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WaterShed

contents

‘So long, and thanks for all the fish!’

by Professor Gary Jones
Chief Executive

The CRC for Freshwater Ecology (CRCFE) set out in 1993, under the leadership of Professor Peter Cullen, my predecessor, to help improve the health of Australia’s inland waters, particularly rivers and wetlands. By June 2005 we had completed two six-year terms, with Peter at the helm for nine of those 12 years.*

With the new eWater CRC due to start officially in September, it is time to reflect on the achievements of the CRCFE, and to look ahead as we begin to merge with new partners and move into broader fields of work.

I can say with certainty that CRCFE has helped improve Australia’s inland waters, and that we have made a difference to water management in Australia. The CRCFE’s research activities in four states and the ACT have produced fundamental information and advice to help pave the road towards numerous and widespread policy developments and changed attitudes in water management over the past decade. We have identified measures and indicators of ecological ‘health’, developed monitoring and assessment programs, and explored both the factors causing a loss of ‘health’ in some river reaches and ways of rehabilitating them. We have also helped deepen the general understanding of freshwater ecosystems and their components.

The CRCFE has contributed to the notion of the ‘healthy working river’ — a river that is providing adequately for human and ecological needs even though it may not be in the same condition as the ‘natural’ river it was before European settlement.

CRC FOR FRESHWATER ECOLOGY
http://freshwater.canberra.edu.au

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

CRC AUSTRALIA

Flow regimes

Environmental flows (e-flows) are now a recognised part of the management of healthy working rivers. We can trace CRCFE 'footsteps' through a progression of environmental flow initiatives over the last decade. The term and concept were around before the CRCFE began, but they have been developed and strengthened by the CRCFE and its partner organisations. Our research and river management staff have helped devise e-flow regimes for rivers in Victoria, NSW, Queensland and ACT, including the River Murray.

We have tried to define the ways in which river ecosystems respond to flow regimes. There appear to be a series of complex (rather than simple) relationships, and there is strong evidence that riparian plants and trees, fish, macroinvertebrates, waterbirds and microscopic organisms respond in a range of ways to various aspects of flow regimes. These observations add support for the hypothesis of many aquatic ecologists that flow is a key driver of ecological condition, including water quality, in rivers and floodplain wetlands.

Water quality and ecological condition

Biological methods for measuring water quality have come into use particularly during the life of CRCFE. Compared to physical and chemical measurements, biological methods have advantages because organisms that live in river water integrate the quality characteristics of that water and habitat. The national assessment of river condition, led by CRCFE and CSIRO Land and Water in 2000–2001 for the National Land and Water Resources Audit, used existing biological, physical and chemical data (supplemented by modelling where necessary) to identify the ecological condition of river reaches throughout the intensively managed areas of inland and coastal Australia.

Professor Gary Jones.
Photo L. Sealie

The CRCFE has funded the development and trial of biological assessment methods based on fish, ecological processes, diatoms (a type of alga) and macroinvertebrates (largely insect larvae, crustaceans and molluscs). Of these, macroinvertebrate methods have been found to be the most useful so far. They can be applied in the widest range of (though not all) conditions, and they are the basis of the AUSRIVAS method for river assessment, which the CRCFE helped develop as part of the National River Health Program. The whole AUSRIVAS package (see http://ausrivas.canberra.edu.au/) has been run, managed and continually developed on behalf of, and in conjunction with, the Australian Government Department of Environment and Heritage and state water agencies by the CRCFE, and that role will be taken on by the eWater CRC.

The Murray-Darling Basin Commission has recently (2004) begun a Basin-wide Sustainable Rivers Audit, as a result of conceptual frameworks, developed jointly by the CRCFE, and a subsequent pilot study. CRCFE staff were also integral to the writing of the revised national water quality and water-quality monitoring guidelines, in 2000.

Rehabilitation and biodiversity

Whether you monitor water quality by physical and chemical measurements or biological assessment, it is only by measuring the status of the organisms and by understanding the ecological processes that affect them that you can really decide what form of ecological rehabilitation is needed. Throughout its life, the CRCFE has aimed to identify whether and why river reaches and floodplain waterbodies need rehabilitating, and how to implement that.

We have studied the ecology of all kinds of rivers and waterbodies throughout the Murray-Darling Basin and beyond — including dryland rivers and their waterholes in the outback of southern Queensland, and tropical rivers in Northern Territory. We can now say that it is very important to ensure that river systems contain not only the everyday habitats that organisms need in normal conditions, but also the refuges — such as billabongs, waterholes and river-bed pools — that can outlast long droughts. Without both kinds of habitat, freshwater biodiversity is less likely to survive climatic extremes. And we have shown that it is not enough just to restore habitats and refuges. Organisms will not necessarily reoccupy their former habitats if factors undermining ecological condition, from upstream or elsewhere in the catchment, are still active.

Apart from the ecological studies already mentioned, CRCFE, via the Murray-Darling Freshwater Research Centre, has developed around 50 taxonomic identification (ID) guides to numerous invertebrates and larval fish. Each new set of ID guides has been released at a taxonomic course giving practical experience to the staff who would visually identify those organisms during monitoring or other activities. Researchers elsewhere in the CRCFE have adopted genetic approaches in their taxonomic studies and already that research is providing valuable advice for the management of waterways and in particular for projects where interbasin water transfers or the re-colonisation of depleted environments are contemplated.

Of course, monitoring the ecological condition of a river and devising e-flow regimes for it is not the same as ensuring it is a healthy working river. One way of tackling that issue is via another important output of CRCFE's operations — ecological risk assessment (ERA). The ERA process, a key focus of research at the Monash University Water Studies Centre, involves identifying all the factors that impinge on the ecological health of inland waters in an area, and calculating the probability of effects from each factor, using Bayesian analysis (see http://www.wsc.monash.edu.au/html/sresearch_ecological.htm). The approach is now in use in Victoria and is beginning to spread to other states. A risk-based ecological assessment approach has recently been incorporated into the Victorian EPA's guidelines for suspended sediments, and ERA has also been applied to Sydney's water supplies.

Having raised awareness of issues, we have then tried to produce operating frameworks for use on those issues. For example, we have recently published a framework for monitoring and assessing the ecological effects of environmental flows, and we have compiled a summary of understanding in monitoring and assessing biodiversity. (Both reports are available at http://freshwater.canberra.edu.au > publications > technical reports.)

Fish

Fish research has been an important activity for our scientists. An outcome of the NSW Rivers Survey in the mid 1990s, part-funded by the CRCFE, was the NSW Water Reform program. The program was based largely on setting up e-flow regimes, one aim being to improve fish habitat. Fish research funded by CRCFE has led to numerous outcomes; for example, the construction of fishways in rivers of the Murray-Darling Basin and along the east coast, monitoring for threatened fish species, habitat rehabilitation for those and other fish species, better understanding of carp control, factors affecting the numbers of fish in a river and their migrations (or not), and predator–prey relationships in fish refuges. Also, the 'low-flow recruitment hypothesis' devised by staff of the Murray-Darling Freshwater Research Centre (part of the CRCFE), is being hailed as a great step forward in understanding fish ecology in Australia. According to this hypothesis, which is being strengthened by subsequent research, several native fish species need warm slow-moving waters and backwaters in early summer for successful spawning and recruitment. These conditions are not necessarily available at that time in regulated rivers, where warm-season flows are often artificially high.

Urban waters

Our knowledge and understanding of ecology in urban waters and urban water supplies has been greatly advanced during the life of CRCFE. Rigorous studies in Melbourne's streams have clarified the factors that lead to ecological decline of urban streams. The accepted wisdom around the world was that streams would be in poor ecological condition once 10% of a catchment was covered in impermeable surfaces such as roads, paving and roofs. But collaborative CRCFE research has questioned that wisdom, by showing that it is actually only those impermeable surfaces that are directly connected to the streams by drainage pipes or channels — that is, the 'effective imperviousness' of the catchment — that cause the ecological damage, largely via the frequent inputs of stormwater, coming from even small rain events. This pioneering work, by staff of both the CRCFE and the CRC for Catchment Hydrology (CRCCH) at Monash University, follows the already strong leadership given in urban water rehabilitation by the CRCFE in ACT; for example, guidelines for integrated land and water management, and stormwater pollution control via wetlands and ponds. (See http://freshwater.canberra.edu.au > publications > technical reports, or > publications > books and guides.)

Exchange of information

To avoid turning this into a mere listing of outcomes and outputs, suffice it to say that the CRCFE has contributed in numerous ways to the science and understanding needed for successful ecological rehabilitation of inland rivers, wetlands and floodplains. The CRCFE's findings have stimulated stronger acceptance of the need to monitor and assess our ecological resources — whether looking at the effects of e-flows, maintaining water quality, or deciding whether individual rehabilitation projects have been an ecological success.

Our influence has been effective. In part that is because of our high-profile leading ecologists and their activities beyond the CRCFE: their role on advisory committees, for example. It is also partly because of the CRC structure. Having scientists able to talk directly with those managing and controlling inland waters has been a very successful way of exchanging information. Such interaction is common to all CRCs, but as our Chairman for 12 years, Dr John Langford, said recently:

> We've built up a strong cohort of land, water and river managers and connected them to the ecological researchers. There's now a far greater awareness of the environmental consequences of our activities in rivers, and the potential harmful effects and the potential solutions than there ever was before. If the CRCFE hadn't been there, I think there'd be a very different water debate going on.

The CRCFE's knowledge exchange program has boosted the effectiveness of that interaction even further. Since Peter Cullen initiated the program, knowledge brokers have been stationed in Albury-Wodonga, Mildura, Goondiwindi, Adelaide, Sydney, Melbourne and Canberra, where they have been on-the-spot contacts, collecting information from their local scientists as an input to management solutions being developed locally and elsewhere.

Our knowledge exchange and knowledge brokers have been unique to CRCFE. Knowledge brokers have the skills to have the *right conversation* with *both* industry practitioners and scientific researchers, brokering productive interaction between people in previously separate fields of work. That said, there is also immense value in scientists making direct contact with the end-users of their research — in effect being both scientist and broker of that science. Scientific staff in CRCFE have very successfully interacted with members of the community and with management agency staff, and significant management outcomes have followed.

The CRCFE's education, training and community-based activities have also contributed to increasing awareness of the tradeoffs required for healthy working rivers. Freshwater schools, training courses, both face-to-face and online, and workshops for management

A river reach in the River Murray system above Yarrawonga Weir. Photo: A Tatnell.

personnel have helped to spread the messages arising from our research. We have trained students in freshwater ecology, and many of them are now in water management agencies around the country and overseas. Indeed, the demand for our postgraduates has been so high that the biggest problem we have had is getting them to write up their theses while 'on the job'!

Looking ahead

Importantly, all the skills in ecological research, scientific advice and knowledge exchange that the CRCFE has built up will still be available to managers, policy-makers and the community, via the new eWater CRC. eWater CRC also comprises expertise and experience in catchment hydrology, water resource economics, systems modelling and prediction.

The new blend of skills and experiences will help us confront issues that I consider to be some of the great unanswered questions in Australian water science. For example, we need to develop an agreed conceptual and theoretical basis for rehabilitating rivers and catchments at multiple scales, from local sites to whole catchments. Another major challenge is to develop new paradigms and mechanistic models for linking ecological condition, habitat, flow regime, and catchment condition. We also intend to conceptualise and predict the connections between climate change, extreme events such as flood, fire and drought, and the health of rivers and wetlands.

The difficulty of these tasks should not be under-estimated, but I know we have world-class scientists who relish the prospect!

There is, of course, a similarly complex suite of management challenges that go hand in hand with these scientific questions. For instance, the changing face of water policy and water markets, and the increasing regionalisation of water resources management, are likely to affect water business and decision-making. Many of our Partners are grappling with these issues already, but only the bravest of pundits would claim that they can clearly see the future of water management in Australia right now.

Our government and industry Partners are working with eWater CRC to develop scientifically robust, repeatable and transparent methods and decision tools to guide public and private sector investment in catchment management and river operations — both urban and rural. And we expect to provide training and support services for the knowledge and tools we produce, as well as packaged knowledge, information 'on demand', and on-ground trials of new models.

We aim to do all this for the next seven years (the period of our Commonwealth and Partner funding). We will also set up funding and business mechanisms that will provide scientific knowledge and decision tools for users in industry, research and the water-market, beyond the life of the CRC.

eWater CRC — which is run by eWater Ltd, a limited-by-guarantee company — has its head office in Canberra, initially at the University of Canberra. Our Communications, Adoption & Commercialisation group is based in Melbourne.

The development of eWater CRC could not have occurred without the support and dedication of a large team of CRC staff and colleagues in Partner organisations. They are too numerous to mention individually, but I thank them all collectively for their hard work and support.

And so, as the CRC for Freshwater Ecology finally leaves the planet, I'll say, in the words of the late, great Douglas Adams:
'So long, and thanks for all the fish!'**

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**from *The Hitchhiker's Guide to the Galaxy*, by Douglas Adams.

Towards understanding and maintaining aquatic biodiversity

Work of the CRC for Freshwater Ecology (CRCFE) has added breadth to general understanding of the biodiversity of Australia's inland waters, as this article outlines.

Biological diversity is officially defined as 'the variability among living organisms from all sources, including … aquatic ecosystems and the ecological complexes of which they are part; … within species, between species and of ecosystems'[1]. Conversely, loss of biodiversity has been summarised as: 'the long term reduction of abundance and distribution of species, ecosystems and genes and the goods and services they provide'[2].

There is agreement that biodiversity (aquatic and terrestrial) has been reduced or altered in areas affected by human activities, but it is not always obvious whether or how we should modify our activities so that biodiversity can build up again; and we are not always sure what 'biodiversity' includes or who should be concerned. This is where the CRCFE has contributed to our understanding, giving some reasons why, some answers to 'how?' and 'what?', and helping a range of audiences be aware of potential trade-offs between biodiversity and human uses of catchments.

Why maintain aquatic biodiversity?

At the CRCFE-run Fenner Conference on biodiversity conservation in freshwaters, in July 2001, Peter Cullen gave four reasons for maintaining biodiversity in Australian inland-water ecosystems. First, international obligation: Australia signed the International Convention on Biological Diversity in June 1993. Second and third, to provide benchmark reference areas from which to assess how managed rivers compare to the natural condition; and to provide 'seeding' sources to help recolonise downstream areas that have been damaged. Fourth, to acknowledge that the various aquatic species are of value in themselves, and that plant and animal communities provide essential and often irreplaceable ecosystem services.

How do we maintain aquatic biodiversity?

To maintain biodiversity in the inland waters of a region, or address its loss, two approaches are thought useful: (i) identify and protect chosen inland-water ecosystems as heritage reserves; and (ii) address the factors and threats causing the losses, and apply rehabilitation where necessary.

Ways of applying the first approach are outlined in CRCFE's *Conserving Natural Rivers: A Guide for Catchment Managers*, which describes how to decide if the local rivers need protection from threats, and how to manage them if so. The ideal would be to set aside special management areas or aquatic reserves, which would not intentionally obstruct current levels of river usage and catchment activity, and would not restrict the cultural need of indigenous people. Instead, the areas would be protected from developments such as:

- further licences to extract water;
- construction of new dams, weirs and levees;
- further de-snagging or other 'river protection' activities;
- further drainage of wetlands;
- further clearance of riparian vegetation;
- stocking with alien aquatic species.

In the past, rivers in national parks have not been protected: consider the Snowy River scheme in Kosciuszko National Park. New wild-rivers legislation has recently been introduced by the Queensland Government, and the Governments of Victoria and NSW have legislative capacity to reserve rivers or sections of rivers. These beginnings may gather further momentum with new CRCFE PhD work on introducing systematic conservation planning to riverine landscapes (by Simon Linke at University of Canberra).

Snags in the Ovens River, Victoria. Photo: Andrew Tatnell

The second approach is part of general river management for ecological values. As listed in *Conserving Natural Rivers*, the main threats to aquatic biodiversity are seen as:

- habitat degradation (including flow habitat and connectivity),
- exotic species,

- over-exploitation,
- secondary extinctions, and
- pollution, including salinisation,

which commonly are already targets of management action. CRCFE has added greatly to our understanding of such threats, especially to fish, amphibians, reptiles and macroinvertebrates (largely, water bugs and crustacea) (see 'Very young Murray and trout cod are sensitive to salinity', p.10) and ways of dealing with them. For instance, Margaret Brock, Jane Hughes, Will Osborne, Richard Norris, John Koehn, Mark Lintermans and David Crook sit on state and federal threatened-species committees, identifying endangered species, ecological communities and key threatening processes, and helping in the processes of recovery and threat-abatement planning.

Ultimately, at the large scale, it is flow regimes and catchment factors that determine the biodiversity status of inland waterbodies. This truism has emerged from many lines of evidence collected by CRCFE over its 12 years. Even complete removal of threats at the local scale may not maintain or restore aquatic biodiversity if there are factors (such as erosion and sand slug formation) at catchment or basin scale that are the ultimate causes of biodiversity loss (see 'Lessons in river rehabilitation', p.11).

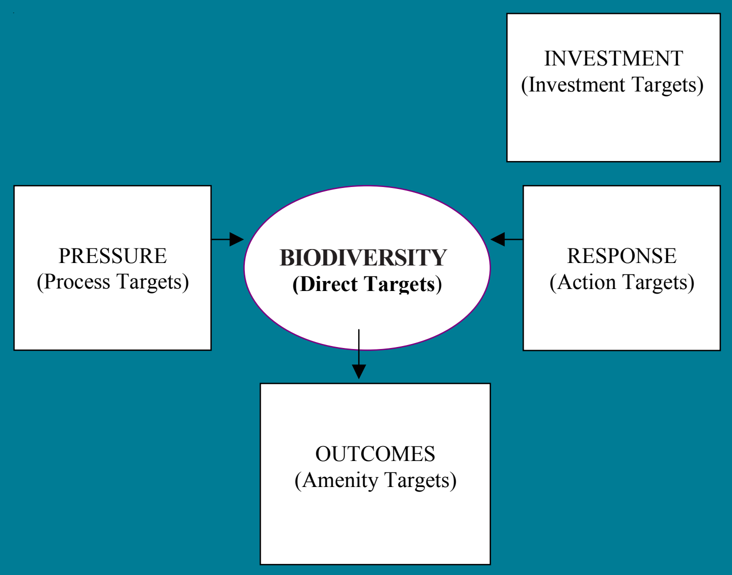
Biodiversity targets

One way of focusing rehabilitation works on maintaining biodiversity is to define some kind of biodiversity target. Ideally, biodiversity targets should relate to the biodiversity measured in suitable reference areas. Arthur Georges and Peter Cottingham of the CRCFE have suggested there are five types of target, and that good targets are measurable, meaningful and achievable. Process targets, action targets and investment targets lead to direct targets (types of biodiversity itself), which can lead on to amenity targets (see framework diagram).

A 'process target' might be to restore 50% of the riparian vegetation across a catchment by 2020, on the assumption that riverside vegetation influences instream biodiversity. Therefore, a process target includes some information about the biodiversity goals and ecological inputs required to achieve them. A corresponding 'action target' might be to fence off 30% of a stream channel from stock by 2005. Although they are more measurable than process targets, action targets focus only on the action.

'Investment targets' realistically underpin biodiversity maintenance and rehabilitation by providing resources — for example, allocate 2% of a catchment management budget to biodiversity initiatives by 2006. 'Amenity targets' also underpin biodiversity work — by attracting stakeholder interest, particularly among those who see little value in conserving and restoring biodiversity if such actions might affect development or economic benefits. Targeting improvement in the catch of native fish by recreational fishermen is one example of an amenity target. Meeting water quality targets because of improved biodiversity in wetland filters is another.

If management can meet targets on, say, sediment or pollution loads, condition of the riparian zone, flow magnitudes and timing and variability, and invasive species, then it is often assumed that substantial biodiversity benefits will follow. However, we rarely know how successful such actions have been because it is rare for the ecological outcomes of a rehabilitation project to be evaluated. Therefore, ideally each



A framework for setting biodiversity targets (by Arthur Georges, Peter Cottingham and Clarrie Hillard (MDBC)) management action will be monitored to test whether the targeted factors are important in regulating biodiversity in each particular natural or managed aquatic system. For example, does simply fencing off stream banks from stock let riparian vegetation recover to the point where it sustainably benefits instream biodiversity, or are other complementary interventions required, such as the management of fire or weeds?

Factors maintaining biodiversity

At a fine scale, we know that a diversity of native animals and plants in rivers depends on there being a suitable diversity of habitats and food sources. These in turn generally depend on seasonally variable flows, healthy catchments and riverside vegetation, and absence of competition from alien species.

For instance, Terry Hillman and his colleagues (mostly from the Murray-Darling Freshwater Research Centre, MDFRC) showed that floodplain biodiversity is maximised when both temporary and permanent wetlands (or billabongs) are allowed to fill periodically. It is also important that temporary wetlands are allowed to dry naturally rather than being rapidly drained. Wetland studies by Margaret Brock (Dept of Infrastructure, Planning & Natural Resources, NSW), Daryl Nielsen (MDFRC) and students have demonstrated how timing, duration and frequency of flooding, and salinity, affect wetland plant and zooplankton (microscopic fauna) communities.

Ben Gawne and Paul Humphries (MDFRC) and colleagues have found strong evidence in lowland rivers of Victoria that warm slackwaters, in macrophyte beds or backwaters, act like incubators for native fish and water bugs. Backwaters do not usually exist when regulated rivers are at high levels in summer. CRCFE studies by John Koehn (Dept of Sustainability and Environment, Vic), Paul Humphries and associates, supported by recent modelling (see article on p.13, ‘Could targeted water management bring invading species under control?’), indicate that the spread of alien aquatic invaders is hindered more by natural flow regimes than by regulated flows. (Alien species such as trout are still being introduced into rivers and dams, although trout are now known to be detrimental to native biota such as mountain galaxias and frogs.)

Numerous CRCFE studies, by Sam Lake, David Williams, John Koehn, Paul Humphries, Angela Arthington, Stuart Bunn, Margaret Brock, Keith Walker and their CRCFE PhD students and colleagues throughout eastern Australia have shown the importance to biodiversity of floods and riverside vegetation. Adequate duration of flooding flows is needed to stimulate growth, flowering, seed set and recruitment in aquatic plants and in riverside and floodplain eucalypts (see ‘Watering patterns for floodplain eucalypts’, p.15). Riparian vegetation can be a source of living (e.g. prey) and dead organic matter (e.g. snags, leaf litter) to river-based consumers, and an important habitat at the river–land interface (as studied by Andrea Ballinger (Monash University) for her PhD). Snags provide shelter and support for fish and invertebrates (from minute bugs to crayfish), traps for river-borne organic matter, perches for waterbirds, substrate for biofilm that incorporates bacteria, algae and fungi that process river contaminants, and small-scale groins to stimulate scouring of river-bed sediment, creating habitats for small biota and macrophytes.

Salinised floodplain forest.
Photo: courtesy of MDBC

As well, management of the greater catchment beyond the riparian zone affects aquatic (and terrestrial) biodiversity. Ultimately, waterbodies are sinks for sediment, salts, fertilisers, sewage, toxicants and general contaminants emanating from catchments and the humans that live there. The result can be impoverished aquatic biodiversity, as demonstrated over the last 12 years by Chris Walsh, Ian Lawrence, Barry Hart, Bill Maher, Richard Norris and coworkers, in urban areas and in intensively used rural areas.

What biodiversity?

To maintain biodiversity, one could argue that an early task should be to assess what there is to be managed, and what has been lost. A full inventory would comprise the numbers and species of plants, animals and microbes (though it is unlikely that anyone can adequately assess microbial diversity). It might also include their ecological functions and habitat interactions, since 'biodiversity' as a complete concept includes composition, structure and function. 'Composition' ranges in scale from genes and species to populations and communities. 'Structure' is the diversity of habitats and landscapes in which organisms live and how they are arranged, and 'function' refers to the diversity of the ecosystem processes and functions performed by the biota, on which they and others depend.

In practice, many managers would say that cataloguing the entire biodiversity of an area would not tell them if biodiversity is being maintained or not. They need to find out if more, less, or different biodiversity should be expected in their management area. Therefore, comparative assessment and monitoring are often used to answer biodiversity-management questions, relative to benchmarks in appropriate reference areas. To clarify some issues in monitoring and inventory, CRCFE has just released a new management guide, on the Web (see 'What do we know about assessing aquatic biodiversity?', p.16). It outlines what we have learnt through CRCFE work on the monitoring and assessment of biodiversity.

A key part of assessing biodiversity is being able to identify the individuals that are collected. The taxonomic guides (around 50 of them) and training organised by John Hawking of Murray-Darling Freshwater Research Centre at Albury-Wodonga, and developed by a range of experts in CRCFE research groups, have greatly contributed to the identification of freshwater invertebrates, larval fish, diatoms and algae. Recent advances in genetic techniques by Jane Hughes and her team have now also demonstrated that within at least some 'species' identifiable by visible characteristics, there are several genetically different 'species' identifiable only by genetic characteristics (see ''Oils' aint (necessarily) 'oils'' (p.18)).

Think biodiversity

Maintaining aquatic biodiversity is a huge challenge that needs awareness and action by everyone, from landholders and fishers to policy-makers. For example, without awareness by fishers and landholders, the survival of turtles in dryland rivers (see 'Life in the slow lane', p.20) and endangered fish (see 'Trout cod in the Murrumbidgee River', p.22.) may be reduced. Many landholders want to care for the natural environment. Therefore the CRCFE, especially at the MDFRC labs, has been teaching both students and adults about the social, economic and environmental value and tradeoffs required to maintain biodiversity in inland waters. School visits, annual Rotary-supported freshwater schools for high school students, hands-on training for Waterwatch personnel, and on-line training modules in river assessment are examples.

We humans must continue to share aquatic ecosystems with native biota, so some sort of balance is needed if we want to retain the ecosystem goods and services that biodiversity provides. With our present knowledge, the dual approaches of (i) setting up aquatic reserves and (ii) addressing the management of flow regimes and catchments may be the beginning of a better deal for the biodiversity of inland waters.

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VERY YOUNG MURRAY AND TROUT COD ARE SENSITIVE TO SALINITY

Results of laboratory tests show that the young of Murray cod (*Maccullochella peelii peelii* Mitchell 1838) are very sensitive to salinity in their immediate environment. In fact, Piyapong Chotipuntu has found that, in the laboratory, larvae of Murray cod and trout cod cannot tolerate even salinity levels that have sometimes been reported in major rivers and wetlands of the Murray-Darling Basin.

For his PhD with the CRC for Freshwater Ecology, Piyapong hypothesised that salinity above a threshold level contributes to the decline of Murray cod in rivers. In particular, saline water could limit early stages of Murray cod development, reducing recruitment and resulting in smaller populations of the adult fish. To test the hypothesis, Piyapong determined the optimal, threshold, upper sublethal and lethal salinities for several developmental stages of Murray cod, including the eggs, yolk-sac larvae, fry and fingerlings, in controlled laboratory conditions.

The fertilisation and larval stages were very sensitive to salinity. Although eggs fertilised in freshwater hatched in salinities up to 10,000 mg/L, many larvae died within four days at much lower salinity levels. Only larvae hatched and reared in freshwater (0–300 mg/L) survived more than a week during the 12-day yolk-absorption period.

The longer the larvae were exposed to saline water, the more they were affected. After 12 days exposure, 50% of the larvae died at salinities of 500 mg/L (trout cod) and 350 mg/L (Murray cod). In comparison, it took concentrations of at least 11,000 mg/L to kill Murray cod fry and fingerlings.

In other words, different development stages of Murray cod had different degrees of tolerance to salinity. In general, yolk-larvae appeared to be the most sensitive life stage, compared to eggs, fry and fingerlings. However, the rates of growth of fry and fingerlings also varied with salinity level, peaking at optimal salinity concentrations before declining as salinity increased further.

Temperature somewhat modified the effects of salinity on fry survival. Fry were seen to grow better and tolerate higher salinity levels when temperatures were close to 20ºC. In their natural habitats, Murray cod spawn in spring where water temperature is 18–25ºC.

A Murray cod caught on the Macintyre River. Photo CRCFE.

Although Murray cod populations in the wild in general have responded to recovery programs that involve snags and changed management of flow and temperature regimes of rivers, some cod populations have not. The results of this laboratory study suggest that one reason for that may be exposure of very early life stages of Murray cod to salinities above their tolerance levels. Many adult Australian freshwater fish species are reported to be able to tolerate salt levels >10,000 mg/L (approximately 15,000 µS/cm EC), but the reproduction, recruitment and growth of juveniles can be substantially reduced, while eggs and larvae are even more severely affected.

The sensitivities measured in these controlled laboratory conditions are not directly transferable to the natural environment, but they provide a guide both for further research and for managers of fisheries who might want to observe the effects of river salinity on their stock. For instance, larvae may be affected by an influx of saline groundwater or other sources of salinity in the natural cod spawning grounds during the spawning season.

This study did not set out to define the relationship between the biology of Murray cod and their environment. However, if these results hold true in future field studies, they imply that if salinity in natural spawning habitats increases above 350 mg/L there will be a significant impact on Murray cod recruitment.

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Lessons in river rehabilitation

*River rehabilitation projects need to recreate both **residential habitats** and **refuge habitats** if animals are to resist and recover from disturbances such as drought and floods*. This is one very important lesson that has come from rehabilitation experiments on the Granite Creeks upland streams in central Victoria.

Sand slugs (long sand deposits in streams, often resulting from erosion combined with slow flow) have formed in Creightons, Castle and other Granite Creeks where these streams flatten out at the foot of the Strathbogie Ranges. The sand slugs, which can be many kilometres long and up to several metres in depth, have blanketed all the bed features that would have existed in the original chain-of-ponds types of streams. As a result, a very simple uniform sandy bed has replaced the natural diversity of pools, runs, backwaters and in-stream timber.

In their experiments, Nick Bond and Sam Lake and a team from Monash University and the CRC for Catchment Hydrology installed red-gum structures with rectangular cross-section (made from sleepers bolted together) in sets of 0, 1 or 4 structures at sites along the sand slugs. Where the installed red-gum structures interrupted streamflow, the turbulence scoured moderate-size pools in the sand. The structures also caught coarse organic matter (resulting in small patches of complex habitat), and the team was able to measure positive associations between fish numbers and habitat patches.

A red-gum structure installed over a sand slug. Photo: CRCFE

That native fish require adequate water-depth and slow flow for their residential habitats had already been identified in the team's preliminary pre-rehabilitation studies of fish habitats in lowland streams. Collectively the data had suggested that adult native fish prefer relatively deep, slow-flowing water near to vegetation cover or woody cover, though they do not necessarily use those features when spawning or during larval development.

While the streams were flowing, the team found relatively large numbers of mountain galaxias (*Galaxias olidus*) in the pools that formed around the red-gum structures. Southern pygmy perch (*Nanoperca australis*) and river blackfish (*Gadopsis marmoratus*) populations also appeared to benefit from the effects of the wood structures. So the rehabilitation experiment was clearly successful, ecologically, for a while.

Then came one of the worst droughts on record. Streamflow dried up, and so did the scoured pools and their resident fish. This meant that many of the initial gains were lost.

After the drought set in, only a few fishes and other animals survived — and only in the few deep pools and perennial stream sections at the downstream and upstream ends of the sand slugs. To recolonise the sand-slugged sections when the drought breaks, the fishes will have to recruit and disperse along the sand slugs from those drought-refuge habitats.

In other words, although the red-gum installations created moderate pools which were useful residential habitat, the fishes need deeper and more persistent pools if they are to survive drought within sand-slugged streams. The design of structures capable of creating such refuge habitats remains an unresolved challenge for further research.

Compiling a set of lessons

It is the speed with which rehabilitated habitats are recolonised, and for how long the recovery endures, that show whether rehabilitation projects have been ecologically successful. Landscape-scale factors that cause the streams to need rehabilitation in the first place (perhaps erosion upstream, feeding sand slugs) need to be controlled, or else the ecological benefits of

Important ecological questions to consider when planning and setting targets for habitat rehabilitation

1. Are there barriers to recolonisation?
   — What and where are the source populations?
   — How can potential barriers be overcome?
2. Do the target species have particular habitat requirements at different life stages?
   — What are these requirements?
   — How should these habitats be arranged relative to each other?
3. Are there introduced species that may benefit disproportionately to native species from habitat rehabilitation?
   — Can colonisation by these organisms be restricted?
4. How are long-term and large-scale phenomena likely to influence the likelihood, or timeframe, of responses?
   — Will these affect the endpoints or just the timeframe of responses?
   — How will this affect monitoring strategies, and can monitoring strategies be adjusted to deal with this?
5. What size habitat patches must be created for populations, communities and ecosystem functions to be restored?
   — Is there a minimum area required?
   — Will the spatial arrangement of habitats affect this (e.g. through the outcomes of competition and predation)?

From Bond & Lake 2003b

downstream rehabilitation may be short-lived. In the table above, Nick Bond and Sam Lake summarise this and other important ecological issues that need to be considered when planning habitat rehabilitation.

A larger summary of lessons on river rehabilitation is about to be published by the CRC for Freshwater Ecology as a management guide. The guide is not a 'how-to' manual. Instead, it aims to capture recent lessons that have emerged from CRCFE research and from the experience of river managers and rehabilitation practitioners.

First, it outlines some of the key river rehabilitation experiments and projects the CRCFE has been involved in. Then it homes in on ecological principles fundamental to successful rehabilitation. One chapter discusses lessons on planning and setting priorities, while the next describes 'tools' for use in rehabilitation, such as:

- changes to flow regime (usually via environmental flows),
- changes to flow-related habitat,
- changes to channel variability and reintroducing wood habitat,
- replanting (especially riverbanks),
- work on the connections between catchment and stream (in rural areas and urban), and
- restocking with desirable animals including fish.

The report also touches on evaluating the effectiveness of rehabilitation projects.

'Recent lessons on river rehabilitation in eastern Australia' by Peter Cottingham, Nick Bond, Sam Lake and David Outhet, is expected to be available by September.

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Could targeted water management bring invading species under control?

'Arrowhead', a weed invading Broken Creek, Victoria.
Photo: Goulburn-Murray Water

by David Williams & Sabine Schreiber

What if there was a software tool that assessed the potential spread of aquatic invading species, such as carp, mimosa or alligator weed, in relation to general water management activities? Could it help us prevent the spread of new, unstudied, invaders?

A broadly skilled team from across the CRC for Freshwater Ecology has begun to make such a tool, and already it is suggesting mechanisms that managers might use to control invading species.

Our team, consisting of plant and animal ecologists, a population modeller and a GIS modeller, wanted to simulate the spread of aquatic invaders, both plant and animal. Instead of focusing on particular species we targeted the pathway common to many different invading species — our waterways — and a common method of transport — water movement. We constructed a model world in which we could simulate a number of scenarios and compare the outcomes of an invasion after a given period of time in each scenario.

In our model world the pathway for spread consists of a series of waterways, such as sections of a heavily regulated river (for instance, the stretch of the River Murray between the Yarrawonga weir and Mildura), or an irrigation system. In both cases, managers in the real world have some control over the amount and timing of water flowing down the channel, which is a major vector in the spread of aquatic invaders.

Our model's concepts, operating rules and scenarios are all based on knowledge of existing species invading inland waters: their population biology, habitat preferences and population responses to environmental factors. For instance, our preliminary literature searches revealed two generalities about invading aquatic species: the life-histories of many of them consist of one to four stages, and in many cases one lifecycle is completed within one year. These observations reflect the statement often made about successful invaders — namely that their reproduction is fast and frequent.

There are rules for the movement of individuals between sections in our model world. They dictate that movement can only be in the direction of water flow — downstream — and only a certain percentage of new recruits to the population are allowed to move into the next section. However, during 'floods' or movement of larger volumes of water in the model, more individuals can move from one section to the next. We also assume that the number of individuals a given section of stream can support depends on the physical length of the section.

We explore a range of scenarios: variations in flood frequencies, in the size of the initial invasions and in the connection of the main river channel to a floodplain. Outputs of the model are displayed via a geographic information system (GIS) and animations that show how an invasion progresses in different scenarios.

To deal with the unknown and often un-knowable variability ('stochasticity') existing in real populations and environmental conditions, we run each modelled population cycle many times in each scenario. After 1000 iterations we start to see the full range of possible trajectories that the population of our model species could follow, within the parameters we set.

We find that flood frequency is very important to the speed and intensity of the invasion. With floods occurring every five years, final population sizes in our model world end up many times greater (in some instances up to 100 times greater) than if a flood occurs every 10 years. The size of this difference suggests that management should make it an imperative to tackle new invasions before the next flood.

Drought conditions, on the other hand, can result in the drying of particular sections and thus interrupt the spread of the invasive species from one section to another. This is simulated in a scenario that has an influx of the invasive species only in year 1. Even when 5000 individuals invade, the population densities decline during the subsequent modelled time period.

In the simulations it takes some time until the invader has passively spread throughout our model world: an invader can have individuals present in low densities for many years but then, due to simple stochasticity, its populations can suddenly increase dramatically. As a result, we cannot assume that an invader that is now present in low numbers is under control and will remain in low numbers.

Australia's quarantine laws for invasive species focus on modes of transport and entry points of invasive species into the country. This is an effective and efficient way of simultaneously targeting a broad range of invaders. The software tool we are building may help catchment managers to adopt a similarly efficient approach for unwanted species that have already invaded our waterways. Instead of needing to develop a new approach for each new species, we may instead be able to manage the means of spread, and thereby potentially target a range of species at once.

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The creature feature for this issue is the darter

Family: Anhingidae
Species: Anhinga melanogaster

Most closely related to cormorants, the darter is also known as the snake-bird, in reference to its slender neck and head — the only parts of the bird visible when it is swimming at the water's surface. The neck has a distinct kink in it, associated with a trigger process in the vertebrae that allows sudden stabbing of the slightly opened bill to spear fish and other aquatic animals while swimming underwater. This manner of feeding gives rise to the less commonly used alternative name of needle-beak shag.

The plumage is easily saturated during its hunting activities, and much of the darter's time out of water is spent with wings outspread drying the feathers. The short legs are placed well to the rear of the body allowing the darter efficient and graceful movement underwater. On land however, when the darter walks it must stretch out its wings for balance.

The species is widespread across mainland Australia but is patchy in distribution, depending on habitat and rainfall. It is an erratic breeder, more commonly nesting during February–April in northern Australia, and August–December in southern regions, but it may still nest at any time when water levels and food are

Darter (Anhinga melanogaster) *in typical pose.*
Photo: Geoffrey Dabb.

suitable. Nests can be solitary, but are more usually in colonies, often amongst cormorants, spoonbills and ibis. The nest is a bulky platform of sticks up to 0.5 m in diameter, well lined with leaves, and overhanging the water in a dead or live tree. Two to six but usually four eggs are laid. Both parents incubate; chicks hatch after four weeks and leave the nest at six to seven weeks.

The darter's preference for deep open water-bodies means that local control of water levels and permanent inundation of wetlands has probably compensated for adverse effects of reduced flood duration on its breeding habitat. However where permanent flooding of wetlands has killed the river red gums used for nesting, this compensating effect may be reversed once the dead trees eventually rot and fall over.

by **Nicki Taws, Greening Australia**

WATERING PATTERNS FOR FLOODPLAIN EUCALYPTS

Studies of river red gum and blackbox trees along the South Australian part of the River Murray have given Amy George insights into the river flows that stimulate these eucalpyts' regeneration and growth.

Working towards her PhD with supervisors Keith Walker and Megan Lewis of the University of Adelaide, Amy examined the growth rings in trees approximately 30 and 50 years old, and matched them up with the corresponding years' river flow records at the South Australian border on the Murray.

Her study suggests that active tree growth in these two species (*Eucalyptus camaldulensis* and *E. largiflorens*) relies on moderate-size river-flows of 40,000–80,000 ML / day and average rainfall (i.e. 250–300 mm/year). Wetter or drier conditions depress tree growth, either through excessive saturation or through drought. Since river regulation, these moderate-size flows occur around half as often as they did before regulation, according to gauge records.

Rate of growth of individual trees is only one part of the regeneration story of eucalypts. Tree health is the most visible expression of the status of a tree stand — and healthy stands play a vital role in maintaining healthy rivers and floodplains. Therefore, Amy examined the implications of tree health on reproduction in these floodplain eucalypts. She found that early stages of regeneration, including budding, flowering, fruit formation and seed production, are severely altered in less-than-healthy trees.

Since a healthy natural stand of floodplain trees is usually multi-aged, Amy also mapped existing stands of river red gum and blackbox, identifying their approximate ages by using relative size as a surrogate for age. Closer examination of the numbers of seedling and sapling trees showed that in 2002 there were too few young trees to replace the existing number of mature trees, should extensive mortality occur. The situation was found to be better among river red gums than among blackbox. The most recent river red gum surveys conducted along the River Murray in 2004 indicate that tree decline has continued, suggesting that floodplain areas would greatly benefit from flows that not only allow the current trees to survive but also provide conditions suitable for regeneration.

*River red gums.
Photo: Andrew Tatnell*

Amy's work illustrates that environmental flows ideally need to do more than simply provide water to stressed trees. Flows of various magnitudes play a part in all stages of the regeneration process of floodplain eucalypts. To ensure that river red gum and blackbox trees persist on the River Murray floodplains, flows should be managed with each regeneration stage in mind.

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Amy is the CRCFE's candidate for the 2005 Young Water Scientist of the Year Award, to be judged at River*symposium*, Brisbane, in September.

What do we know about assessing aquatic biodiversity?

Most management plans for inland waters refer to aquatic biodiversity and the need to protect it. To support those who want to check on the aquatic biodiversity in the inland-water systems they manage, the CRC for Freshwater Ecology (CRCFE) has compiled a summary of advances in our knowledge about monitoring and assessing biodiversity. The summary (briefly described here) outlines aspects of biodiversity that need to be considered before measurements are begun.

As in any study, choosing objectives — the questions that need to be answered — is an extremely important first step in assessing biodiversity. Most study objectives fit into one of three categories: (i) describing how aquatic biodiversity has been affected by human activities; (ii) describing patterns of natural biodiversity in inland waters, and (iii) describing the factors controlling biodiversity in aquatic 'landscapes' — an objective sometimes not completely separable from (ii).

It is important to know that different types of biodiversity study can answer different types of question, and that confusion can arise if the objectives and study type are not matched. Different types of study use different levels of accuracy and precision to estimate biodiversity. Some of the aspects of biodiversity commonly measured include:

- the number of groups (taxa) of plants and animals present in an area (taxonomic richness),
- the composition and ecological functions of the groups present,
- the relative abundance of different groups,
- the integrity of the populations; for example, the proportions of native and non-native biota present,
- the uniqueness of the groups of organisms present.

Generally the most intensive type of study is taxonomic inventory. These studies collect, identify and count a high proportion of species occurring in a particular site or set of habitats. They are labour-intensive and aim for highly accurate and precise estimates of:

- the number of species occurring in a given place or on a given occasion;
- the number of species there are (a) in total, and (b) relative to each other, (c) in a particular habitat or range of habitats.

Often, this type of study is used to describe natural patterns. Yet it can also answer questions about the impacts of some event or activity on particular species (e.g. those that are rare or threatened).

A possibly more common type of biodiversity study engages in rapid comparative biodiversity assessment and monitoring. These studies generally identify to a higher taxonomic level than species (e.g. family or sub-family), and compare the numbers of those taxa occurring in a particular habitat or set of habitats (assessment), through time (monitoring). An essential feature is the *comparison* between the observations and a set of reference values of some kind, which requires a standardised sampling approach. Reference sites most commonly chosen are areas in relatively natural pre-European condition, where available. Assessment and monitoring are efficient ways of answering the following questions:

- what are the impacts of some event or activity on the taxonomic richness of one or more sites or habitats, relative to similar but unaffected sites or habitats?
- what is the ratio of native to non-native taxa in a site, relative to reference?
- what is the site's or area's conservation value?

While mainly used for describing human influences, this study design can also be used to compare the natural biodiversity values of sites.

Answering the question

As suggested above, the summary report emphasises that it is very important to be sure about what we want to know before investing in a biodiversity assessment study of any kind.

Once we know the question, we can decide which biotic groups to measure and whether to measure all or only some biotic groups; whether we need to involve genetics as well as visible characteristics to identify the biota; and whether surrogates (for example higher taxonomic richness) will be adequate to answer our question. Knowing which biotic groups to measure helps us decide how long the study must last and how far it should extend. For instance, studies framed around trees and long-lived migratory fish may need a longer time-frame and perhaps a larger area than studies based on short-life-cycle invertebrates and algae in confined habitats.

If the biodiversity is to be studied in relation to disturbance, the scale of the study will depend on the geographic influence of the disturbance and the number of years for which its effects will be felt. There is a danger that 'noise' in biodiversity patterns at a scale of a few kilometres or months will mask fundamental patterns of biodiversity across catchments and years.

The number of samples needed (and consequent labour, funding and storage resources required) depends on the question. Inventory studies may need more samples than relative assessment studies, and accurate assessment of impacts could need more samples than routine monitoring studies. Sampling times and sampling gear will also depend on the question and the biota being sampled.

Equally, the way the data are collected and interpreted to gain information about biodiversity will depend on the question. Measures of composition and abundance help identify community structure, while measures of native vs non-native species or numbers of particular feeding types will answer questions about ecosystem integrity and function.

The management guide, *Assessing and monitoring aquatic biodiversity: what have we learnt?*, outlines advances in our capacity to 'answer the question'. (A classification of different types of question in aquatic biodiversity studies, and a formal framework for applying the classification, are part of an ongoing PhD by Simon Linke, a student of Richard Norris at University of Canberra.) The guide has been compiled by Ruth O'Connor and Amanda Kotlash, in consultation with a biodiversity forum that included a range of CRCFE researchers and managers. It is available on the CRCFE web site at http://freshwater.canberra.edu.au.

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Sandy Creek, near Lake Cordeaux, NSW.
Photo: courtesy of Sydney Catchment Authority

'Oils' ain't (necessarily) 'oils': the importance of knowing what you're dealing with

For detailed observations of the effects of management actions, it is useful to know which species are being affected. To assist in this, the CRC for Freshwater Ecology has added considerably to knowledge of the species-level taxonomy of, particularly, freshwater invertebrates and algae.

During 1993–2005, the CRC for Freshwater Ecology (and in particular the Murray-Darling Freshwater Research Centre (MDFRC) at Albury-Wodonga), through John Hawking and his colleagues, has published around 50 identification guides to species of freshwater macro-invertebrates (largely insect larvae and crustaceans), algae and fish larvae. MDFRC has also held annual taxonomic workshops offering training in species-level identification. This huge body of work helps both scientists and water managers to know the species they are working with. The taxonomic information is fundamental to understanding why particular conditions cause animals and plants to die out or move away.

All living things (plants, animals, microbes, etc.) are classified into a seven-tiered taxonomic system, using Latin names. The same taxonomic system is used all over the world; so a world-travelling species of fish, for example, may have numerous common names, varying from region to region, but a single Latin name that identifies its genus and species — i.e. its place in the universal classification.

The taxonomic levels, from highest to lowest, are:

Kingdom (e.g. Animalia, Plantae, etc.)
- Phylum
  - Class
    - Order
      - Family
        - Genus
          - Species.

Individual genera and species within sub-families or families can have quite different functions and needs from each other, which cannot necessarily be identified by sorting samples only down to family. The visible differences between species are useful both for visual identification and also to reveal something of the species' habits and activities. For example, species that live in fast flow have streamlined bodies, whereas species that hide in niches in river snags or behind rocks do not. Shapes and types of mouthparts such as teeth reveal feeding methods, and shapes of claws and ovipositors suggest digging and egg-laying behaviour that cannot be observed in other ways. This information, together with records of habitat conditions, can tell researchers a great deal about a species' role in its ecosystem. For instance, leech species have a range of mouthparts, allowing some to prey on other invertebrates and others to feed on the blood of fish, reptiles, amphibians, waterfowl or mammals.

By collecting, sorting and identifying individuals to the lowest taxonomic level, researchers can measure the populations of a particular species or genus, and detect such details as predator–prey relationships or the proportions of particular feeding groups; e.g. shredders compared to filter-feeders. Repeated measurements over time make it possible to detect subtle changes. (In contrast, rapid assessment methods, of which AUSRIVAS is one example, generally look for presence or absence of particular *families* rather than species, and the resulting data mainly indicate river condition, rather than the reasons for change.)

Species are observed to differ in sensitivity to water temperature. For example, the water released from a dam is often cold relative to the natural river temperature, and as a consequence it cools the reach immediately below the dam. The artificially lowered temperature delays the maturation of temperature-sensitive invertebrates. This reduces the production of eggs and then of new larvae, ready for fish larvae to eat later in the year. Larval fish (often only millimetres long) have very small mouths and cannot manage large prey. So there is a flow-on effect to the fish populations. If you know the species in your samples in spring, you can tell if this sort of effect is happening, and you have a chance to modify the

Populations of freshwater prawn (Macrobrachium australiense) *can look the same but differ genetically. Photo: Mike Bell*

flow regime suitably. Further analysis can suggest effects on the whole food web.

Observations of ‘riverine’ families, which have both adult and larval stages always in the stream, show that they deal with temporary decline in their habitats by changing into dormancy stages and trying to sit out the changed conditions. Examples are the yabbies and freshwater crayfish (all in family Parastacidae), which burrow and wait for better times. When conditions become more suitable, they emerge and carry on with life, though they may then find themselves out of sync with other parts of the riverine ecosystem.

Another type of behaviour is shown by ‘opportunists’ — particularly fauna families and sub-families whose adults are terrestrial or winged. Backswimmers (Notonectidae) are in this group. When conditions deteriorate in their billabong they rapidly mature and fly out to find a more suitable billabong. *Cheumatopsyche* (a genus of Hydropsychidae, one of the families of caddisflies) is another example. These filter-feeding predators are adapted to flowing water, and when their reach stops flowing they have to make do with pool conditions or transform into their adult winged form and produce a new generation elsewhere.

Variability of flows and depths across an area makes a range of habitats available, which organisms can move to. However, artificial variability, e.g. drawdown in a billabong, needs to be operated at a rate slow enough to allow the mature stages of, say, backswimmers and chironomids to develop so they can fly out. Thus smart and knowledgeable water-management can produce ecological benefits that can be detected because we can recognise and identify the species involved.

At a still finer level of detail, Jane Hughes and her team at Griffith University in Queensland, using molecular techniques, have identified individuals that are classified as the same species based on their visible features but that are different at the genetic level. This work is complementing the visible taxonomy that has been so carefully explored in the CRCFE. Some genetically distinct species that look similar to one another have been shown to have been evolving separately for millions of years. They may also be very different ecologically. For example, within a group of such species, some may flourish in streams with high levels of pollution, while others depend on streams with low pollution levels. Lumping them all together in an analysis will mask any pollution effects.

Information about genetic differences is also very important for fisheries biologists and water managers who translocate fish stocks and transfer water between basins. Without knowledge of the amount of diversity present in the natural populations in each place, it is not possible to predict the effects of these management actions, let alone to conserve and manage the biodiversity for its own sake.

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Caddisfly larva (Cheumatopsyche), *without case. Photo: John Hawking*

Life in the slow lane: how a freshwater turtle comes to thrive in the outback

by Arthur Georges, Mel White, Enzo Guarino, Nancy Fitzsimmons and Tara Goodsell

For its long-term persistence, the Cooper Creek turtle depends on the existence of semi-permanent and permanent waterholes, as well as episodic flooding.

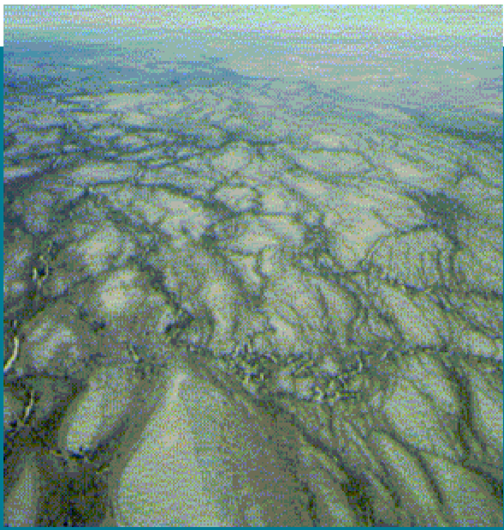
Australian freshwater turtles are members of a group not found outside the Australasian region and South America, even as fossils. Those that remain today in Australia have had to cope with progressively increasing aridity, and they have adopted many novel mechanisms for doing so. The northern long-necked turtle (*Chelodina rugosa*) survives by burying in the soft mud of its wetland at the beginning of the tropical dry season and waiting ('hibernating') beneath the cracked mud until the rains return. The northern stinkpot (*Chelodina canni*) lives in drier country of the wet–dry tropics. When the water dries up, it moves away and waits in crevices, hollow logs, or burrows of other animals until the rains come, perhaps at intervals as great as five years. Further south, the common long-neck turtle (*Chelodina longicollis*) manages the cycle of wet and dry by moving between ephemeral and permanent water, often spending many weeks or months on land. Other species, primarily river turtles of the genera *Emydura*, *Elseya*, *Rheodytes* and *Elusor*, cop out, and are only found in permanent water. It comes as a bit of a surprise then, that one of these occurs in the arid outback — *Emydura macquarii emmottii* of the Cooper Creek drainage, where most water is not permanent.

The Cooper drainage has its headwaters in tropical and subtropical Queensland and runs south-west as a broad distributary network through land of very low relief before flowing into Lake Eyre. It is a dryland system with episodic flow, fed by rains in its headwaters under tropical monsoonal influence. During the extended dry periods, water retreats into river-channel waterholes scattered through the arid landscape. They form important refuges for aquatic organisms that do not have desiccation-resistant stages in their life-history. During the episodic floods, the waterholes become interconnected across a vast, inundated floodplain.

Recent work by the CRCFE's Dryland River Refugia team, as part of the large project of the same name, examined turtle populations in the waterholes. The team found that, except for a few wayward individuals, the turtles never occupy waterbodies that dry annually or that have a life of only a few years. They do, however, live in the semi-permanent waterbodies that dry up during protracted drought. Any turtles present when the waterholes dry up most certainly perish.

The Tanbar Homestead Waterhole is one example of a semi-permanent waterbody. It dried completely for about three years in the 1983 drought, but has held water consistently since. The population there is at the beginning of the successional series, with a low population density, plentiful food per individual, rapid growth rates, and a good recruitment of young turtles for the forthcoming generations. It is a population on the upswing. The other end of the successional series is found in large deep permanent waterholes that have never dried. An example of this is Eulbertie Waterhole, again on Tanbar Station. The population consists almost entirely of large adult turtles in exceptionally high densities — one large turtle per 7 m^2. (You would not want to dive in too often!) There are few food resources

The Cooper Creek turtle. Photo: A. Georges



Aerial view of the Cooper Creek channels.
Photo: CRCFE

per individual, slow growth rates, and little or no evidence of recruitment. A number of other waterholes lie in intermediate positions on this spectrum: Fish Hole, Waterloo, and Broadwater Waterhole, for example.

Both permanent and semi-permanent waterholes, together with the episodic floods that reset the semi-permanent holes after infrequent drying, appear to be essential for the long-term persistence of the Cooper Creek turtle. The permanent waterholes serve as sources of individuals that disperse across the floodplain during flooding, when the waterholes are interconnected, but most of the recruitment occurs in the semi-permanent waterholes where the populations are active. The distributary character of the Cooper Creek drainage, the refuge waterholes, and the extensive episodic flooding, all combine in a dynamic system to make it possible for this water-dependent riverine turtle to survive and thrive in arid conditions.

Apart from dry periods in the waterholes, there are human pressures on the turtle populations. Illegal netting is widespread in the Cooper drainage — that is, a number of fishers illegally use 'square hooks' (nets or pots) to rapidly secure a catch. Quite apart from their impact on fish stocks, gill nets and submerged pots trap turtles and cause them to drown. The Dryland River Refugia team found evidence (dead and dying turtles) during the study, and the impact of fishing can be seen in the size distributions of turtles in heavily fished waterholes that are accessible to the general public. The larger animals suffer most. In such a large area, fisheries inspectors and park rangers have a difficult task controlling such fishing.

The Cooper Creek turtles are a prominent and unique feature of the Cooper system. Some of the large adults that are caught and killed to retrieve a fish-hook or that die in nets are certainly over 80 years old, possibly much older. Turtle populations around the world can accommodate high mortality among eggs and hatchlings, but few can sustain high mortality among the adults.

However, times are changing. There are now landcare and catchment management groups bringing together members of the community to address environmental issues and work towards sustainable land-use practices. The community may be able to reduce the incidence of illegal netting. As producers and consumers we are all working to further the economic viability of our rural communities and give them a good future. Maintaining biodiversity on our lands, and especially in critical habitat such as the dryland refugial waterholes, can be considered an essential ingredient in securing that future.

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A Cooper Creek waterhole.
Photo: CRCFE

Trout cod in the Murrumbidgee River

by Jason Thiem

Radio-tracking has explored the behaviour of trout cod introduced into the Murrumbidgee River, NSW.

The endangered trout cod (*Maccullochella macquariensis*), also known as bluenose cod, persists as a natural population in the River Murray below Yarrawonga and a translocated population in Sevens Creek, Victoria. In the past, trout cod raised in hatcheries have been released in the Murrumbidgee River as fingerlings, to try and restore the species there. However, restocking trout cod fingerlings into the species' former range has not always resulted in self-sustaining populations. A new project run by Environment ACT with support from the CRC for Freshwater Ecology* has been testing the success of releasing older fish instead.

Trout cod fingerlings (left) and adult (right).
Photo: Environment ACT

Fifty-eight young trout cod were fitted with radio-transmitters, then released 5 km upstream of Narrandera, NSW, and radio-tracked for 12 months. Twenty-seven of the cod came as two-year olds (300–430 mm long and 500–1550 g weight) from the Snobs Creek Hatchery in Victoria. The other 31 were 'wild' sub-adult trout cod (370–630 mm and 600–3700 g) previously stocked as fingerlings in the Murrumbidgee River and recaptured by boat electro-fishing for the project, with the help of staff from NSW Department of Primary Industries.

From analysis of the movements of the radio-tagged fish in the study reach between Yanco Weir and Berembed Weir, we found that the two-year old hatchery trout cod dispersed much further than the wild fish. The wild fish mostly stayed within 5 km of the release site (both upstream and downstream) whereas the hatchery fish gradually moved up to 50 km downstream. By four weeks after release, both river and hatchery fish had set up home-sites that they returned to regularly — usually a pile of in-stream wood or an individual log or hollow. Interestingly, the home-sites of 13 of the 31 wild fish were within 50 m of the original locations from which they had been captured. Several even returned to their pre-capture log or log pile.

During late spring or early summer, the project examined the fishes' home-ranges and daily activity over a number of 24-hour periods. We found that most of the individuals used a home-range no more than 272 m long. They appeared to be relatively sedentary during the day and more active at night. However, the remote telemetry loggers that were stationed at Berembed and Yanco weirs revealed that five individuals had made large-scale round trips of 20–60 km during the year. Manual tracking confirmed that after each journey these mobile individuals returned to exactly the same log, indicating that some trout cod travels may not be detected using conventional monthly tracking.

Other types of movement were also noticed during the study: the two largest fish were nomadic ('no fixed address') and one individual relocated to a new home-site 35 km away for four months, before returning to its previous home-site.

The project has contributed information useful for management of stocking densities and for understanding the ways individual restocked fish use home-sites. The information is now being extended to smaller rivers by radio-tracking two-year-old hatchery trout cod in the Cotter River (ACT) and the ACT section of the Murrumbidgee River.

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Northern Basin Lab winds up

by Janey Adams and Glenn Wilson

Due to a business decision made by the Board of Directors, the Murray-Darling Freshwater Research Centre's Northern Basin Laboratory in Goondiwindi ceased operations on 30 June 2005. Some personnel will be continuing their research contracts at universities that were CRCFE partners, while others will be moving on to other career opportunities.

The role of freshwater ecological research in the northern Murray-Darling Basin is acknowledged, and it will continue in various projects, from a different base. For example, the Narran Lakes Project, funded by the Murray-Darling Basin Commission (MDBC) and outlined below, is continuing, and there is ongoing monitoring for the MDBC's Sustainable Rivers Audit, as well as new studies on the impacts of managed flows on fish spawning and recruitment.

History

The Northern Basin Laboratory (NBL) was established in July 2000 by the CRC for Freshwater Ecology (CRCFE) with support from the Queensland Department of Natural Resources and Mines (NR&M) and Griffith University. Initially having a staff of one (Glenn Wilson), it was housed in the NR&M offices before relocating in August 2003 to separate premises. By March 2005, the NBL had a staff of nine:

- Dr Glenn Wilson, Scientist-in-Charge
- Dr Cassandra James, Research Scientist
- Dr Tariq Khan, Aquatic Ecologist (NR&M)
- Dr Minal Khan, Aquatic Ecologist (NR&M)
- Ms Janey Adams, Senior Community Scientist
- Ms Melissa White, Research Assistant
- Ms Angelene Wright, Research Assistant
- Mr Adam Logan, Research Assistant
- Mrs Christine Dinsdale, Admin Assistant.

The Northern Basin Lab, August 2003–June 2005. Photo: CRCFE.

During its existence, the Northern Basin Laboratory has focused on the effects on local aquatic ecosystems when there is increased water diversion from rivers; the functioning of dryland rivers as ecological refuges during drought periods; and improved means of monitoring aquatic ecological health.

Staff of the NBL have participated in the following projects.

Dryland River Refugia. This CRCFE-funded project examined the significance of permanent waterholes to the aquatic biodiversity of dryland river systems. From 2002 to 2005, the team studied patterns in waterhole biodiversity, turtles, fish, macroinvertebrates, algae, benthic metabolism, water chemistry, and plankton across the landscape of Cooper Creek (Lake Eyre Basin) and the Warrego and Macintyre-Barwon Rivers in the Darling Basin. NBL staff contributed a major portion of the fish component of this project.

River health assessment in the northern Murray-Darling Basin. This CRCFE-funded project (2001–2003) had two broad components:

- comparing different aquatic health indicators (e.g. macroinvertebrates, diatoms, plants) along gradients of salinity, flow alteration and in-stream sedimentation; and
- using information on fish habitat requirements and the distribution of key habitat components across a catchment to assess stream health.

Study sites were located in the Warrego, Condamine-Balonne, Border Rivers, and Gwydir catchments.

Ecological character of the Narran Lakes ecosystem. This MDBC-funded project is a four-year study (2003–2006). It is investigating the ecological character of the Ramsar-listed Narran Lakes ecosystem in north-western NSW and assessing changes likely to occur under various water-resource development and climate change scenarios. NBL staff have played a major role in this study, particularly in the research examining the effects of flow on the area's vegetation, macroinvertebrates and fish, all in collaboration with other CRCFE scientists from Monash University and University of Canberra. Meanwhile, the local knowledge of the lakes is being documented through interviews with long-time residents of the Narran River valley.

Biodiversity of riverine landscapes: the role of patches and connectivity. Funded by Land and Water Australia, this three-year (2004–2006) project is examining the importance of particular types of habitat (anabranches, deep holes, riffles, and so on) to fish, plankton production, organic matter and water chemistry in the Macintyre River.

Northern Basin Freshwater Forum. NBL staff hosted the inaugural Northern Basin Freshwater Forum in November 2004, in which catchment managers and researchers, as well as educators and social scientists, gathered to share their expertise and discuss ways to improve the connections between researchers, managers, and the community of the Northern Basin region.

Outcomes

The opportunity to do research in and be part of the northern Murray-Darling Basin region and communities has provided new scientific information and insights, particularly about fish and wetlands, which have contributed to understanding and management of:

- fish growth and the timing of breeding,
- carp,
- native fish populations,
- wetlands,
- regional and catchment planning for natural resources and freshwater ecology,
- river rehabilitation.

The lab has hosted postgraduate researchers from University of Canberra (Mark Southwell, Heather McGinness) and Griffith University (Elvio Medeiros, Susan Lutton); and around 12 scientific papers and reports, 10 conference and workshop presentations, and numerous other presentations to the regional water industry and community bodies have been derived from the lab's work.

It's been a productive five years.

SideStream

2005 Terry J. Hillman Honours Scholarship Awards

The Terry J. Hillman Honours Scholarship, awarded annually by The Murray-Darling Freshwater Research Centre (MDFRC) acknowledges the significant role that Terry Hillman played during his years as Director of the MDFRC from 1993 to 2001. It is open to students commencing Honours from either Charles Sturt University (CSU) Albury or Wagga Wagga campuses, or La Trobe University (LTU) Wodonga or Mildura campuses. Congratulations to the 2005 winners who were: Rose Barrett from LTU for her project entitled 'The relationship between aquatic macrophyte communities, water regime and wetland type in wetlands along the Murray River', with supervisors Roger Croome (LTU) and Daryl Nielsen (MDFRC); and Emily Mendham from CSU for her project entitled 'Factors affecting landholder adoption of native vegetation best management practices in the Murray Land and Water Management Plan area', with supervisors Joanne Millar and Allan Curtis (CSU).

Terrry Hillman. Photo: CRCFE

Waterwatch Macroinvertebrate Workshops 2005

Recently, Waterwatch Victoria, with the support of John Hawking, Lyn Smith and Kathie LeBusque from the Murray-Darling Freshwater Research Centre and CRCFE, held two successful macroinvertebrate training workshops. These annual workshops are intended to increase Waterwatch Coordinators' skills and confidence in field-sampling and taxonomy. In turn, these support the monitoring efforts of schools and community groups. The workshops were an excellent opportunity to try out the online colour guide, 'Identification and Ecology of Australian Freshwater Invertebrates', currently being developed by John Hawking's team. Coordinators were impressed with the draft guide and its potential as both an educational and a capacity-building resource.

New South Wales award for CRCFE student

Craig Boys has been awarded the annual John Holliday Student Conservation Award, by the NSW Department of Primary Industries. Craig is a CRCFE PhD student at the University of Canberra, working with supervisor Associate Professor Martin Thoms. He has been researching associations between freshwater fish and their habitats in the Barwon-Darling River.

Moving on

Michelle Bald who was the CRCFE Knowledge Broker at the Mildura Lower Basin Laboratory of the Murray-Darling Freshwater Research Centre and CRCFE moved to Adelaide in April to join the South Australian Department of Water, Land and Biodiversity Conservation. *Bronwyn Rennie*, who has been a Community Scientist with the Canberra office of CRCFE, has moved to Perth to join the Western Australian Department of Environment.

Young Water Scientist of the Year 2005

River*symposium* is again hosting the CRC Water Forum's Young Water Scientist of the Year Award, in early September in Brisbane. Postgraduate students who are associated with a cooperative research centre, and who are either in the final year of a PhD or have just submitted the thesis, summarise their research findings for a panel of independent judges. The judges choose one finalist per CRC. The finalists then present their work at a major conference, both verbally and as a written paper for the Proceedings, and the judges select one winner on the basis of the conference presentations and papers. This year the award has been opened to any CRC PhD students working on water-related topics. The finalists are: Brett Anderson (CRC for Catchment Hydrology), Cara Beal (CRC for Coastal Zone, Estuary and Waterway Management); Amy George (CRCFE); Michael Rose (Australian Cotton CRC) and Ian Stewart (CRC for Water Quality and Treatment). For details, see http://freshwater.canberra.edu.au/waterforum/.

NABS

The 2005 Conference of the North American Benthological Society (NABS) was held recently in New Orleans, USA. CRCFE work was well represented, with papers on geomorphology of large dryland river systems, autocorrelation within dendritic stream networks, hybridisation between wild populations, macroinvertebrate response to urban land use, dryland-river benthic algal production and food webs, biological history via sand islands, conservation planning in river landscapes, multiple lines and levels of evidence for ecological responses, flow regime and invertebrates in upland rivers, and defining macroinvertebrate reference communities in disturbed areas. Professor Richard Norris (University of Canberra and CRCFE) took up the role of Chair of the Executive Committee of the Society at the conference.

New reports and guides on the CRCFE web site

Assessing and managing biodiversity: what have we learnt? is a new management guide compiled by Ruth O'Connor and Amanda Kotlash of CRCFE. It is available now at http://freshwater.canberra.edu.au > publications > technical reports.

Floodplain inundation and fish dynamics in the Murray-Darling Basin. Current concepts and future research: a scoping study, by Russell Graham and John H. Harris, is now available at http://freshwater.canberra.edu.au > publications > technical reports.

Riparian vegetation diversity in the Sydney Catchment Authority's area of operation, by David Williams and Jane Roberts, is now available at http://freshwater.canberra.edu.au > publications > technical reports.

Photo: Andrew Tatnell

Feature plant: Cumbungi
by David Williams

Family: Typhaceae (10 species in the world)
Species: *Typha* spp. (3 species in Australia)

Long known in Australia as cumbungi, the two native species of *Typha* (*T. orientalis*, *T. domingensis*) and the single introduced one (*T. latifolia*) are large perennial aquatic herbs that can dominate vast areas of permanent and seasonally flooded areas. They grow in wetlands, on floodplains and along streams and channels, and have increased in abundance where flows have become more regular, nutrient enriched or slower, as in weir pools. Their extensive rhizome systems produce shoots with leaves that can be more than 3 m long. Flowering is in early summer. Each flower stalk has a male flower spike on top of the larger female spike (typically associated with cumbungi). Most fully-grown shoots die in late autumn and the remainder are dormant during winter. Cumbungi species contribute carbon to wetlands and rivers; are used in treating wastewaters; are food and shelter for animals; and reduce some kinds of erosion by trapping silt and absorbing wave energy; but they also reduce flow in irrigation channels and drains and can be a weed of irrigated rice crops. Control methods can involve cutting under water, burning, draining, cultivation and herbicides.

Comments are welcome and can be sent to:

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