycle model that is readily accessible to, and understandable by, people working in large river catchments. The model will be used to estimate fluxes and impacts of a range of contaminants including nutrients, sediment and salt, under various management and climate change scenarios. This next generation model is a collaborative venture between CSIRO Land and Water, the Integrated Catchment Assessment Management Centre of the Australian National University and the Cooperative Research Centre for Catchment Hydrology. The breadth of collaboration reflects a commitment by researchers to focus Australian contaminant modelling on a smaller set of approaches to maximise resources, minimise duplication and reduce confusion amongst end-users.

The involvement of end-users in the model development process is the key to its success and adoption. Close interaction with policy makers, analysts and catchment managers is required to establish how and when they use such models, and what features support and/or inhibit their use. Consultation is a feature of this project and strong links with end-users have been established and will continue to be supported, to ensure that their needs are met and confidence is built in the model.

The project will also serve to integrate knowledge generated from several other National River Contaminant Program projects. Collaborative arrangements have been established with researchers from the following projects:

~ In-stream and riparian zone nitrogen dynamics (Fellows, page 14);
~ Catchments, nutrients and sediment budgets: identification of knowledge gaps (Bormans, page 21);
~ Development of risk-based approaches for managing contaminants in catchments (Pollino & Hart, page 30); and
~ Rivers, nutrients, ecological processes, storage reservoirs/dams, adoption/changed practice (Ryder et al., page 26).

These projects will contribute to improved representation of contaminant processes in the model.

The development of the contaminant cycle model is supported by experience and ongoing research activities in each of the organisations that are contributing to the project — in the development and application of the Environmental Management Support System at CSIRO Land and Water, the development and application of the Catchment Scale Management of Diffuse Sources modelling system at ANU and the development of the Catchment Modelling Toolkit at the Cooperative Research Centre for Catchment Hydrology.

Contaminant modelling survey

A survey of model users, exploring issues associated with development, needs and use of contaminant cycle models, has just been completed. We asked:
~ how models are used by decision makers;
~ which pollutants should be modelled;
~ which types of management interventions should be investigated;
~ which ecological and habitat value indicators are of interest; and
~ how results should be communicated.

The online survey was very successful in reaching a wide range (250 responses) of interested parties, including managers / policy developers (37%), researchers (36%) and consultants, community representatives and teachers. Preliminary analysis show that the primary interest in the use of contaminant cycle models

contaminant cycle modelling

is for water quality improvement. Pollutants identified as 'very important' are suspended sediment (47%), salt (44%) and phosphorus (43%). Measures of total nitrogen, pesticides and pathogens are also highly ranked. Land use change, riparian zone management and flow management emerged as the most important management interventions for inclusion in the contaminant cycle model. Ecological indicators that ranked most highly were macro-invertebrate populations and floodplain/riparian condition.

Respondents showed a strong preference for model results to be expressed in lumped measures such as total annual loads, with maps as the preferred means of communicating results.

A full description of the survey is available in a CSIRO Technical Report titled 'Contaminant Cycle Modelling — an analysis of end-user needs' scheduled for publication at the end of December.

Contaminant modelling requirements

As a complementary exercise to the survey, we have undertaken a review of the strengths and limitations of some existing models, applicable in the Australian context — the Environmental Management Support System (EMSS), the Local Scale Environmental Management Support System (LEMSS) and the Catchment Scale Management of Diffuse Source (CatchMODS) modelling system (Newham et al.). This review has identified the following as core requirements for contaminant cycle models:

~ an ability to identify critical source areas that currently, or potentially, contribute high loads of contaminants to streams;
~ the potential to simulate the impact of future land and in-stream management practices and sensitivity to climate variability;
~ modest and readily available input data requirements;
~ an ability to be comprehensively tested;
~ possessing of strong visualisation capabilities and short model processing times to enable results to be effectively communicated to users; and

~ an ability to incorporate qualitative models to assess the response of aquatic ecosystems to changing contaminant loads.

Future contaminant cycle model

Already, we can describe some of the fundamental structure of the next generation contaminant cycle model. It will be a scenario-based tool to enable users to investigate the effects of management change, including but not limited to land use change, flow regulation, point source loading and riparian zone management, on contaminant loads and contaminant impacts. A node-link structure will be used to represent the spatial structure of streams and catchments systems and the contaminant cycle processes occurring in them. The model will operate at daily time intervals to enable the incorporation of qualitative ecological response models.

To support model development and adoption, prototypes will be built for the Murrumbidgee and Brisbane Rivers catchments. This provides a vital two-way link with end-users to ensure that model structure and formulation is easy to use and adapt for application in new catchments.

Timeframe

Full technical specifications and a prototype of the model will be prepared by the end of May 2004. Preliminary model results for the case study catchments will be available by November 2004 and a revised version of the model, incorporating input from end-users and review by technical specialists, will be available in May 2005. The project runs to August 2005.

Reference

Newham, L.T.H., Cuddy, S.M., Vertessy, R.A. & Jakeman, A.J. (submitted), Determining future directions in contaminant cycle modelling through an valuation of existing modelling systems, International Conference on Water and Environment WE-2003, Bhopal, India, 15–18 December 2003, CSIR, India.

Project website:

http://www.clw.csiro.au/research/catchment/contaminant_cycle/

For further information

Lachlan Newham
Australian National University
Tel: 02 6125 8129
Email:
lachlan.newham@anu.edu.au

DEVELO*p*MENT OF risk-based approaches management of contaminants in

By Carmel A. Pollino
and Barry T. Hart

Contaminants in our waterways threaten not only the consumptive and commercial users of water resources, but also their ecological health. Contaminants in riverine systems also pose a threat to downstream receiving waters, particularly estuarine and coastal areas. Contaminants of concern in our waterways include biocides, heavy metals, nutrients, suspended particulate matter and salinity.

The growing awareness of the importance in protecting and restoring catchments has led to a demand for better tools to assist managing our river systems. Riverine environments can be contaminated from a multitude of sources, but despite this, the majority of approaches used by natural resource managers tend to examine individual contaminants in isolation. These tools rarely link physical and chemical characteristics of a catchment to ecological endpoints.

In reality, environmental stressors rarely occur in isolation. The many activities in catchments, as a result of both urban and rural usage, often result in highly altered systems. Currently, there are few available tools that take a holistic approach to catchment management, limiting their potential to inform management actions. To address this gap, tools that examine multiple stressors and the resultant effects on biota within a catchment context, is seen as a research priority. The aim of this project is to develop risk-based assessment guidelines to assist natural resource managers in assessing aquatic assets at risk from degradation, and to identify options to manage these risks. This new risk-based decision support tool will focus on improving management of diffuse contaminants to minimise adverse ecological effects.

What is a risk-based approach?

Risk-based approaches focus on quantifying the relationships between causes and effects. They seek to account for the inherent complexity and variability within natural systems, and incorporate uncertainties associated with our knowledge of relationships. The outputs are quantitative predictive models that can be used to inform management actions. The advantages of using a risk-based approach are that the process encourages stakeholder involvement, is rigorous and scientific, and is a transparent natural resources management decision making process. Risk-based approaches in natural resources management have the potential to assist managers in incorporating ecological criteria in decision-making and can assist in developing ways for achieving sustainability of catchment water resources and the protection of riverine environments.

Development of risk-based assessment guidelines

To facilitate the adoption of risk-based approaches in natural resources management, guidelines are required to assist managers to undertake risk-based assessments. Guidelines will:

~ assist in the identification of stressors or threats to biota in catchments;
~ assist in the development of qualitative conceptual models; and,
~ focus on the scientific/technical aspects of how best to develop quantitative predictive models linking stressors or threats from contaminants with specific ecological effects.

So that they can be directly applied, the quantitative predictive models will link catchment contaminant reduction targets (e.g. end-of-valley targets for nutrients, salinity, suspended particulate matter, pesticides) with the ecological benefits in receiving waterbodies. These models will be important for predicting the magnitude of ecological effects under a range of possible management scenarios, thus enabling managers to prioritise risks and manage accordingly. The project will also address the need for increasing the capacity for natural resources management to undertake risk-based approaches.

for improved catchments

Guideline development will be informed by a series of case studies. We are currently working with the:
~ Goulburn-Broken catchment, focusing on the conditions resulting in the fish kill in Broken Creek;
~ Brisbane River catchment, focusing on nutrients and suspended particulate matter and related ecological effects; and the,
~ Murrumbidgee catchment, in association with CRC for Catchment Hydrology, linking existing physical models with ecological endpoints.

The final risk-based guidelines will facilitate the:
~ development of qualitative and quantitative models (cause and effect models);
~ prioritisation of ecological risks from multiple contaminants in a catchment context (i.e. multiple-stressors resulting in multiple issues);
~ prioritisation of management options for managing ecological risks;
~ catchment management decision-making process;
~ identification of research gaps; and,
~ improvements in the direction of research and monitoring efforts.

The project team is a collaborative effort between Monash University, University of Melbourne and CSIRO.

For further information

Barry Hart
Water Studies Centre
Monash University
Tel: 03 9905 4070
Email: Barry.Hart@sci.monash.edu.au

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Rivers Arena

Research Reports

These reports focus on key river and riparian management topics, and are generally produced as outputs from research projects as well as workshops and conferences. Some of the topics covered to date include: inland river management, legislative approaches to river management, assessing the ecological value of rivers and building capacity for riparian restoration.

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RÍPRaP

RIVER AND RIPARIAN LANDS MANAGEMENT NEWSLETTER

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Jennifer Bruce
Publications Officer
Land & Water Australia
GPO Box 2182
Canberra ACT 2601
Tel: 02 6257 3379
Fax: 02 6257 3420
Email: subscribe@lwa.gov.au

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