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WaterShed

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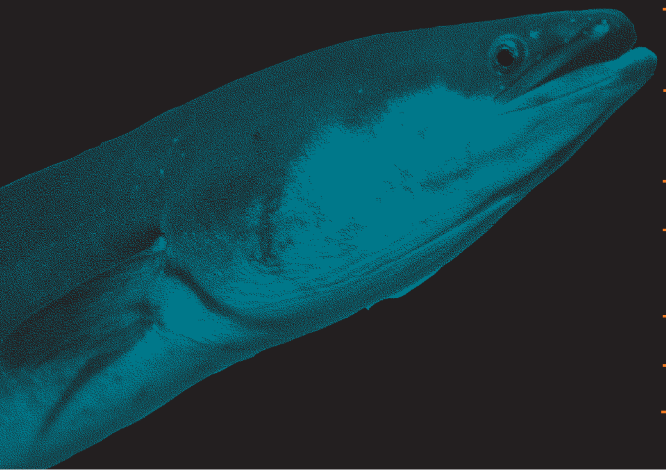

The role of science and innovation in Australia's water policy reform

by Professor Gary Jones

Future decisions on water will be based on the best available scientific and socio-economic information, assessed through open review processes...Smart and innovative solutions to provide more water to the environment and to minimise the impacts on entitlement holders will be emblematic of our new approach. (The Hon. Craig Knowles MP, NSW Minister for Infrastructure and Planning, and Natural Resources, June 2004)

The Government's task is to build strategically on the individual knowledge bases generated by the [catchment management] authorities, through supporting research that lays a comprehensive knowledge platform to support the sustainable management of our water into the future. (Victorian White Paper, *Our water, Our future*, June 2004)

This agreement identifies a number of areas where there are significant knowledge and capacity building needs for its on-going implementation. (COAG Intergovernmental Agreement on a National Water Initiative, June 2004)

June was certainly an eventful month in Australian water resources management. The collective powers of COAG reached an agreement on the National Water Initiative (NWI); the Victorian Premier, Steve Bracks, and the Minister for Water, John Thwaites, released their long awaited White Paper, *Our water, Our future*; and NSW Minister for Infrastructure and Planning, and Natural Resources, Craig Knowles, released his vision for securing NSW's sustainable water future.

It seems that the majority of people in and around the water industry, myself included, have had a positive response to the NWI agreement. As in all things policy, the devil will be in the implementation detail. We also have yet to arrive at a truly national approach that recognises the water issues current throughout Australia, including Western Australia and Tasmania. Nevertheless, there is reason to be optimistic that Australia has set itself on the path to water sustainability.

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The Cooperative Research Centre for Freshwater Ecology develops ecological understanding to improve and protect Australia's inland waters.

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The states are now faced with the challenges and difficulties of implementing their own policy visions and ensuring that they align with the spirit and word of the NWI. Clearly this is no easy task. It is one thing to agree that water access and property rights will be codified and legislated as a key first step. But, arriving at a practical and legally robust system of title definition, and a system for registering titles which will protect all interests, as well as withstanding the tests of time and legal challenge, is something that will keep our best minds busy for some time yet. And we can be sure that the banks and other financial institutions are keeping a very close eye on proceedings!

Similarly, we have agreed on a free market for water-trading. Yet there are many social and environmental issues that must be given a full and complete airing before the water market can be considered 'free'. There are those who fear the rise of 'water barons' who will profit from the water market without using water in a productive manner. And there is no doubt that large cities will give serious thought to entering the market to obtain irrigation water for use in the suburbs. Adelaide has already had a go at this, and Canberra is considering bidding for Snowy-Mountains water currently stored for Murrumbidgee irrigators, as one of three options for sustaining Canberra's long-term water supply needs.

It also seems to be widely assumed that water trading will be either good for the environment or, at worst, benign. I am not so sanguine on this issue and have already raised the matter with the government in the CRCFE's submission to the NWI earlier this year. We need to ensure that a sound set of ecological principles is used to guide smart water trading. Economists may be right in claiming that without water trading we cannot achieve the environmental flows that are needed, but we don't want to end up saying, as a great surgeon once proclaimed ... 'the operation was a success but sorry to say the patient died!' (more on this topic in the next *Watershed*).

There is plenty of pressure on irrigators to use water more efficiently, but city dwellers rightly are also required to deliver significant water-use savings under the NWI. While they may have done so more or less gladly throughout the drought, whether they will continue to embrace such strategies in the long term, as lawns stay brown and gardens are without their owners' favourite water-thirsty exotic blooms, is a vexed question. In its White Paper the Victorian Government has floated the idea of permanent 'level 1' restrictions. These include only night-time garden-watering, bans on hosing pavements, trigger guns for garden hoses, and controls on the filling of swimming pools. Other governments — local and state — are considering similar measures.

Professor Gary Jones, Chief Executive of the CRC for Freshwater Ecology. Photo: L Sealie

What of the role of environmental and social scientists in all these water-reform processes? My analysis of the various water-policy documents rolling around the country suggests a clear need for scientific knowledge to guide and inform:

- system-level frameworks for sustainable water allocation
- an ecologically relevant definition of 'stressed-' and 'over-allocated' rivers (rather than a definition based solely on water resources management as is currently applied)
- sustainable water trading — maximising economic outcomes without damaging communities and the environment
- conjunctive management of surface water and groundwater, and protection of groundwater-dependent ecosystems
- scientifically sound and cost-effective protocols for the monitoring and assessment of (i) environmental condition and (ii) the performance of environmental flows management and other river restoration activities
- understanding and management of future risks to water sustainability arising from, among other things, changes to climate and land use,
- a systems approach to technological innovation in:
  - water-use efficiency (everyone has their favourite 'fix', but how does an investor or planning authority decide on the most suitable option, and how are individual technologies best brought together to provide the most efficient and cost-effective system, whether urban, rural, or on-farm?)
  - smart environmental infrastructure and monitoring technologies (e.g. carp traps, fishways that work, remote sensor webs)
  - decision-support systems for river, groundwater and floodplain operations and management
- training and support for future agency- and community-based water managers (for example, 'establishing a capable manager of the environmental water reserve' — Victorian White Paper).

How we go about doing research, and how we deliver the new knowledge to those who need it, are just as important, maybe more so, than the topic we agree to work on. And, before starting any new research project, we must be certain about our 'social licence to operate'. Have we talked to those people who may be affected by our research findings? Have we sought their advice and local knowledge? Have we started by building a basis for mutual respect and trust, and for productive future discussions as the research findings emerge?

In summary, have we agreed on the fundamentals for developing 'bona fide improvements in the knowledge of water systems', as required under the NWI?

As for how we deliver the new knowledge that emerges from science research, there is no 'one size fits all' approach. Some research knowledge is best developed and exchanged through one-to-one partnerships between scientists and regional stakeholders. In other situations, knowledge may be efficiently delivered to a broader 'market' when packaged in a form that can be seamlessly integrated into a user's business operating system. Examples might be software models for operating rivers, or decision systems for guiding water allocation and restoration investments (this is the approach being taken by the proposed eWater CRC that I wrote of in the last *Watershed*).

We also have a responsibility to help private-sector companies analyse and manage risks to their businesses as a consequence of water-market reform, and also seek new business opportunities.

Perhaps NSW Minister Craig Knowles's statement best points to the enormity of the intellectual and practical challenges that we face:

> *In short, our reforms will ensure the means for establishing healthy catchments, for stimulating competitive, high value and efficient agricultural industries, and for maintaining economic and social well being in our regional communities and townships.*

The big question for science-based organisations such as the CRC for Freshwater Ecology (and, we hope, a new eWater CRC) is ... are we up to the challenge?! I know that for us the answer is a resounding 'yes'. I will be doing my utmost to make sure we all work as smartly and transparently as possible to provide our investors — including the Australian public — with the return on their investment in scientific and socio-economic research that they have the right to expect.

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The creature feature for this issue is the short-finned eel (*Anguilla australis* Richardson).

Family: Anguillidae
Species: *Anguilla australis* Richardson

Short-finned eels (*Anguilla australis* Richardson) are born deep in the Coral Sea. From here the larvae drift to coastal areas of eastern Australia before metamorphosing into elvers which migrate upriver during October–January. These eels can get around weirs and waterfalls by moving overland across wet surfaces, absorbing atmospheric oxygen through their skin while out of water. Adult short-finned eels prefer still water, but live in a wide variety of habitats including rivers, lakes, wetlands and swamps, from south-eastern South Australia to south-eastern Queensland and in lowland Tasmania and islands of the Bass Strait. They burrow into soft sediment when water temperatures are below about 10°C. Prey includes fish, crustaceans, aquatic insects and molluscs. Short-finned eels maintain home ranges about 400 m long until they reach sexual maturity when they stop feeding and migrate downstream and back to the Coral Sea to spawn and die.

Short-finned eel (Anguilla australis *Richardson).*
Photo: MDBC

Adult females are around 90 cm long and live for 18–24 years; adult males are only around 50 cm in length and live for around 14 years.

World experience focuses on streams suffering 'urban syndrome'

Urban streams across the world are apparently in remarkably similar condition. At an international symposium on urbanization and stream ecology held in Melbourne last December, it was evident that many urban streams are contaminated and ecologically below par.

The Symposium on Urbanization and Stream Ecology (SUSE), organised by representatives of the CRCs for Freshwater Ecology (CRCFE) and Catchment Hydrology (CRCCH) and Melbourne Water, attracted researchers and managers who work on urban freshwaters in ten countries, both developed and developing, temperate and arid. Invited guest speakers — Dr Peter Groffman (Institute of Ecosystem Studies, NY), Professor Nancy Grimm (Arizona State University), Associate Professor Derek Booth (University of Washington, Seattle), Professor Judy Meyer (University of Georgia) and Dr Cathy Tate (US Geological Survey, Colorado) — presented new research from across the USA and facilitated discussions.

'Urban syndrome' is the term the symposium delegates adopted to describe the changes that can be expected in streams as their catchments are taken over for urban land-use. Four broad, interrelated forms of disturbance affect streams in urban areas. Generally, there are changes to (i) volumes of flow and flow regimes, (ii) the shape of the channel and the stability of the banks, (iii) the water quality, and (iv) the habitat features that make streams suitable for flora and fauna life-cycles and for ecological processes such as energy transfer and nutrient cycling. These types of disturbance can also be found in rural streams, but urban development brings some special stresses to urban streams, particularly with the discharge of runoff via stormwater systems (see 'Let's cure urban syndrome', below).

Traditionally, oily water and contaminants drain off roads and into stormwater pipes that carry them directly to urban creeks. Photo: Chris Walsh.

For many city- and townspeople the local stream is a social asset important for recreation and aesthetics. For that reason there are often calls to rehabilitate urban streams.

Despite many streams suffering similar forms of disturbance (see box), it was evident at the symposium that aquatic animals (e.g. fish and macroinvertebrates such as water bugs) and plants (such as algae) can be affected differently in different regions. That is, the degree of urban syndrome can vary from stream to stream, even before rehabilitation.

There are numerous possible reasons for the variations, and while some are well recognised, such as differences of:

- geography;
- climate, including patterns of rainfall and runoff;
- soil type and geology;
- changes that have already taken place in response to earlier land-use;
- species and their sensitivities to environmental change;
- local ecology;
- type of drainage infrastructure carrying urban wastewater to the stream;
- type of sewerage or septic tank development;
- the nature of riparian zones, whether wide or narrow, wild or mown;
- the part of the catchment that is urbanized, whether upland or lowland;

there is less clarity about the role of other factors, for example:

- socio-economic cycles and community willingness to pay for new urban infrastructure, and
- global differences in economic development (for many countries, the emphasis is on the protection of public health rather than stream health).

'Rehabilitation' can have several meanings, including improving amenity, and/or water quality and ecological function. It does not necessarily imply returning the stream to a fully natural condition, though that may be possible in some cases. Rehabilitation can involve such actions as undoing structural changes to channels, replanting riverbank vegetation, trapping rubbish before it reaches the stream, and not using the urban stream for carrying wastewater.

The form of rehabilitation adopted will be governed by the values assigned to streams by stakeholders. For example, the general public may place high value on a stream having clean water, good access and amenity, and an aesthetically pleasing landscape, though rehabilitation to meet these values will not necessarily improve in-stream ecology and ecological function. It is important to have clear statements of the values to be enhanced or protected, when formulating rehabilitation objectives. And we should not expect to use the same rehabilitation methods for old urban areas and new developments.

Stormwater pipes and concrete-lined drain leading directly to a stream, Belconnen, Canberra. Photo: B Rennie.

The researchers at the symposium workshops described some of the key lessons learnt while implementing projects in urban areas.

- Urban streams can be subject to numerous, and interacting, sources of stress. Unravelling cause and effect among multiple stress factors and ecological responses is likely to be very difficult.
- Multi-disciplinary discussions are essential when forming and refining a conceptual model of stream ecology and condition, and for deciding on the objectives for rehabilitation. Such discussions can also help define reference conditions (that is, standards against which to measure improvement). And they can identify indicators for use in assessing whether rehabilitation has been successful.
- Where possible, indicators of urban impacts need to be logically linked to factors under management control (such as wastewater treatment measures, road density, number of urban drains entering the steams).

Managers and planners can be confident that it is now possible to protect the ecological condition of at least some urban streams, funds permitting. It remains important to be aware of scale in rehabilitation. For example, development in an upstream part of a catchment can upset or reverse the gains made from downstream rehabilitation efforts in a sub-catchment.

One important task is to assess the ecosystem values provided by urban streams so that we can analyse costs and benefits of various rehabilitation approaches. Another important task is to determine how stream condition is related to urban growth and infrastructure (such as stormwater channels) and socio-economic cycles, so that planners can manage the accumulated impacts of small developments at a catchment scale. Decision support systems such as MUSIC (developed by CRCCH) are tools that can predict the likely consequences of management actions. Biological information provided by CRCFE is being included in MUSIC so that the ecological consequences of urban development can be considered.

The world's population is expected to increase from 6.1 billion to 8.1 billion over the next 25 years, and the extra 2 billion people are most likely to live in the urban areas of each country, increasing the stress on urban drains and streams. We need to address urban syndrome now to minimise problems in the future.

Typical symptoms of the urban syndrome in streams

Flow

- More stormwater runoff (total volume)
- Less low flow volume (e.g. intermittent flow in previously permanent streams) in temperate and tropical areas,
  or more low-flow volume (e.g. permanent flow in previously intermittent streams) in arid areas
- More frequent and larger peak flows
- Shorter flow events
- Less groundwater recharge and lower water-tables
- More variable water velocity, much increased following storms

Channel form

- Faster channel erosion (and sediment transport, depending on the age of catchment development)
- Simplified channel form

Water quality

- Larger loads of contaminants (e.g. nutrients, carbon, sediment, heavy metals, pesticides)
- Poorer water quality (e.g. increased contaminant concentration, altered pH and temperature)

Ecology

- Less frequent connection between the stream channel and associated floodplain and wetland systems
- Simplified habitats
- Less diverse plant and animal communities
- Decreased nutrient retention and altered patterns of nutrient and energy cycling
- Altered ratio between production and respiration
- Reduced connection between the stream and its streambank or nearby landscape

Biodiversity

- Decreased biodiversity values (at genetic, species and community levels)

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Further reading:

Cottingham, P., Walsh, C., Rooney, G. and Fletcher, T. (2004) Urbanization impacts on stream ecology — from syndrome to cure.
See http://freshwater.canberra.edu.au > publications > technical reports.

Let's cure urban syndrome

Restoring in-stream habitat alone may not be enough to bring an urban stream back to good ecological condition. In the mid-1990s, a CRCFE experiment set out to test if the common management practice of building artificial rock riffles in urban streams resulted in any ecological improvement. Reaches of the streams had been straightened, causing streamflow to deepen them, removing areas of shallow stony bed (riffles). Three reaches were given graded-rock riffles, three were given large rock riffles and three reaches were left as they were. Macroinvertebrates were netted and counted within, upstream and downstream of the sites twice before and twice (at seven and nine months) after riffle placement. No change was found in the macroinvertebrate communities then, or since. The species present continue to consist mainly of pollution-tolerant groups typical of contaminated urban streams. In other words, the streams' poor ecological condition was not the result of the in-stream changes that had originally taken place, but was being caused by something else.

This finding encouraged the CRCFE's Chris Walsh and coworkers to search for the real factors behind poor ecological condition in urban streams ('urban syndrome'). They postulated that contaminants in the stream catchments were causing the degradation when they were washed into the stream during rain and storms.

As Walsh and his team reported at the Symposium on Urbanization and Stream Ecology, streams that drain from urbanized areas of the Dandenong ranges, on the urban–rural edge of Melbourne, have altered ecological function, more filamentous algae and fewer sensitive macroinvertebrates than streams that drain nearby rural areas.

Indicators the team found (and other symposium delegates have found) useful for demonstrating the in-stream effects of increasing urban development include:

- water quality (concentrations of phosphorus, nitrogen and organic carbon, and electrical conducitivity);
- algae on the stream-bed (species and biomass);
- ratio between photosynthesis and respiration in the water;
- assemblages of macroinvertebrates;
  and, in eastern Melbourne,
- populations of the endangered Dandenong amphipod (*Austrogammarus australis*).

Nitrogen and nitrogen oxides concentrations in Melbourne streams were not so much related to degree of urban development as to numbers of septic tanks per hectare, though the mass of nitrogen delivered over a year *was* related to the degree of urban development.

The team wanted to identify one or more measures of urban density that would consistently explain the urban syndrome. Studies elsewhere have focused on the proportion of waterproof (or impervious) urban surfaces (such as roofs, roads and carparks) relative to earthen or grassed areas per hectare; and they have obtained varying degrees of correlation between those proportions and the expressions of urban syndrome in local streams. Therefore Walsh and his team homed in on the impervious urban surfaces that drain into a pipe or concrete-lined channel which leads directly to a stream. They reasoned that contaminants washed off in rainwater from such 'well-connected' impervious surfaces would have much more effect on streams than the same contaminants on other impervious urban surfaces where rainwater runs off onto earthen or grassed areas and soaks in before reaching the urban stream.

Their reasoning paid off. The team found that the degree to which an urban area is drained by stormwater pipes explained much of the variation in ecological condition that was not explained by measures of urban density alone.

The upshot is that effective imperviousness (EI: the proportion of a catchment covered by impervious surfaces with direct connection to the stream) is generally well correlated with stream condition, and certainly better correlated than total imperviousness.

As a result of this very exciting finding there is a good chance that the ecology of streams in urban areas can be rehabilitated, or not damaged in the first place. Town planners can now choose to improve the ecological condition of urban streams, in new developments for example, by not designing large impervious areas with 'well-connected' drainage systems, and instead allowing as much rainfall as possible to evaporate or be trapped and absorbed into the ground where it falls. The result would be much less frequent inputs of stormwater into the streams. Stormwater-pollution-control ponds and wetlands can also be incorporated into the design of urban sub-catchments to intercept those contaminants that do run off, before they reach local streams.

effective imperviousness is generally well correlated with stream condition – better than total imperviousness

At suburban scale, rainwater tanks, paving stones set in sand not cement, 'rain gardens' that catch the rain from downpipes on buildings, gravel-lined or vegetated swales, and commercially available porous paving are some of the methods that can be used to prevent urban rainfall from draining directly and frequently into streams.

The team has built a computer simulation model that shows it is possible to redesign the drainage of a typical suburban catchment so its stormwater runoff has minimal impact on local streams. In the model, much of the rain is allowed to soak in, near where it hits the ground. The next step is to test this model design in a controlled experiment in a pair of real urban sub-catchments, and measure the effects on a range of in-stream ecological indicators.

The CRCFE team:

Chris Walsh, working with Mike Grace, Belinda Hatt, Sally Taylor, Pua Tai Sim, Peter Newall, Simon C. Roberts (all of Monash University or EPA Victoria and CRCFE) and coworkers from CRCCH, Monash University.

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Rapidly assessing thousands of kilometres of river condition across Australia

by Richard Norris and Ann Milligan

When the first National Land and Water Resources Audit called for a report on the ecological condition of Australia's rivers — all of them — to be delivered in a year, it was clearly going to be a big challenge. The situation sounds a bit like the old German fairy tales in which young people were ordered variously to spin piles of straw into gold thread, or collect thousands of tiny objects, by dawn.

In those tales, the task was completed on time, but only because of generous and spontaneous help from others (such as Rumpelstiltskin and ants). In a similar way, a team assembled by the CRC for Freshwater Ecology with CSIRO Land and Water was able to meet the challenge because of pre-existing data contributed, in willing collaboration, by water management agencies in all states and territories of Australia.

As the second National Land and Water Resources Audit gathers momentum, it is timely to reflect on this achievement in 2000–2001 during the first Audit. The comprehensive Assessment of River Condition (ARC) was called for so that the information could guide management decisions at national scale. The ARC provided information vital for devising policies such as the National Action Plan for Salinity and Water Quality and the National Water Initiative.

This first national ARC gave an overview. It identified stretches of Australia's rivers that were functioning well and those that appeared to be declining. It avoided homing in on individual areas of salinity, over-allocation of water, non-point source pollution, erosion and sedimentation.

In a few words ...

The results, which were comprehensive, are only outlined here in passing. The full story is in Norris *et al*. 2001.

In 31% of the total river length assessed, there were only 50–80% of the various expected groups of water bugs. In 2% of the river length assessed, almost three-quarters of the expected water-bug inhabitants were no longer present. This assessment could have been more damning if it had not been made relative to reference sites that had already changed markedly from natural, as a result of human activities, particularly in the lowland rivers of the Murray-Darling Basin and Western Australia

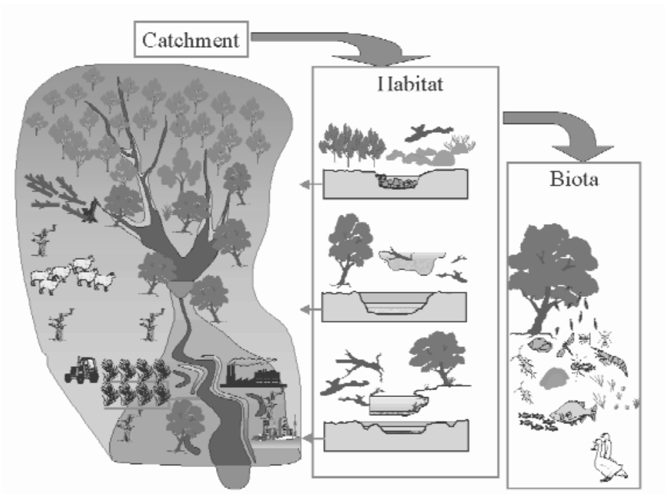
Unsurprisingly, most of the river length in basins containing intensive agriculture was rated as being modified or disturbed, on the basis of catchment land-use, and nutrients and suspended sediment in the water, and because riverbank vegetation had been removed. Even rivers in national parks were disturbed, being affected by damming, flow modification, grazing, mining and resort developments. In more than half the river length assessed, the streambeds were affected by sedimentation and the riverbank vegetation had been cleared.

About one tenth of the total river length in the assessment area was regulated or confined by dams or levees. Data were available for only about half of that regulated length. On the basis of that sample the biggest effects of regulation were in altering flood frequency and maximum and minimum river heights.

So how was this comprehensive assessment done?

Conceptual approach

The team took an ecological view that the biota and their environment together represent the ecological condition, and devised ways of measuring both. The freshwater biota is considered the most important indicator of river condition, because the species have to deal with flow and water quality and have a place to live (habitat) if they are to survive. But monitoring biota alone cannot show *why* it is improving or declining. And unless all river biota is monitored continuously, an assessment will miss seeing some types of disturbance. For example, the chosen group of organisms may not react to a particular stressor, or there may be a time lag between environmental disturbance and biotic response. Therefore, to be a good guide for management decisions, a comprehensive assessment must also collect information about the biota's environment. This conclusion was represented in a conceptual model. The baselines or 'reference conditions' for the ARC consisted of a combination of data from minimally disturbed sites, historical data, modelling of past conditions and professional judgement.

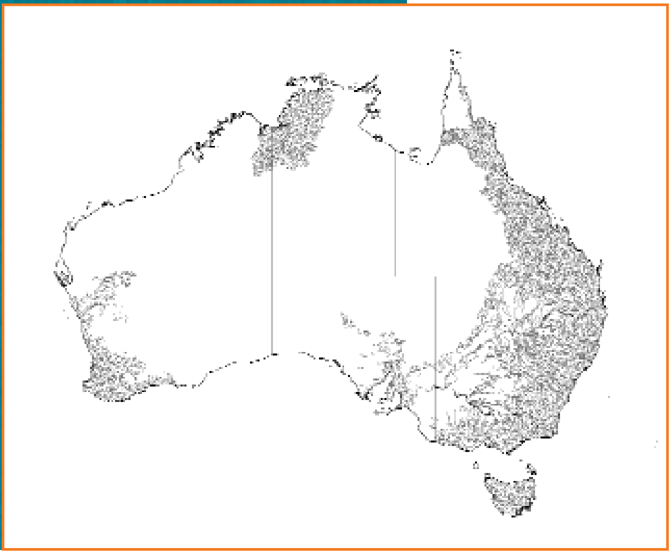


Conceptual model of factors related to river condition, including connectivity (affected by dams and levees), land-use, habitat features (riverbank vegetation, snags, channel form), and biota (vegetation, insects, fish, waterbirds)
Diagram: ARC team

Reaches

The next step was to make the task manageable. There were 193 river basins to be assessed in 3.3 million square kilometres of intensive land-use across most of the four eastern states and small areas of South Australia, Western Australia and the Northern Territory (see map). That is over 209,000 km of rivers: short; long; running from uplands to lowlands; in climates ranging from temperate to tropical; and in catchments varying from urban to outback. A base unit of river was needed so that widely different types of river could be treated comparably and used in the calculations.

The team decided to subdivide each river into 'reaches', on paper, as the base units. A reach was defined as the stretch of river between tributary junctions, and each reach had relatively uniform physical character and slope. Headwater reaches were grouped so they related to at least a 50 km^2 catchment area. Interactions between reaches and reservoirs or lakes were taken into account. Then, via a national digital elevation model of topography, the team identified the characteristics of the land draining to each reach and therefore the contribution of each of the environmental measures to individual reaches and their biota.



River reaches in the area assessed.
Map: ARC team

Deriving indices from data

The main task was to decide on measures and use them to derive indices (summary numbers that could guide policy makers) and report the outcomes. All indices were calculated at the scale of the river reach.

The data used in this study, contributed by Australian state and territory agencies, described sections of river, entire rivers, or an entire state. The data-sets used were those that had been collected by methods that were consistent across the whole study area.

Working within the framework of their conceptual model of river function, the ARC team focused on five components that reveal human effects on the ecology of rivers:

- catchment condition, habitat condition, hydrological condition, and water quality and suspended sediment load, representing the environment (ARC_E), and
- biological condition (ARC_B).

The ARC produced indices representing these five components. Together they provided a picture of river condition as well as information about possible sources of disturbance.

— Biota index (ARC_B)

Data describing water bugs (invertebrate insect larvae, crustaceans, molluscs) were converted into a biota index to represent biological condition. Data for fish, water plants, algae, and riverbank vegetation would have been ideal, but in practice they were not extensive or consistent enough to be used. Assessments were based on AUSRIVAS models, which take the number of families of invertebrates found at a site and compare it with the number that could be expected to live there if it were in 'reference condition'. (AUSRIVAS = Australian River Assessment System.)

Data (and associated information about the environment at each site) had been collected at about 6000 sites during the First National Assessment of River Health, but they did not cover all the reaches defined for the ARC. Therefore, predictive modelling had to be used to generate modelled 'observed' values and expected values for the unsampled sites. (For details see Norris *et al.* 2001.)

— Overall environment index (ARC_E)

An overall index of environmental condition was generated by combining four sub-indices describing catchment disturbance, habitat, hydrological disturbance, and nutrient and suspended sediment load.

The *catchment disturbance index* was a measure of the effects of land-use, change in vegetation cover, and infrastructure such as roads and railways, on water quality and physical habitat (such as deep pools, or crannies between stream-bed cobbles). The land-use categories were weighted differently to account for their different impacts, and then added together.

The *habitat index* was built up from estimates and measures of (a) the sediment moving down a stream, (b) the condition of riverbank vegetation, and (c) the barriers to movement along or out of the river (dams, weirs, levee banks). Sediment movement was estimated based on information about bank erosion and gully erosion upstream. It was assumed that any accumulation of sand and gravel on the streambed would have a negative effect on physical habitat. National data for vegetation cover provided information about the vegetation on the riverbanks: cover ranged from complete to zero. Upstream–downstream 'connectivity' (freedom of movement) is important for the migration and breeding of many fish species, and it was calculated from the nearness and size of in-stream barriers such as dams or weirs. A section of river with a major barrier was assessed as disturbed, and the effects of barriers decreased with distance.

Connectivity with the floodplain (capacity to move out of the channel) is important during flooding. It was calculated from the length of the levees in each reach sub-catchment and the length of the reach. Where the total levees were twice the length of the reach, it was assumed that they confined the reach on both sides.

The *hydrological disturbance index* recognised the importance of the streamflow regime to aquatic ecosystem function, and focused on four aspects of it:

- changes in total annual flow volumes resulting from diversions, abstractions and inter-basin transfers,
- changes in the overall variability of flows or flood frequencies,
- changes in the seasonal timing of high and low flows, and
- changes in the sizes of seasonal flows.

Data from hydrological stations across the study area were used to calculate these measures, which were then related to undisturbed conditions preceding water resource development (to assess the degree of change), and combined.

The *nutrient and suspended sediment load index* was calculated from modelled data for suspended sediment load, nutrient loads, and salinity. Total phosphorus and total nitrogen were calculated as ratios between modelled 'natural' loads (pre-disturbance) and existing loads for each reach. Measures of hillslope, gully and riverbank erosion were fed into models to calculate fine sediment entering each reach, in 'natural' (pre-disturbance) and existing conditions. The bulk of the annual load is transported during high intensity storms and floods; the model allows for deposition of sediment on floodplains and in reservoirs and lakes. Modelling was used rather than measurements because of the scarcity of data in Australia. The worst of the values for nutrients, sediment and salinity then became the overall index value, on the reasoning that that if any one of the three measures was bad enough to signify poor stream condition, then the reach was in poor condition.

Other assessments

The ARC approach allowed the team an overview of reaches across the whole continent at once, and it was able to identify groups of reaches disturbed by the same environmental issues. For example, reaches in far north Queensland, eastern Victoria and western Tasmania turned out to be largely undamaged by human activity. Most river reaches in Queensland, north coastal NSW, western Victoria and south-west Western Australia were carrying sizable loads of nutrients and suspended sediments, but their habitats and catchments were in near-natural condition. A small group of reaches in Tasmania were affected by dams but otherwise were in near-natural condition. River reaches where disturbance was most intrusive (nutrients, suspended sediments, dams, changes to habitats, catchments and riparian vegetation) occurred in the Murray-Darling Basin, the Western Australian and South Australian wheat belts and western Victoria.

Outcomes

The assessments of environmental features and biota were useful, although they did not match each other as closely as might have been expected. This is probably because only invertebrate data could be used. Data on fish, water birds and other aquatic biota such as water plants would have added much to the biological assessment.

The grouping of reaches highlights useful information about river condition and appropriate management responses. For example, in reaches where both biota and environment show the effects of human disturbance and a cause or causes can be identified, management can focus on intervention or rehabilitation, using the ARC environment indices to guide the types of remediation needed. For reaches in which biota are recorded as disturbed but the environmental components are not, a fuller investigation may pinpoint the causes of disturbance.

In reaches in which the environment indices show disturbance but the biota do not, the effects of environment disturbance may be too weak or too recent to have affected the biota, and the outcome can be taken as a warning. To pass a final judgment about the condition of the ecosystem, other assemblages such as fish, algae, macrophytes or diatoms could be examined.

Reaches where there were minimal or no effects of disturbance on the biota or the environment could be targeted for immediate protective management, to 'save what we have'.

The Broken River, Victoria.
Photo. C. Merrick

The Narran River.
Photo: G Wilson

Overall, the ARC provided a framework for assessing river condition to guide policy, in jurisdictions ranging from local to national. Practically, its grouping of reaches where change is most profound has made large-scale management or policy decisions possible and focused them on particular target areas.

Limitations of the approach used in the ARC

The ARC would be a stronger assessment had there been more measured data available, and had it had to rely less on modelling. However, modelling is a powerful and appropriate approach to use in situations where monitoring data are sparse and expensive to acquire. Ideally a model's predictions should be checked thoroughly for the geographical range it covers, and this was done as thoroughly as possible for all indices. Yet, to gather complete and comprehensive measured datasets for a national ARC would be a massive undertaking and there will always be areas where more data would benefit such an assessment. The challenge is to produce useful, reliable information on river condition with the available data, and to identify crucial elements for future assessments.

Acknowledgements

The ARC study was funded by the Natural Heritage Trust with support from agencies in all Australian states and territories.

The ARC team consisted of Ian Prosser, Bill Young (then both members of CSIRO Land and Water), Richard Norris, Peter Liston, Nerida Davies, Fiona Dyer, Simon Linke, Martin Thoms (then all members of CRC for Freshwater Ecology).

Further reading

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The Daly River, NT.
Photo: B. Rennie

Primary-schoolers hunger for facts about freshwater

by Sylvia Zukowski

'What do Murray cod eat?'

One of the best ways of stimulating primary-school children to listen and take-in facts is to involve them in the subject matter. And one way to involve them is to ask them questions such as the one above, and give them the task of coming up with answers. If the group cannot answer the question, it helps to ask another question that will steer them towards the answer to the original question.

We know this because teachers regularly invite staff from the CRC for Freshwater Ecology Lower Basin Laboratory at Mildura's Murray-Darling Freshwater Research Centre (MDFRC) to class, both indoors and out, to tell the children about freshwater life (including Murray cod), environmental issues, and the research methods used to tackle these issues.

Primary school visits are aimed at increasing awareness of environmental topics, particularly in a regional area where water issues are so relevant to daily life. The presentations always focus on learning in a creative, illustrative and interactive fashion, and often have a hands-on component. We use a range of activities: from how to use research instruments, to show-and-tell about animals or bugs that we take into the class, to going out to a wetland or other waterbody and finding water-bugs and other features of the freshwater environment.

The class teachers generally suggest a topic that is relevant to a current project that the school or class is running. Topics have included native and introduced species, fish and turtles, weir pools, blue-green algae, salinity, and what researchers do. It is also very beneficial to integrate a presentation with other parts of the curriculum, so that the lesson turns into more of a cross-discipline experience than an isolated 45-minute classroom session.

One way of doing that is to let the classes develop environmental drama plays from facts learned during an MDFRC presentation or field-trip. For example, Mildura West Primary School created a school play about native versus introduced fish species, and presented it at the International River Health Conference held in Mildura and Broken Hill.

Another exciting activity is a field trip to a wetland to do a bug survey, or to a local lock to learn about the regulation of our rivers.

Primary school children also find it fascinating to come to the MDFRC lab to see work in progress. Here a presentation can be tied in with demonstrating some of the equipment used in research, including fishing nets, water quality measuring devices (called Horibas), microscopes, and the ever-present waterbugs and fish larvae.

The presentations need to keep the children interested and make them feel they are part of the action. We always start with an outline of the tasks of freshwater researchers and some current projects, to set the mood. The children are asked to identify some of the roles that different kinds of researchers may have, and they are encouraged to think how these may be used in projects related to the local area. Say, 'Jim Smith is researching the way algae grow. How could that be useful in the Mildura region? One possible answer from the class, 'Blue-green algae can be a problem locally', could then lead us to discuss the environmental conditions that cause it to become a bloom.

Students in Year 5/6 at Mildura West Primary School with the play they wrote, directed and cast themselves, about native and introduced fish species, at the 2003 International River Health Conference. Photo: D. Loram, courtesy of the 2003 International River Health Conference.

Pictures are essential during in-class talks. Each slide is introduced with 'Can you think of ...?', followed by an interactive session (definitely with hands up or else it becomes very noisy), before the answers are revealed on the next slide. For instance, 'Can you think of ways rivers have been affected by humans?' If the students are not kept interested with pictures and photographs, we very quickly have a group of wriggling and whispering youngsters who are not listening.

One point learnt early on: if the presentation is not working for the class and the interest isn't there, be flexible and adaptable and change the presentation or the style of delivery instead of continuing with no attention! We sometimes need to get up and walk around the classroom asking those questions that will bring the class back on track and get their interest again, before going in a slightly different direction with the talk.

All presentations or trips finish with a 'What have we learnt?' slide, so the class can tell the presenter what they now know about each key point. About three minutes is left at the end for open questions from the students, but questions are encouraged throughout the session because the younger children tend to forget questions by the end of the talk. Of course, we always hope the visit will end with big applause and possibly a box of chocolates for the presenter!

Educating school groups of all ages is important, as they are the future water users and will soon be the ones making a difference. During the course of a year, we visit many of the schools local to Mildura, in Victoria, NSW and South Australia, and we are also invited to visit groups of schools further away.

I think these school visits are triggering long-term interest in a lot of the children. After we've visited a school, children from the classes will almost always approach me, if they see me at another local activity, and ask me further questions, either about the topic I was teaching them or some other relevant subject. And several have presented me with further information that they have found regarding the topic.

And what do Murray cod eat? ... They eat anything animal that will fit into their mouths, including fish, yabbies, shrimp, mussels, baby turtles, baby birds or ducklings.

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Teaching Year-3 students how to distinguish between small native and introduced fish species at Kings Billabong on World Wetlands Day 2003. Photo: R. White.

It's like reality TV underwater ... almost

by David Crook

Recent research using radio-tracking and other developing techniques is beginning to open up the world of fish behaviour to those of us restricted to life on dry land.

Just like land animals, fish negotiate and fight amongst each other, court mates, build and renovate their homes or nests, visit local attractions and travel to far flung places ... all in the depths of our inland river systems. And now scientists are increasingly finding ways to follow some of their movements.

For example, David Crook, while working for his PhD with Charles Sturt University and CRCFE, tracked native golden perch and introduced carp in the Broken River in north-east Victoria using tiny waterproof transmitters attached to the fish's backs. He wanted to investigate the types of habitats the fish used and to describe their movements within and between habitats. Put plainly, the study aimed to find out whether these species are home-makers, or nomads, or a bit of each.

The results of the study showed that both golden perch and carp moved only short distances most of the time and were very attached to particular regions of the river. In fact, fish that were transported and released 2–3 km away from their original capture sites often returned to the exact location of their capture within a day or two of release. The characteristics of these particular areas, known as home ranges, were different between the species. Golden perch tended to have home ranges of less than 100 m in length, while carp had home ranges of up to 500 m. Deep water appeared to be the main factor in determining the locations of golden-perch home ranges, with most fish occupying deep pools on the erosional sides of meander bends. Woody debris appeared to be important as a secondary habitat feature; golden perch tended to congregate around submerged snags within their home pools. Carp, on the other hand, were less specific in their choice of habitats. The home ranges of carp included both deep pools and relatively fast flowing and shallow runs.

*A carp (*Cyprinus carpio*) with a radio-tracking device attached to the dorsal fin. Photo: David Crook*

On first inspection, the findings of the study seem to contradict some of the previous work on the species, which have reported that both species are highly mobile. A 1983 study by Reynolds[1], for instance, found that a small proportion of golden perch marked with external tags were recaptured more than 1000 km from their original site of capture. This finding resulted in golden perch developing a big reputation as a mobile species. More recent radio-tracking studies[2,3] in the River Murray also found that movements of more than 50 km were relatively common for both golden perch and carp.

On further thought, however, the results of the various studies start to fit into place and suggest that any distinction between site-attached fish (home-makers) and mobile fish (nomads) is not clear-cut. In fact, it appears that individual fish may be either, depending on the conditions at the time. The radio-tracking studies by the Arthur Rylah Institute on the River Murray, for instance, showed that long-distance movements by golden perch and carp generally occurred in response to rising water levels that coincided with relatively high water temperatures. The rest of the time, the fish displayed the same type of site attachment behaviour as reported here in the Broken River radio-tracking study.

Assembling the evidence collected so far, it appears that golden perch and carp tend to be strongly attached to 'home' regions within rivers most of the time. However, these periods of site attachment appear to be interspersed with periods of much more extensive movement. The purpose of the more extensive movements is not entirely plain at present, although it has been suggested that they are associated with reproductive or dispersal strategies.

It is clear that fish exhibit complex behaviour and that there is a lot happening under the water that we don't yet know about. With further development of the technology for spying on fish in their natural settings, we will become increasingly well placed to integrate this information into waterway management.

Maybe then we will be able to produce some reality TV underwater.

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Further reading:

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*Golden perch (*Macquaria ambigua*), commonly growing to more than 2 kg, occur naturally in the Murray-Darling Basin, the Lake Eyre Basin and in some rivers in Queensland. Photo: MDBC*

SideStream

Positive fifth year review report for CRCFE

CRCFE received a positive report at its fifth year review in June. Professor Ian Rae (University of Melbourne), Assocociate Professor Jenny Davis (Murdoch University) and David Dole (retired General Manager of River Murray Water) assessed the accomplishments of the CRCFE, based on written information and presentations over two days. The reviewers said, among other things:

> *The CRC has performed well against the milestones set out in the program for achievement at year 3 and has made substantial progress against those for the longer term, 5–7 years. ... It is our judgment that the CRC, through its research and investigation and consequent ability to provide advice to the industry partners, has made significant improvements to improving the condition of Australia's inland waters.... The CRC has adapted to the needs of the community and their partner organizations so that their overall approach reflects social, economic and ecological values.... They have achieved this holistic position without relinquishing their great strengths in research.*

The reviewers made a number of useful recommendations that program leaders will consider for improving the value of CRCFE R&D in its remaining time. The review covered the major findings and achievements in all aspects of CRCFE research and knowledge exchange since mid-1999.

Beyond Extinction Rates workshop

Professor Richard Norris of the CRCFE was invited by the Royal Society of London to attend a workshop entitled 'Beyond extinction rates: Monitoring wild nature for the 2010 targets'. The workshop developed scientifically sound measures of progress towards achieving the 2010 biodiversity target, organised by the Convention on Biological Diversity, part of the UN Environment Programme. Richard joined 60 other scientific experts from around the world to work on the issue. Results of the discussions can be seen at www.twentyten.net/.

Young Water Scientist of the Year Award 2004

Sara Lloyd, representing the CRC for Catchment Hydrology, is the 2004 Young Water Scientist of the Year. Sara was one of five finalists who all presented talks during the 7th International Riversymposium in Brisbane early in September. Her topic was 'Quantifying environmental benefits, economic outcomes and community support for water sensitive urban design'. The panel of independent judges commended all five candidates for their excellent presentations, which also dealt with fish in billabongs (Dale McNeil, CRCFE), fish in estuaries (Ross Johnston, CRC for Coastal Zone, Estuary and Waterway Management), water filtration membranes (Para K. Parameshwaran, CRC for Waste Management and Pollution Control) and blue-green algae (David Moore, CRC for Water Quality and Treatment).

Catchments to Coast scoping study

As part of the second National Land and Water Resources Audit, the CRCs for Freshwater Ecology, Catchment Hydrology, Landscape Evolution and Mineral Exploration, and Coastal Zone Estuary and Waterway Management, along with CSIRO Water for Healthy Country, have joined together to scope a 'Catchments to Coast' project. From CRCFE, Ralph Ogden (University of Canberra) is the project manager, Richard Norris (University of Canberra) heads the science leadership group and Fran Sheldon (Griffith University) is a member of the leadership group.

The project aims to develop a suite of tools and methods for performing integrated assessments of catchment condition. Integration will be between different catchment compartments — groundwater, surface water, estuaries — and also economic and social condition through links to a social and economic audit project. For details, please contact Ralph Ogden, phone 02 6201 5369.

Generic framework for e-flows-monitoring designs

Following a workshop held at Monash University in December 2003, a generic framework is being developed to help in the design of monitoring for effects of environmental flows (e-flows). The workshop explored the issues involved in monitoring e-flows, and the need for consistency between jurisdictions, and recommended that a design framework be developed collaboratively. Peter Cottingham of CRCFE is leading the project, supported by a steering committee, which includes Richard Norris, Gerry Quinn, Bruce Chessman, Alison King and Chris Marshall.

Congratulations to Peter Cullen

Congratulations to Professor Peter Cullen who was made an Officer of the Order of Australia in the Queen's Birthday Honours list, for his contributions and service to freshwater ecology. The award focused on areas of policy development, implementation and sustainability in relation to water and natural resource management. The award was also in recognition of his efforts in education.

Also, the Societas Internationalis Limnologiae has awarded Professor Peter Cullen the honourable 'Einar Naumann-August Thienemann' Medal. It was awarded to Peter for his exemplary scientific leadership and extraordinary efforts to communicate complex limnological and water resources issues to colleagues and decision-makers, which over the past three decades have led to improved understanding about, and wiser allocation of, critical water resources in Australia.

New Chief Executive of MDBC

We welcome Dr Wendy Craik, the new Chief Executive of the Murray-Darling Basin Commission, one of the CRCFE partners. Dr Craik has considerable expertise and experience in natural

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resources management and in managing intergovernmental bodies. She stepped down as President of the National Competition Council and the Chair of the Australian Fisheries Management Authority to lead the MDBC.

Angela Arthington assists Ramsar Convention

Professor Angela Arthington (Griffith University and CRCFE) is assisting the Ramsar Convention's Scientific and Technical Review Panel with the development of guidelines describing environmental flow methods for rivers, wetlands and estuaries.

World soil scientists visit lab at Goondiwindi

On 1 July, a group of international soil scientists from Germany, the USA, China and Botswana visited the CRCFE's northern laboratory at Goondiwindi, where they were informed about regional projects in freshwater ecology and entertained with a barbecue dinner. They were in Australia attending the International Soil Conservation Organisation conference in Brisbane, and touring the SE Queensland Border Region, looking particularly at the contrasts in land use and environmental issues.

DIVERSITAS Scientific Committee

Professor Angela Arthington (Griffith University and CRCFE) has been appointed to membership of the Scientific Committee of the DIVERSITAS cross-cutting network on freshwater biodiversity, for a period of three years. This network is chaired by Prof. Robert J. Naiman (University of Washington, USA). DIVERSITAS is an international scientific program dedicated to the science of biodiversity, with the backing of ICSU, IUBS, SCOPE, IUMS and UNESCO. The Scientific Committee will define and implement an international scientific agenda on Freshwater Biodiversity. More information (and explanation of the acronyms) can be found at: http://www.diversitas-international.org.

North American Benthological Society (NABS) committee

Professor Richard Norris (University of Canberra and CRCFE) has been elected the next chair of the NABS executive committee.

AUSRIVAS Online update

The AUSRIVAS Online training course is currently running for the second time this year. Since the first course started in February, 57 people have been enrolled in some or all of the five modules offered (four theory modules, delivered online, and one practical workshop module). The course, run by the CRCFE and the University of Canberra, teaches the skills and knowledge needed to assess river health to an acceptable standard using AUSRIVAS methods. Those who complete its requirements successfully are eligible for accreditation from the relevant state or territory agency. The next AUSRIVAS Online course is scheduled for February 2005. See http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/Training/

Water Education Network (WEN), by AWA

The WEN is a new initiative of the Australian Water Association which aims to facilitate contact between practitioners of water education in all forms and at all levels across Australia. For details, contact Corinne Cheeseman at ccheeseman@awa.asn.au.

RACI medal, twice

Professor Bill Maher (University of Canberra and CRCFE) has become one of the very few people in Australia to receive a second Royal Australian Chemical Institute Medal, this time in recognition of his outstanding work in promoting environmental chemistry and for his contributions to the Institute. His previous medal, in 2002, was for analytical chemistry.

CRC for Catchment Hydrology releases TREND

TREND is software designed to facilitate statistical testing for trend, change and randomness in hydrological and other time series data. Based on statistical tests that are relatively robust and easy to understand, TREND is reported to be easy to use. The software, User Guide and an example Excel spreadsheet can all be downloaded via http://www.toolkit.net.au/trend.

New knowledge broker

Amy George has just begun work as the CRCFE's latest knowledge broker. She is based in Adelaide, at the Department of Water, Land and Biodiversity Conservation in Grenfell St.

Amy recently completed her PhD with the CRCFE and the University of Adelaide, examining the way eucalypt communities respond to flooding on the Lower Murray Floodplain. She can be contacted by phone, 08 8463 6805, or email, george.amy@saugov.sa.gov.au.

Oral history in progress

Interviews are under way around the Narran River and Lakes, to build an oral history of the area. Long-time residents living between Walgett and St George have volunteered to share their local knowledge about the ecology of the river and wetlands. Dianne Tyson, Historian at the Back O'Bourke Exhibition Centre, is working with Janey Adams, Senior Community Scientist at the Murray Darling Freshwater Research Centre's Northern Basin Laboratory at Goondiwindi, on the project, collecting historical information about natural events such as flooding, fish spawning, pest invasions, and changes in the appearance of the area over the past fifty or more years.

Annual report on web site

The Annual Report of the CRCFE for 2003–2004 is now available via a link on the CRCFE's home page at http://freshwater.canberra. edu.au.

CRCFE web site:
http://freshwater.canberra.edu.au

Photo: Abyss Diving, Queensland

Feature plant

by David Williams

Cabomba or Fanwort

Family: Cabombaceae
Species: *Cabomba caroliniana*

Cabomba is a species of submerged flowering plant, regarded as one of Australia's worst exotic weeds. It is prolific in nutrient-rich, relatively still and permanent water-bodies, producing a variety of serious impacts. The plant grows best on silt, in acidic water as deep as 3 m, where its stems can be over 2 m long, but even when detached from the soil it continues to grow. In temperate zones, growth and flowering occur mainly in summer. Although a native of South America, cabomba has been taken all over the world by the aquarium trade and is now found in much of tropical and temperate Australia. It is spread intentionally and accidentally by human transport of plant fragments — pieces as small as 10 mm long can survive for weeks if kept wet. For more information, especially regarding control of this invasive species, refer to the DEH web page http://www.deh.gov.au/biodiversity/invasive/weeds/c-caroliniana.html, from which some of the information here was sourced.

Areas mentioned in this issue.

Comments and ideas are welcome and can be sent to:

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