COOPERATIVE RESEARCH CENTRE FOR
FRESHWATER ECOLOGY

KEEPING A FOCUS ON FRESHWATER ECOLOGY

G Jones

Knowledge is essential

The Cooperative Research Centre for Freshwater Ecology (CRCFE) set out nine years ago to help improve the health of Australia's rivers. In this task we are beginning to be successful. Through our nineteen research- and industry-partners, and our research- and knowledge-exchange teams, we are seeing awareness raised at all levels of government and throughout the rural community. In spite of severe drought, environmental flows are being planned and in some cases implemented in rivers that have been regulated by damming or diversions. The need to ensure ecological health in rivers and streams, upland and lowland, is now widely accepted.

But the work of restoring river health is just beginning. River managers and the community across Australia are willing, but they need detailed quantitative knowledge as well as predictive tools for evaluating scenarios, at both small scale and at catchment and landscape scale. This is where the CRCFE continues to focus its efforts.

Knowledge transfer – we prefer to see it as knowledge exchange between scientists and stakeholders – is central to our mission. With knowledge exchange staff now in Goondiwindi, Mildura, Sydney, Melbourne and Canberra, we are linking our growing knowledge base with existing information regionally and in capital cities across the eastern states. By synthesising and delivering useful knowledge, we are helping address the problems faced by industry and society when managing freshwater health. Ministers, agencies, the media and the community seek our advice on many existing issues, and we are in a special position to look ahead to the future of water resources and their health.

In its drive to produce useful knowledge, the CRCFE has a research portfolio that contains a mixture of long-term integrated field and laboratory projects addressing strategic priorities, and short-term projects addressing immediate needs and knowledge gaps. Several large multi-disciplinary projects currently form the core of the CRCFE's research portfolio. Probably only in a Cooperative Research Centre context can geomorphologists from Canberra work with invertebrate ecologists from Brisbane, fish ecologists from Mildura and chemists from Melbourne on the same project.

The CRCFE research portfolio addresses five key national issues:

- the effects of regulation of our river systems, and the pressure for development of currently unregulated water resources;
- the serious degradation of many of our urban and rural aquatic systems and the lack of knowledge about how to rehabilitate them;
- the loss of ecosystems and biodiversity;
- the lack of detailed information about the condition (or health) of Australia's aquatic ecosystems;
- the lack of fundamental scientific understanding of the functioning of Australian inland aquatic ecosystems, and how human actions affect biological communities and ecosystem processes.

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Our research is managed through four research programs:

A. Flow-related Ecosystem Processes (Program Leader: Associate Professor Gerry Quinn, Monash University)

B. Restoration Ecology (Program Leader: Professor Stuart Bunn, Griffith University)

C. Conservation Ecology (Program Leader: Dr Margaret Brock, NSW Dept of Land and Water Conservation)

D. Water Quality and Ecological Assessment (Program Leader: Associate Professor Richard Norris, University of Canberra).

Flow-related ecological processes

How does flow affect ecological processes in rivers and their floodplains? Australia's rivers and wetlands occupy a huge diversity of geographic and climatic conditions, including the coastal fringe and inland, summer and winter rainfall regions, and temperate and arid zone systems. The flow patterns in many of these systems are among the most unpredictable in the world, but regulation has resulted in many changes to their spatial and temporal patterns of flow. Although we know that total flows in many regulated systems are reduced and seasonal flow patterns are often reversed or evened out, our understanding of these effects of regulation on river ecosystems is still limited.

PHOTO: ANTHONY SCOTT

On 22 November 2002, the Hume Dam was about 17% full. The CRCFE is devising principles for managing the ecology of water bodies during drought and will release them early in 2003.

Therefore we are examining selected ecological processes in river channels and their floodplains and wetlands. Also we are continuing flow manipulation experiments in upland and lowland rivers, often interacting with the environmental flow allocation processes occurring in Victoria, NSW and Queensland.

As a result, the program is quantifying relationships between different water release regimes and effects on target species or communities chosen to represent potential 'response' groups. These response groups are not only biota (e.g. fish, invertebrates, riparian and floodplain vegetation), but also ecological processes (e.g. fluxes of carbon and nutrients, nutrient spiralling) and food web dynamics. The program is also challenging the traditional wisdom that the floodplain is the main source of carbon and biota for lowland rivers. In-channel processes and habitats (for fish recruitment, for instance) in the Murray, Ovens and Broken rivers seem to be much more important than previously thought.

Restoration ecology

The recent Land and Water Resources Audit has painted a grim picture of the condition of our streams and rivers. Millions of dollars are being spent on restoration. Unfortunately, little of the past restoration effort has had a strong scientific base, and few attempts have been made to measure resulting environmental benefits. The Restoration Ecology Program of the CRCFE is building our understanding about the ecological processes that underpin stream rehabilitation, so that disturbed stream ecosystems can be more easily restored, and so they will be resilient to natural disturbances. Case studies are being established with relevant management groups as adaptive stream rehabilitation experiments. For example, in a recent experiment in Victoria, structures made from red gum have been installed on degraded streambeds, changing the bed topography by generating scour pools immediately downstream, as predicted. The structures themselves have been rapidly colonised by both algae and invertebrates, and native fish have shown a strong positive response. Results like these encourage us in our aim, namely that river restoration practice will become an important part of total catchment management.

Typical questions asked in the restoration ecology program, then, are these:

- Is it true that if you rebuild or recreate physical habitat (the focus of much river restoration action) then organisms will return and ecological condition will improve?
- Can aquatic plants and animals recolonise disturbed sites? Can they disperse from the refuge areas they occupy now, if any, and how far can they move?
- Is it possible to restore key ecosystem processes (such as primary production, nutrient cycling) without completely restoring all elements of the original biological communities?

Conservation ecology

Loss of biodiversity continues to be one of our most serious environmental concerns. Whether we look at wetlands or salt marshes, mangroves or bushland, inland rivers or estuaries, the same story emerges. Degradation of habitat, the major source of biodiversity loss, is continuing at an alarming rate.

The Conservation Ecology Program is busy defining freshwater biodiversity. The program is addressing the questions: What do we have left? What can we do? In Queensland, the Dryland Refugia project is examining fragmentation and connectivity of dryland ecosystems. In other words, are waterholes effective as refugia for aquatic organisms in dryland river catchments? Large integrated data sets are now being processed to answer this question.

A long-term biodiversity monitoring program is being set up for the Sydney Catchment Authority, to (a) measure and assess fish, macroinvertebrate and riparian vegetation biodiversity; (b) identify locations of high conservation value based on their biodiversity characteristics; and (c) monitor and assess biodiversity changes over time. In the rice-growing areas of southern NSW and northern Victoria, the relationship between rice-farming and biodiversity is being studied at farm and regional scales, and a new study on cotton ring-tanks is soon to commence (sponsored by the Cotton Research and Development Corporation) in northern NSW.

Water quality and ecological assessment

Our fourth program investigates water quality, in large urban and other inland areas. On the urban front, the program is investigating processes that degrade urban streams along a rural-urban gradient, with particular focus on stormwater drainage infrastructure. The resulting relationships between indicators of condition and drainage connection provide a link to the emerging field of water-sensitive urban design.

In both urban and rural areas, river-management agencies are moving towards management for the sake of river health, and therefore they increasingly turn to biological assessment methods for measuring the effectiveness of their actions. The CRCFE has been pivotal in the development and adoption of rapid techniques for biological assessment, particularly AUSRIVAS under the National River Health Program.

However, it is not enough to have developed a method and had it accepted. A powerful tool like AUSRIVAS also needs testing in comparison with other techniques, to identify the best method for each situation. Therefore, several biological assessment methods are now being compared in situations of salinity and sedimentation gradients, in three geographical regions. The sensitivities of biological methods in detecting the effects of different impacts have not been thoroughly explored before.

AUSRIVAS and other biological assessment methods depend on reference sites against which to assess the condition of test sites. Sometimes, the comparison is hampered because appropriate reference sites cannot be found in regions that have been significantly modified, including urban areas. Therefore the Water Quality and Ecological Assessment research program has recently developed a new approach, using sites protected by good management practices to define reference condition.

Past and future

So far, this overview has described only some of our current and recently completed work. Over the last nine years, much has been achieved. The CRCFE, under Professor Peter Cullen, had brought together partners from water agencies and industry during those critical years in Australia's freshwater history. Now, having led the CRCFE since its beginning, Peter has retired.

As the new Chief Executive, I have asked the CRCFE to think about how we do research, not just what we work on.

PHOTO: R. ASHDOWN

The Cooper Creek floodplain becomes a slow-moving wetland during a flood.

We are encouraging our researchers to think at the landscape scale and to develop capabilities in ecological prediction and in evaluating management scenarios. These tactical goals will be key drivers of the CRCFE's research portfolio from 2003 to 2006.

Our new thrusts are apparent in the new research portfolio that will soon come into force.

The Flow-related Ecology program will be making measurements during planned ('regulated') and natural flow events, and continuing in-channel manipulations of hydraulic habitat in several rivers. The measurements will provide data for developing quantitative empirical and mechanistic relationships between flow regime, habitat and ecological response, at a range of spatial scales. Statistical analyses of new and existing data will test for quantitative relationships between flow, habitat and biotic response. This program will have formal links with the CRC for Catchment Hydrology.

The Restoration Ecology group will be evaluating methods for rehabilitating rivers. The group will set up experiments to examine the ecological constraints to successful river rehabilitation projects and develop novel process-based techniques for monitoring ecosystem recovery.

The group plans to look for large- to medium-scale genetic connectivity between river and floodplain plant and animal populations. Natural patterns of connectivity found may guide restoration management plans. Predictive ecological modelling will also be a focus of this group, to simulate responses to disturbances and potential management actions, and to optimise resource investment outcomes.

The Conservation program will be asking the question: How do aquatic communities respond to rising salinity? Initially, they will examine wetland biodiversity and ecological processes in saline situations of varying intensity, analysing small-scale experimental manipulations and disturbed field sites.

The structure and ecological pressures that influence or control aquatic biodiversity, in a water-body, catchment or basin need to be identified. The group will be looking for the impacts of human disturbances on large-scale biodiversity patterns, and measuring the conservation value of individual water bodies from several perspectives.

Conservation Ecology is also the program that will be responsible for modelling and predicting the spread and establishment of potential invasive aquatic pests, based on functional characteristics and groupings.

The fourth program, Ecological Assessment and Water Quality, will build a framework for assessing aquatic ecology and water quality with relation to descriptions of habitat. Work on alternative approaches to 'reference' condition in rivers will continue.

In urban areas, this program group, formally linked with a project in the CRC for Catchment Hydrology, will be expanding the relationship between stormwater flow and urban stream health, testing a number of climatic or geographic zones.

In short, interesting new areas of work, challenging scales of thinking, and a developing capacity for ecological prediction should be the hallmark of the CRCFE in the coming seasons.

PROTECTING AUSTRALIA'S RIVERS: URBAN AND INLAND

A Milligan, C Walsh, R Norris, P Liston, I Lawrence

Ecological Integrity

As countries around the world grapple with the poor conditions of their rivers and lakes, the research of the Cooperative Research Centre for Freshwater Ecology (CRCFE) is helping to improve them. The CRCFE has been a main player in developing and assessing methods for measuring the condition of lakes and rivers. In particular, the CRCFE has also met the challenge of controlling urban stormwater pollutants that affect the ecological integrity of downstream waters.

Ecological integrity can be defined as the capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements and processes expected in the lakes or streams of a region. If managers of a river system can maintain ecological integrity in their rivers and streams, then they are almost certain to ensure that the widest possible range of uses and amenities is supported. This is the aim for aquatic systems in Australia and around the world, but few fit the description.

Ginninderra Creek, Canberra, downstream of the dam wall: the health and ecological values of urban waterways can be maintained by upstream flow attenuation and interception of pollutants.

Part 1. Urban waterways

In urban areas with large numbers of people and large areas of impervious surfaces, the ecological integrity of streams is often poor. Urban areas are major sources of contaminants that degrade receiving waters, whether fresh or estuarine. Sewage (and industrial effluents) and stormwater runoff are recognised as major contaminants to receiving water quality in urban areas. Sewage treatment technology is now well advanced in developed parts of the world. It is possible to drink the treated water emerging from a sewage treatment plant in, say, Canberra, although some aspects of the effect of treated sewage on the ecology of receiving streams are not well understood.

Stormwater runoff has less predictable composition than treated sewage. Until the 1970s, when sewage pollution began to come under control in urban areas, stormwater pollution was not recognised as a threat to streams. Yet stormwater regularly contributes nitrogen, phosphorus, heavy metals and other toxicants, COD and suspended sediments to urban drains, streams, lakes and coastal waters.

A drainage system designed to minimise flood risks by efficiently transporting water from the catchment is one of two main characteristics common to urbanised areas in the developed countries of the world. The other characteristic is imperviousness. In hydrological terms, an efficient drainage system carries stormwater and its pollutants quickly and directly from impervious roads, roofs, carparks and paths into urban streams. Imperviousness is the proportion of a catchment that is covered by impervious surfaces (roads, paths, roofs). In large urban areas in the northern hemisphere, imperviousness is blamed for degradation of receiving waters. As a rule of thumb, workers there expect the quality of receiving waters to be poor if 10% or more of their catchment is impervious.

In recent work, Chris Walsh and coworkers from Monash University, a research partner in the CRCFE, have developed a preliminary measure of 'drainage connection'. Drainage connection is defined as the proportion of impervious areas in a catchment that is directly connected to a stream by a stormwater pipe or sealed drain. Walsh's team found that drainage connection is at least as important as imperviousness in explaining patterns of stream degradation.

The team used a variety of biological assessment methods to compare the impacts of imperviousness, drainage connection, density of septic tanks, and density of unsealed roads on the health of small streams in the Dandenong Ranges on the eastern fringe of Melbourne. Attributes assessed included the composition of macroinvertebrate and diatom (microscopic algae) assemblages, abundance of algae on the stream bottom and concentrations of nutrients (such as nitrogen and phosphorus).

Impervious areas and roads were mapped using GIS software, geocoded according to land parcel data, and checked against digital aerial orthophotography. Stormwater drains were tracked from Council and water authority data, and their linkages to impervious areas were identified. Catchments were outlined from topographic maps and stormwater pipe data. Septic tank data came from the rural shire office concerned. Sixteen catchments of varying urban density were chosen for study, with the main criterion for selection being that land use in the catchment be primarily either urban or forest.

Catchment imperviousness was calculated as the proportion of total impervious area to catchment area. Drainage connection was calculated as the proportion of connected impervious area to total impervious area in a catchment. Unsealed road area was assessed in proportion to catchment area. Septic tank density was the number of tanks per km^2 in each catchment.

Across the study area, imperviousness was positively correlated with connection and negatively correlated with unsealed road density; these three factors broadly defined urban density. Subcatchments with 1–10% imperviousness varied widely in their degree of connection.

Differences between streams in macroinvertebrate and diatom assemblage composition, algal biomass and baseflow phosphorus concentrations were all broadly explained by urban density. However, in most cases, the effect of drainage connection independently explained more variation in these biological attributes than did imperviousness. Catchments of 5–10% imperviousness with more than 25% of their impervious surfaces directly connected to streams by pipes, showed strong shifts in species present. Such streams had less than half the sensitive mayfly, stonefly and caddisfly families found in catchments with no urbanisation. None of the streams with more than 25% connection supported an endangered shrimp-like species, *Austrogammarus australis*, found commonly in streams of the study area with fewer stormwater pipes. Furthermore, phosphorus concentrations and densities of algae growing in the highly connected streams were much greater than in non-urbanised streams.

The measure of drainage connection used in this study, while being a strong predictor of stream condition, is somewhat simplistic. However it encapsulates a major element of major stormwater treatment approaches, almost all of which reduce connection between the catchment and the stream by allowing water to infiltrate into the ground or by retaining water in wetlands for treatment. Further research is planned to develop connection as a catchment-scale indicator by incorporating the disconnecting effects of stormwater treatment measures, such as grassed swales, bio-retention systems, wetlands and ponds. From this work it is hoped that catchment planners will be able to predict the effects of different urban designs on the ecological condition of streams.

Key in-stream processes

An important CRCFE research contribution to urban water management has been the understanding of the key in-stream physical, chemical and biological response processes on an ecosystem and pressure (stressor) basis, including the factors (such as flow, pH) that may modify these processes. This research has highlighted the central role of biota (including microbes) in mediating the transformation of nutrients and organic material discharged to waterways, and the role of habitat and flow in determining the structure and composition of biota.

As a result, urban land use and management practices can now be linked to water quality and ecological outcomes. Equally, the understanding enables urban waterway ecosystem options (streams, lakes, ponds, wetlands) and values to be designed and built. They have implications for the sustainability of catchment land use and management.

The CRCFE research has established four pre-requisites to restoration of urban stream health:

- restoration of the geomorphology and physical habitat (including macro-plants);
- restoration of flow regimes and disturbance patterns (environmental flows);
- reduction in water pollution stressor loads to sustainable levels;
- re-establishment of lost species, where local recolonisation sources no longer exist.

The revised *Water Quality Management Guidelines for Fresh and Marine Waters* (ANZECC/ARMCANZ 2000) identify the 11 major issues threatening ecological health or water use. In the case of non-point sources of pollutants (such as urban stormwater), the effects on the receiving waters are 'indirect response processes'. That is, the load of sedimented organic material creates reducing conditions, transforming sedimented nutrients and toxicants into bio-available forms.

Other factors, such as suspended solids loads, flow and detention time, temperature and wind mixing may be important modifiers of these response processes.

The biota associated with the processing of discharged material are the same biota responsible for the ecosystem functioning of the receiving water, and are reflected in measurement of lake or stream health.

Principles guiding sustainable urban development

A set of guiding principles is emerging from this growing understanding of water quality and ecological processes, adaptive management based approaches, and urban water balance based research. The principles also build on the *National Water Quality Management Strategy* planning framework for catchment and stakeholder partnerships.

In principle, sustainable urban development needs to:

- be catchment-based;
- be a partnership, between community, industry and government;
- be knowledge-based, linking catchment management practice and waterway values;
- be an integrated 'water in the landscape'-based design (using total water cycle (TWC) or water-sensitive urban development (WSUD));
- capture multi-functional benefits of urban elements (waterways, wetlands, roads);
- conserve water, by reduction, recycling and restoration;
- use performance assessment and an adaptive review of strategy.

The TWC-based management comprises the integrated use and management of urban water (rainwater, wastewater, groundwater, mains supply) across the landscape to secure a range of social, economic and environmental benefits. The WSUD focus is primarily on residential block arrangements (at-source), which enhance on-site detention (rainwater tanks, infiltration trenches, swales, porous pavements) and conservation of water (rainwater tanks, water efficient appliances, recycling of water). When these two are integrated together, the result is a holistic landscape-based approach to urban water management. Improved information on options for integrated measures for residents, planners, water managers and consultants is the key to this approach.

These approaches can accrue significant water quality benefits because one-in-three-month to one-in-two-year average-return-interval storm events make up 70% to 90% of annual average export of stormwater and pollutants. As well, if infiltration, retention and recycling, and detention (reduced drainage connection) can displace the need for stormwater pipes, there can be major cost savings. Other major benefits are the restoration of soil and groundwater water balance, and the restoration of environmental flows in local urban streams.

Much of Australia's urban water infrastructure is now reaching the end of its economic life. This ageing infrastructure could be replaced by new infrastructure arrangements, based on total urban water-cycle-based management, that yield substantial economic, social and environmental benefits to the community.

Increasingly, urban communities are taking decisions affecting urban sustainability and stream values. Many communities are adopting designed wetlands and stormwater ponds to reduce drainage connectivity. Such an approach can also yield a range of other benefits: open space and amenity, recreational values, pollution control, flow attenuation and drainage management, water supply, conservation and education. Well-designed wetlands can capture all of these social, economic and environmental benefits.

Only through processes enhancing open communication, sharing of knowledge and development of trust, can the ideas and capacity for change be harnessed.

Part 2. Assessment of inland river condition

Away from large urban areas, catchment disturbance is mainly implicated as a cause of deteriorated water quality and reduced ecological integrity. Part of the problem is similar to that in urban areas - contamination by excess nutrients, whether from faecal matter or from fertiliser and surface soils. As well, where vegetation cover has been lost on the riverbank and in the catchment, in-stream habitats are being degraded by sediment that washes into streams during erosion. Hydrological change, imposed when the river flow is artificially reduced by storage or pumping, upsets the natural sequences and seasonal functions of the river and its biota.

The CRCFE, together with CSIRO Land and Water, last year completed a national assessment of river condition as part of the National Land and Water Resources Audit (NLWRA; see www.nlwra.gov.au). The assessment was a huge achievement, because not only were new methods chosen, so the assessment could be consistent across a whole continent, but also it was completed in little more than a single year. A follow-up assessment within the Murray-Darling Basin is reported in the *Snapshot of the Murray-Darling Basin River Condition.*

The *Snapshot,* and the Australian audit, was based on the premise that ecological integrity, as assessed by the aquatic biota, is the fundamental measure of river condition. Biota are usually the end point of environmental disturbances and pollution, so they are the primary indicators of disturbance, the more so because society places high value on some river biota, such as fish, frogs, turtles, yabbies.

A CRCFE research team led by Richard Norris of the University of Canberra, devised a model of river condition, based on models also used in the Snowy River and the Victorian Index of Stream Condition. Put simply, the model 'says' that the condition of the biota depends on the condition of their habitat, and the condition of their habitat depends on catchment condition.

The *Snapshot* reported the condition of individual reaches and of 23 river valleys in the Murray-Darling Basin, based on data for individual organisms, habitats and catchments. For each river reach, the *Snapshot* presents an assessment of the condition of the biota, and of the biological response to environmental pressures ('drivers'). It does that via five indices: a biota index, a catchment disturbance index, a nutrient and suspended sediment load index, a hydrological disturbance index and a habitat index. Special attention was given to seven hydrological zones defined by the Murray-Darling Basin Commission along the Murray, from Dartmouth Dam downwards.

Assessment of ecological condition is based on an estimate of how far rivers have changed from 'natural condition'. To calculate the biota index, a set of reference sites, defined as minimally disturbed, was adopted. In some cases, the reference condition was only available as a model, often of conditions thought to have prevailed pre-1750. Reference conditions are as near to natural or desirable as it is possible to achieve in each district.

The indices representing environment conditions described the effects of:

• land use (catchment disturbance index, derived from existing government land surface data);

• suspended sediment and nutrients (nutrient and suspended sediment load index, derived from modelled NLWRA data for N, P and sediment);

• total and seasonal flow volumes, their variability and periodicity (hydrological disturbance index, derived from hydrological stations across the Murray-Darling Basin);

• bedload, vegetation and connectivity (habitat index, derived from modelled bedloads, and data for land cover and connectivity, integrated using the standard Euclidean distance).

The team grouped the environment indices into four bands: largely unmodified, moderately modified, substantially modified and severely modified. The biota index was also reported in bands: reference condition, significantly impaired, severely impaired and extremely impaired.

The assessment would not have been possible without the use of data that had already been collected for particular purposes within each state or territory, though only data that provided consistent basin-wide coverage were used.

Few data were consistently available about fish or vegetation (despite their high value to society), so the biota index was derived only from data on macroinvertebrates, gathered using the AUSRIVAS method (see www.ausrivas.canberra.edu.au).

Groups of reaches with common problems were identified using multivariate statistics.

The findings can be summarised succinctly. In 40% of river length assessed in the Murray-Darling Basin, the populations of biota were significantly poorer than expected. In 10% of assessed river length, the damage was worse, with fewer than 50% of the expected macroinvertebrate groups present. Environmental conditions were found to be degraded in some way in over 95% of the river lengths assessed, most commonly by catchment disturbance and/or loads of nutrients and suspended sediment. The hydrology of over half the reaches assessed had been modified, particularly immediately downstream of dams and in lowland reaches used to supply irrigation.

Which method to use?

Assessment of river condition, whether in urban or other areas, is now ongoing and widespread in Australia. The assessment teams need methods that are cost effective and can be integrated into monitoring programs. Can any one set of methods produce accurate data in all the degraded situations that may be encountered? Important ecological stresses that have been identified include nutrient enrichment, increasing salinity, pesticides, sediment loading, water extraction, flow regulation, loss of riparian vegetation, effluent discharge, introduced species, and habitat degradation.

At first, when reliable methods were needed for early assessments of water quality, macroinvertebrates were seen as offering the greatest potential as indicators. However, the existing macroinvertebrate methods are in need of rigorous testing, comparing their use with other potential methods. Further, they do not address all aspects of freshwater ecosystems. Monitoring agencies still find themselves using physical and chemical methods to meet their legal obligations. Biological techniques still need integration into monitoring programs to provide useful outputs for managers.

Therefore, Peter Liston of Environment ACT, a CRCFE partner, working with Richard Norris, has begun testing the sensitivity and accuracy of a range of biological assessment methods, including macroinvertebrates used in AUSRIVAS, diatoms, fish, macrophytes, carbon and nitrogen isotopes and benthic metabolism.

International implications

Water quality is being measured by nations all over the world as international environment obligations and expectations come into force. AUSRIVAS, and the methods from which it was derived (RIVPACS), is being used for assessments in several countries, taking its place alongside other methods developed overseas, such as IBI (in USA), RIVPACS (in UK) and BEAST (in Canada). Likewise, the CRCFE understanding of nutrient-sediment interactions is being called into use in other countries, as the move to rehabilitate urban waters gathers momentum.

The links between research groups and transfer of knowledge that are a natural part of the Cooperative Research Centres program in Australia could be said to be now benefiting humankind in general.

The Authors

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THE IMPORTANCE OF BIODIVERSITY

A Kotlash

Biodiversity is one of those terms coined to try to capture the meaning of a complex concept. It is most often used to describe the diversity (or variety) of living things (plants, animals and microorganisms), usually in terms of species richness.

People often think of biodiversity as the number of different species living in an area and that the higher the number the better. Others think of the conservation of endangered species, and take the view that their conservation constitutes good biodiversity management. But it is not always appropriate to aim for high species richness/number, or to maintain recognised endangered species, without at least a fundamental understanding of the structure and function of the ecosystems in which they live.

The diversity of species must be appropriate for the type of system, its location, the time of year, and so on (for example, healthy native species reproducing from an adequate gene pool). In the case of endangered species, good management can only be planned if the ecology of the species is known and understood and acted on in ways that create sustainable solutions. In the words of Peter Cullen:

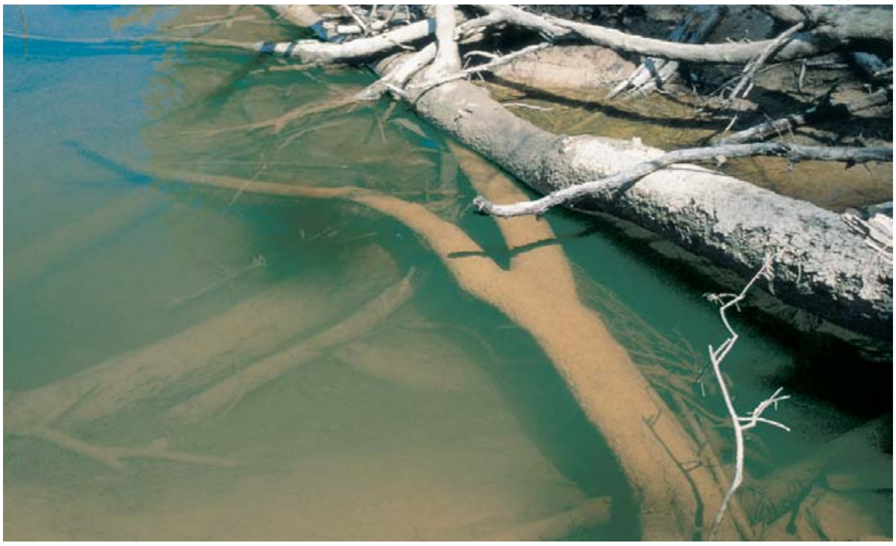
> 'Focusing our conservation efforts on severely threatened organisms, and developing expensive recovery plans that may not work, could mean Australia has the best-documented extinctions in the world'.

We must do better than this, we must manage our biodiversity with the knowledge we have.

Species richness and iconic species may well be the endpoint on which we focus, but for the purposes of managing biodiversity, the other facets of diversity are often the most important operationally. They provide a perspective on the ecosystems that we need so that we can conserve and restore biodiversity now and for future generations.

Biodiversity can be considered at a range of scales, from genes and species to populations and communities. Inextricably linked to these scales of biodiversity is the diversity of the habitats and landscapes (structural diversity) in which organisms live and the diversity of the functional processes on which they depend (functional diversity).

PHOTO: A MOSTEAD



Snags (branches lodged in waterways) offer a diversity of habitats for aquatic biota.

In broad terms, aquatic structural diversity, which is also referred to as ecosystem diversity, is represented by the range of inland aquatic systems such as:

- streams and rivers;
- billabongs, backwaters, lakes and impoundments;
- floodplains, swamps and other wetlands, both permanent and ephemeral;
- inland saline systems;
- mound springs, caves and groundwater.

Inland waterways are made up of an assortment of living, once-living and non-living structural elements, water being the most obvious non-living one. There are geomorphic elements such as channels, bars and islands and living elements such as riparian vegetation and aquatic plants. Animals, too, can form structural elements within an aquatic system; for example by playing hosts to a wide variety of parasitic organisms. Snags (that is, once-living trees and branches that fall into and lodge in our waterways) are a good example of a structural element of an aquatic system.

Adding to the complex structural make-up of our aquatic systems is that they change character, over time and from place to place, with resultant changes in biodiversity. This can happen as a result of a disturbance. Disturbance may be natural or human-induced or combinations of the two. A good illustration of a natural disturbance is the episodic floods that extend over vast floodplains of rivers in Australia. For much of the time these rivers exist as networks of ephemeral channels and turbid waterholes. As water floods and recedes these systems change, often dramatically over space and time. In some areas weirs and levees change these natural processes of flooding and drying.

The form of a river changes continuously along its length, from its source to the end of its catchment, effectively varying over space and time. Changes in structural make-up are also evident across a river channel; for instance where there are different water depths, flows and types of substrate and small-scale structural elements such as snags. Snags provide habitat for a wide variety of aquatic plants and animals at various stages of their life cycles. Snags modify the flow conditions of a river and help shape its bed and banks. The natural breakdown of snags causes alterations in their character and position, illustrating how structural elements change over time and from place to place.

Natural change during the development of ecological communities is a good example of functional diversity. We can use riparian vegetation to explore this

PHOTO: CATHERINE MOORE

Macroinvertebrates, such as this waterboatman (about 8 mm across in real life), are near the base of the food chain in freshwater ecosystems.

concept. Riparian vegetation goes through a number of stages of development - which can take years, decades or even centuries - from bare banks sprouting a few species, to mature communities. The riparian zones of most rivers are continually going through this process to some extent. The balance between rejuvenation and terrestrialisation processes sustains the diversity of these differing stages in riparian zones. Since the various stages are characterised by distinct communities, species richness is high where there is a wide range of riparian communities at different stages. Low diversity may be a natural situation when viewed at smaller scales.

We can also see natural ecological changes in the progressive colonisation of snags.

Defining threats to biodiversity is the first step in conserving freshwater biota and ecosystems. This takes time and is continued throughout the steps of the conservation process. Decisions regarding appropriate responses often need to be made immediately or very early in the conservation process. An adaptive approach, where intervention and research, including monitoring and evaluation, go hand-in-hand to achieve improved conservation outcomes, is appropriate for the needs of these short timeframes. An increased understanding of the principles of conservation ecology is vital to underpin decisions for restoration and the abatement of threats in the longer term.

The Cooperative Research Centre for Freshwater Ecology (CRCFE), by virtue of its strong industry linkages and its multi-disciplinary research capacity and knowledge base, is uniquely placed to provide leadership in research and in applying the research to conserving and restoring biodiversity values in a range of freshwater ecosystems.

The CRCFE's Conservation Ecology Program aims to:

- assess biodiversity and its distribution in freshwater ecosystems, and to gain insights into processes that regulate levels of biodiversity at various scales in space and time;
- identify threats to biodiversity, to measure their impacts on biodiversity, and to undertake research leading to a greater understanding of the mechanisms by which they act; and
- develop responses to these human-induced pressures, to monitor the outcomes of those responses, and to evaluate the effectiveness of the responses.

The research program is addressing these aims through two themes: Biodiversity Assessment and Regulation, and Conserving Biodiversity. The questions being addressed include: What do we have left - what of our natural freshwater biodiversity remains relatively intact, how do we measure it, and how is it distributed across the landscape? How does the system work - what are the factors that regulate biodiversity in natural and modified ecosystems? We are also addressing what can we do. For instance, how can we identify key threatening processes, manage their impacts, protect biodiversity values in natural and partially degraded systems, and conserve threatened species and communities?

Progress is being made through research projects and communication of our knowledge. The CRCFE has expanded its influence in the conservation of biodiversity through national and state forums. It is participating in discussions, at national and state level, of the need to conserve biodiversity in all ecosystem types. The program contributes to these debates both directly, through outcomes of its projects, and indirectly by advice to committees. For instance, the listing of 'Alteration of natural flow regimes of rivers and streams and their floodplains and wetlands' and 'Clearing of native vegetation' as Key Threatening Processes in NSW under the Threatened Species Conservation Act, in 2002, provides major legislative recognition of threats to aquatic ecosystems and their biodiversity.

Biodiversity assessment and regulation is being addressed through a number of projects. The Dryland River Refugia project is examining questions of fragmentation and connectivity of ecosystems in Cooper Creek, Warrego River and the Border Rivers. It is determining the importance of water holes as refugia for aquatic organisms in dryland river catchments and identifying the biophysical processes that sustain biodiversity and ecosystem health in these refugia. This project has produced large integrated data sets now being processed to answer these questions.

Designing and developing a long-term biodiversity monitoring program for the Sydney Catchment Authority has also added to our knowledge. We have learnt how to effectively and efficiently measure and assess fish, macroinvertebrate and riparian vegetation biodiversity and how to identify locations of high conservation value based on their biodiversity characteristics. We have also gained insights into how best to monitor and assess biodiversity changes over time.

A project on Sustainable Management of On-farm Biodiversity in the rice-growing industry is contributing to our knowledge of the relationship between this farming system and biodiversity at farm and regional scales.

Conserving biodiversity is also being addressed through a number of other projects. The 'Adaptive Management in Restoration Ecology' project completed its first phase in 2001-2002 by simulating a cycle of introduction for the re-introduction of trout cod. Phase 2, which will refine this model, looks at alternative approaches to monitoring and planning and will instigate an on-ground program for re-introduction with stakeholders. It is about to begin. Conservation biology and systematics of the individual species or groups, for example mountain galaxias, mayflies and crayfish and frogs are being addressed by a number of projects.

The Author

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