



Cooperative Research Centre for Freshwater Ecology

Annual Report 2004–2005

Established and supported under
the Australian Government's
Cooperative Research Centres
Programme



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Cooperative Research Centre for Freshwater Ecology

Vision

The Cooperative Research Centre for Freshwater Ecology exists to improve the condition of Australia's inland waters.

Mission

The Cooperative Research Centre for Freshwater Ecology provides ecological understanding to improve and protect Australia's inland waters by collaborative research, education, resource management, policy advice and community liaison.

Objectives

- ▶ To deliver high quality scientific research that contributes to the understanding of the ecology of aquatic ecosystems. With in-depth understanding, it is possible to predict how aquatic ecosystems react to different scenarios.
- ▶ To develop and test ecological theory, through our research program.
- ▶ To provide knowledge of the principles of ecology, so they can underpin management decisions and actions and address key management issues facing Australia's water industry.
- ▶ To increase the capacity of Australia's water industry to predict the ecological consequences of management actions.
- ▶ To produce methods and tools for assessing ecological conditions, to assist water managers to measure the effects of their actions.
- ▶ To contribute an ecological perspective to policy debates within the water industry.
- ▶ To maintain international linkages so our work is known internationally and to ensure our science is at the best possible standard.
- ▶ To provide ongoing professional education to build up a capacity within the water industry to understand ecological issues.
- ▶ To provide high quality postgraduate education and experiences that equip graduates with skills and knowledge appropriate to industry needs.



The Cooperative Research Centre for Freshwater Ecology is a collaborative venture between:

ACTEW Corporation

CSIRO Land and Water

Department of Infrastructure, Planning and Natural Resources, NSW

Department of Natural Resources and Mines, Queensland

Department of Sustainability and Environment, Victoria

Department of Water, Land and Biodiversity Conservation, South Australia

EnvironmentACT

Environment Protection Authority, NSW

Environmental Protection Authority, Victoria

Goulburn-Murray Rural Water Authority

Griffith University

La Trobe University

Lower Murray Urban & Rural Water Authority

Melbourne Water

Monash University

Murray-Darling Basin Commission

Sydney Catchment Authority

The University of Adelaide

University of Canberra

Foreword

It is exciting to be writing the last Foreword for an annual report for the CRC for Freshwater Ecology (CRCFE). The excitement comes from knowing that the work of the CRCFE is not over, even though the CRC ceased operations as at 30 June. Instead, the ecological know-how that has been accumulated is now part of the strong foundation from which the eWater CRC is emerging.

Water is a Z to A issue: if there is plenty of water about nobody worries about it. When there's no water about, or it is flooding through houses, or it does not appear when the tap is turned on, water does not just go up the alphabet of issues incrementally, it shoots from Z to A because people realise how fundamental it is to their lives. If you are thinking ahead when water is a non-issue ('Z'), you can be ready to act and take the opportunities that arise when water issues become 'A'. So, the CRCFE, being in the right place at the right time, and ably led first by Professor Peter Cullen and latterly by Professor Gary Jones, has been able to capture interest and attract funding to support its vision of improving the condition of Australia's inland waters.

Having Victoria, New South Wales, Queensland and the ACT as early partners in the CRCFE allowed it to present a wide view, augmented in later years when South Australia joined as well. The CRCFE and the CRC for Catchment Hydrology have together

been the most effective forums I have seen for interstate collaboration on water. They achieved a consensus among professionals across river management bodies of the states and the Murray-Darling Basin Commission in support of good science being done well.

The CRCFE has been able to connect a range of science-streams to build a picture of the ecology and ecological condition of river systems — the river, floodplains and wetlands. We have learnt an enormous amount about the behaviour of river systems and the factors that potentially make them healthy or unhealthy. That is a really good platform for the eWater CRC as it moves into predictive work.

There have also been almost 100 PhD graduates coming out of the two periods of the CRCFE. Those bright individuals have received an education, done some research on a river system and been connected with industry or river managers. They have been working on problems that are really going to make a difference to the water industry. Coming from a multi-university and a multidisciplinary environment of river managers and academics, these PhD graduates are a cohort for the future and I see them as a very, very important output of this CRC.

Putting knowledge brokers — people who understood research — into the operating agencies so you could get practical two-way communication between CRC scientists and the people in the water management agencies, was very effective. This was a very strong

innovation that Peter Cullen personally drove, and it has been expanded in recent years by Gary Jones. There is little point in doing good science and leaving it unpublished, or in publishing it only in scientific journals that few managers read. The knowledge brokers have been very important in establishing dynamic two-way communication between river managers and researchers, to get the science to the managers and provide input to planning of research portfolios.

The CRC for Freshwater Ecology has been remarkably successful in stimulating collaborative research in ecology and making good use of it. The collaborative culture has extended right from the Board members to the teams on the floodplains and in the labs, and a major result has been that the whole collective research effort has been greater than the sum of the parts by quite a degree.

The vision for the CRCFE was to really make a difference to the condition of rivers. There's now a far greater awareness of the environmental consequences of human activities in rivers, and the potential harmful effects and the potential solutions, than there ever was before. If the CRC for Freshwater Ecology had not existed I think there'd be a very different water debate going on.

Having chaired the Boards of both the CRCs for Freshwater Ecology and Catchment Hydrology from start to finish, I figure, like many politicians and cricketers, that it is better to get out while you are still hitting the ball in the middle of the bat. The eWater CRC, though derived from both those CRCs, is a very different-looking

organisation, with a new team taking it into the future, and a new Chairman — Don Blackmore.

My thanks go to Gary Jones and Peter Cullen, the senior management team, my fellow members of the Board, our industry personnel, and all the staff who have been part of the CRC for Freshwater Ecology since it began in July 1993, for these productive and memorable years.

I wish the new CRC and its teams the highest success.

Professor John Langford AM

Chairman of the Board
CRC for Freshwater Ecology



Chief Executive's overview

The CRC for Freshwater Ecology (CRCFE) set out in 1993, under the leadership of its Chairman John Langford and my predecessor Professor Peter Cullen, to help improve the health of Australia's inland rivers and wetlands. As we close the doors of CRCFE and open those of the new eWater CRC, I am confident in saying that in its 12-year history the CRCFE has helped make a real difference to the effective management of the Australian water environment.

The CRCFE's research activities in four states and the ACT have produced robust scientific knowledge and advice to help pave the road towards numerous and widespread policy developments and changed attitudes in river management. In particular, we have helped to elucidate and communicate the fundamental importance of ecological health in ensuring the long-term sustainable use of Australian rivers.

We have identified measures and indicators of river 'health', developed monitoring and assessment programs, and explored the factors causing a loss of 'health' in rivers, as well as ways of rehabilitating them. We have deepened the general understanding of freshwater ecosystems and their functional components, as well as contributing to the concept of the *'healthy working river'* — a river that is providing adequately for both economic and ecological needs even though it is not in the same condition as



the 'natural' river it was before European settlement.

Environmental flows are now a central facet of the management of healthy working rivers, and we can trace CRCFE 'footsteps' through a progression of environmental flow initiatives over the last decade. Working with and through our state government partners, we have defined the ways in which river ecosystems respond to altered flow regimes. Consequently, we now have clear evidence that flow is a key driver of ecological condition and water quality in rivers and floodplain wetlands. Mind you, there is still much to learn, as it was not possible, even in 12 years, to study in detail the responses to flow of more than a comparatively small group of fish, plants and invertebrates as well as key water quality parameters.

Freshwater ecology must become a truly 'predictive' science if it is to continue to provide useful information for waterway managers and for the community in the new century. One of the central objectives of the new eWater CRC is to ensure that the individual ecological relationships quantified by CRCFE scientists are integrated into user-friendly, whole-of-river-system predictive models. We have much to learn from our CRC for Catchment Hydrology colleagues in this respect, and I am very optimistic that we will achieve this end, working together in the eWater CRC over the next seven years.

Biological methods for measuring water quality have become a practical tool for scientists and managers alike during the life of CRCFE. We have developed and

applied biological assessment methods based on fish, algae, macroinvertebrates and rates of key ecological processes. Of these, macroinvertebrate methods have been the most widely applied so far, via the 'AUSRIVAS' method for river assessment, which the CRCFE helped develop as part of the National River Health Program.

The CRCFE's work in Australia mirrored a world-wide trend throughout the 1990s moving from a reliance on chemical measurements to define river condition, to a broader approach that includes the health and condition of plants and animals that live in rivers and wetlands, and direct measurements of important ecosystem processes such as photosynthesis and respiration.

CRCFE staff have also been integral to the writing of the revised national water quality and water-quality monitoring guidelines. And the Murray-Darling Basin Commission's Sustainable Rivers Audit is based on conceptual frameworks the CRCFE helped develop.

Throughout its life, the CRCFE has studied the ecology of all kinds of rivers and waterbodies across a wide range of geographic and climatic zones — from the cool, temperate rivers of southern Victoria to the tropical and arid zone rivers of Queensland and the Northern Territory. Especially in the highly flow-variable rivers of the arid zone we now know that it is very important to protect not only habitats that organisms use under normal conditions, but also *refuge* habitats — such as billabongs, waterholes and river-bed pools — that can outlast long dry

periods. Without these refuge habitats, freshwater biodiversity is less likely to be maintained throughout climatic extremes, especially during prolonged drought.

Our scientists have also shown that in helping to rehabilitate degraded rivers, 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 (such as poor flow regime or water quality) are still active.

Measuring biodiversity has been just as important for us as protecting it. Via the Murray-Darling Freshwater Research Centre (MDFRC), the CRCFE has developed around 50 taxonomic identification (ID) guides to numerous invertebrates and larval fish. At the same time, researchers at Griffith University have adopted molecular 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 inter-basin water transfers or re-colonisation by rare and endangered species are being contemplated.

Fish researchers in the CRCFE have demonstrated the valuable outcomes obtained from the construction of proper fishways in rivers of the Murray-Darling Basin and along the east coast, monitored and reported on threatened fish species, and developed habitat rehabilitation strategies for those and other fish species. Also there is now far better understanding of carp control, factors affecting the numbers of fish in a river and their

migrations (or not), predator-prey relationships in fish refuges, and the factors such as salinity and cold water pollution affecting the recruitment process in native fish species.

CRCFE Mk I (1993–1998) had a major research program on the ecology and control of toxic algal (cyanobacterial) blooms. The Chaffey Dam study led by CSIRO and MDFRC was one of the first very detailed studies of the efficacy of artificial mixing to control algal blooms in Australia. Similar work on the Murrumbidgee River found that flow could potentially be manipulated to minimise temperature stratification in weir pools and, hence, reduce the frequency and severity of blooms.

Understanding of the ecology and pathways to restoration in urban waterways 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, showing that it is run-off from impermeable surfaces that are directly connected to the streams by drainage pipes or channels that causes the ecological damage, largely via the frequent inputs of stormwater, coming even from small rain events. A quantitative relationship has been developed between this 'effective imperviousness' of the urban catchment and the waterway ecological health. This is proving to be a powerful tool for urban planners and managers. It provides clear direction on the way urban sub-divisions and drainage networks can be designed to meet their intended task (flood control) while improving the health of urban streams, previously considered

'basket cases' by many, ecologists included!

This pioneering work by staff of both the CRCFE and the CRC for Catchment Hydrology at Monash University, follows the strong leadership already 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.

We have been fortunate to have a number of high-profile freshwater ecologists leading teams within the CRCFE, and they have also played important roles on influential advisory committees and expert panels across the water industry. Their influence on the industry has been supported by the CRC structure, through which our scientists have been able to exchange information directly with partner agencies and authorities who are the day-to-day managers and controllers of inland waterways across eastern Australia.

We have also at all times encouraged our researchers to communicate our science and learnings to members of the public and to regional communities potentially affected by changes to river operations and management. 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. Knowledge brokers are scientists with a penchant for communications and for seeing the adoption of scientific knowledge by the water industry and the public. In taking on the role, they leave the day to day life of a scientific researcher behind, but can bring those skills and experiences to a broader communications and outreach job. Importantly we have ensured they learn and acquire the skills needed to have the *right conversation* with *both* industry practitioners and scientific researchers, brokering productive interaction between people in previously separate fields of work. Without doubt, significant management outcomes have followed, and other organisations in Australia have taken up the knowledge broker concept initiated by the CRCFE.

Additionally, we have, in recent years, adopted a policy of 'advice not advocacy' in matters relating to the input of science to public debates on water resources management. It is my strong view that, as a taxpayer-funded organisation, we must fairly undertake and represent science in the interests of the entire Australian community, not just sub-sections of it.

The CRCFE's education, training and community-based activities have contributed to increasing awareness of the trade-offs required for healthy working rivers. Freshwater schools, training courses — both face-to-face and online — and workshops for management personnel have helped to spread the messages arising from our research. We have also helped to train almost 100 post-graduate students in freshwater ecology, and many

of them are now in water management agencies around the country and overseas. We have augmented traditional academic training, provided to students by our university partners, with short courses in project management, public speaking, and media communications. We have also encouraged students to work in multi-disciplinary, cross-agency research teams so they are exposed to the practical realities of river and waterway management from early in their careers. Consequently, our students have remained in high demand by water industry employers throughout the life of the CRC and many are now working with water resources management agencies across Australia. I can say that this is a big and important change from my days as a young postgraduate where the thought of taking up a job in a government management authority was the last thing on my mind!

Since news of the success of the eWater CRC bid in Christmas 2004, the CRCFE has focused solidly on completing its project responsibilities within six years rather than seven (it is the nature of CRC transitions that year-7 funding of the old CRC gets rolled into year-1 of the new). 2004 has therefore been a transitional year for our staff, firstly being required to finish CRCFE projects by June 2005. I am very pleased to say that all project teams took to this task without complaint and have completed the required work on time. Most of CRCFE's researchers are by now part of new multi-disciplinary teams and well into the planning of new projects that fit into the eWater CRC vision for integrated water

management. As well as undertaking project planning, the second half of 2005 — officially the first six months of eWater CRC — has provided our staff with time to publish results from their CRCFE research projects, and also for them to work with our industry partners on the application of their CRCFE findings in real-world management situations.

2005 has also been a time to celebrate the contributions of key members of staff to the success of the CRC. At the final Annual Meeting of the CRC for Freshwater Ecology in June 2005, I was pleased to present special CRC awards to:

- David Crook, Alistar Robertson and Alison King (also a student) for *Best Published Paper with a CRCFE Postgraduate Student as Lead Author*;
- Paul Humphries, Alison King and John Koehn for *Best Published Paper with a CRCFE Scientist as Lead Author*;
- Chris Walsh and colleagues for *Best Multidisciplinary Team Research Project*;
- Rhonda Sinclair for *Best Support Person*; and
- Richard Norris and Ian Prosser for *Best Knowledge Exchange Activity or Project*

All these awards covered achievements over the 12-year life of the CRC and all the awardees should be very proud of the work for which they have been recognised. (Indeed, over its life the CRCFE's staff have published approximately 610 refereed journal papers, 180 books and book chapters, and 420 technical and consultancy reports.)

Special 'Life-time' Achievement Awards were also presented to *Peter Cullen, Barry Hart, Ben Gawne* and *John Langford*, in recognition of their outstanding contributions to the CRCFE.

As always, our staff and associates have received a number of external awards and honours this year. Our congratulations go to *John Langford* who was made a Member of the Order of Australia (AM) in the Queen's Birthday Honours, 'for service to water resource management, particularly through organisations that regulate and research water supply, quality and usage'. We also proudly congratulate *Peter Cullen* on being awarded the prestigious 'Einar Naumann–August Thienemann' Medal by the Societas Internationalis Limnologiae (SIL), for exemplary scientific leadership and extraordinary efforts to communicate complex limnological and water resources issues to colleagues and decision-makers.

In December, Professor *Sam Lake* (Monash University) was awarded one of three inaugural Senior Research Fellowships by Land and Water Australia. The award allows Sam to concentrate on a review of ways in which drought affects freshwater ecosystems. I thank him for all his wise words to us as a leading researcher and then as Chief Ecologist of CRCFE since 1993. Professor *Richard Norris* (University of Canberra) and his research team were awarded one of two Vice-Chancellor's Distinction Awards for Creativity and Innovation in Research and Enterprise, at the University of Canberra. Their innovative studies on the Cotter River, ACT, before and since the 2003 bushfires,

have supported active adaptive management by Canberra's water managers, to the benefit of the environment and the Canberra community. Craig Boys (University of Canberra) has won the John Holliday Student Conservation Award, presented annually by NSW Fisheries, part of the NSW Department of Primary Industries. We have just heard that Mark Kennard and Angela Arthington have, with Brad Pusey, all of Griffith University, won the much-sought-after Whitley Award for zoological publishing, from the Royal Zoological Society of NSW, for their recently published book *Freshwater Fishes of North-eastern Australia*.

Also, *Mark Carey* (MDFRC summer scholarship student) was awarded the North-east CMA Prize at the Annual Presentation of Awards and Prizes Ceremony at La Trobe University in July 2004. *Tim Page* (Griffith University) won Best Student paper at the Australian Society for Limnology's 43rd Annual Congress, Adelaide, in November–December 2004. *Ben Smith* (University of Adelaide) was awarded the Australian Society for Fish Biology's 2004 International Travel Scholarship (worth \$5000), on the basis of his technical publications.

It has also been a year of significant appointments for several staff. Dr *Sabine Schreiber* (Arthur Rylah Institute, Victoria) and Professor *Stuart Bunn* (Griffith University) have been elected President and Vice-President respectively of the Australian Society for Limnology. Professor *Richard Norris* became Chair of the Executive Committee of the North American Benthological Society, in May.

Professor *Stuart Bunn* was invited to join the inaugural Scientific Steering Committee of the Global Water Systems Project (a joint project of DIVERSITAS, the International Geosphere-Biosphere Program, the International Human Dimensions Program and the World Climate Research Program under the auspices of the Earth System Science Partnership), and Dr *Will Osborne* (University of Canberra) has been appointed as Chair of the ACT Flora and Fauna Committee.

Congratulations to you all for your outstanding achievements! We are fortunate that nearly all of you are now part of the eWater CRC.

We were sorry, early in 2005, to see the departure of Associate Professor *Gerry Quinn*, who had been with CRCFE since 1993. However, we all congratulated him on being appointed the Professor of Marine Science at Deakin University. And, after almost 10 years with the MDFRC (Albury) and the CRCFE, one of our key researchers, *Paul Humphries*, left at the end of 2004 to move to Charles Sturt University. He has spent the first part of 2005 using a Harold White Fellowship at the National Library of Australia, collating historical accounts of fish distributions in rivers in the Murray-Darling Basin. Thank you both for your very significant inputs to the success of the CRCFE over the years.

A cooperative research centre could not be a success without the expertise, knowledge, cooperative spirit and drive that are found in all its staff. I would like to thank all our current researchers, our valued industry personnel, our team

leaders, our knowledge brokers, our vital support staff, and the members of the Board for all their contributions over not just the last 12 months but also the last 12 years. And special thanks to the University of Canberra for its financial and practical support for the CRC headquarters and office of the Chief Executive throughout the CRC's life.

Finally, in closing this last Chief Executive's report, I would like to personally thank two people who have not only been central to the success of the CRCFE but have supported me in becoming Chief Executive and functioning in that role: former Chief Executive, Peter Cullen, for his leadership, mentoring and friendship; and John Langford, the CRCFE's one and only Chairman, for his wise and patient leadership and counsel.

Forward — to the eWater CRC!

Professor Gary Jones

Chief Executive
CRC for Freshwater Ecology



1. Structure and management

The Cooperative Research Centre for Freshwater Ecology (CRCFE) was formally established on 1 July 1993 as part of the Commonwealth Government's CRC Programme.

In 1998, the CRC successfully applied for a further seven years of funding. CRCFE II came into being on 1 July 1999.

CRCFE has just been involved in another successful rebid, this time to become part of a larger new CRC (eWater CRC). Hence CRCFE has ceased operations as at 30 June 2005, the end of the sixth year of its second term.

In January 2004 a new partner, the Department of Water, Land and Biodiversity Conservation, South Australia, joined the CRCFE, taking its number of partners to 20. Then on 1 July 2004 two partners (Lower Murray Water and Sunraysia Rural Water Authority) merged to form Lower Murray Urban and Rural Water Authority. Therefore, at its close the Centre was an unincorporated joint venture between 19 partners:

- ▶ ACT Government (Environment ACT)
- ▶ ACTEW Corporation
- ▶ CSIRO Land and Water
- ▶ Department of Environment and Conservation, NSW (DEC)
- ▶ Department of Infrastructure, Planning and Natural Resources, NSW (DIPNR)
- ▶ Department of Natural Resources and Mines, Queensland (QNRM)



- ▶ Department of Sustainability and Environment, Victoria (DSE)
- ▶ Department of Water, Land and Biodiversity Conservation, South Australia (DWLBC)
- ▶ Environmental Protection Authority, Victoria (EPAV)
- ▶ Goulburn-Murray Rural Water Authority
- ▶ Griffith University
- ▶ La Trobe University
- ▶ Lower Murray Urban and Rural Water Authority
- ▶ Melbourne Water
- ▶ Monash University
- ▶ Murray-Darling Basin Commission (MDBC)
- ▶ Sydney Catchment Authority (SCA)
- ▶ The University of Adelaide
- ▶ University of Canberra.

CRCFE Board and committees

The CRCFE has been governed by a Board comprising the following members at 30 June 2005:

- Chair:* Prof. John Langford (University of Melbourne)
- Dr Jane Doolan (DSE, VIC)
Dr Colin Chartres (CSIRO Land & Water)
Dr Maxine Cooper (Environment ACT)
Dr Ruth Foxwell (University of Canberra)
Mr Brian Spies (SCA)
Mr Bruce Cooper (DIPNR, NSW)
Mr Scott Keyworth (MDBC)
Mr Grant Wilson (Melbourne Water)
Mr Lamond Graham (DNRM, QLD)

- Prof. Nancy Millis (Independent)
Prof. Robert Norris (Monash University)
Prof. Roger Braddock (Griffith University).

The Board has met four times per year, as a rule.

The Finance Committee and the Research Committee continued to operate during 2004–2005. The Finance Committee's role is to oversee the CRCFE's finances and make recommendations to the Board. It met once per quarter. The Research Committee has overseen the research undertaken and provided input into research program development.

Finance Committee

Chair: Prof. John Langford

Mr Grant Wilson

Dr Ruth Foxwell

Mr Charles Robinson (CRCFE Chief Administrative Officer)

Prof. Gary Jones (Chief Executive)

Research Committee

Chair: Prof. Nancy Millis

Mr Tom Vanderbyl (QNRM)

Dr Jane Doolan

Mr Bruce Cooper

Prof. Sam Lake (CRCFE Chief Ecologist)

Prof. Gary Jones (Chief Executive)

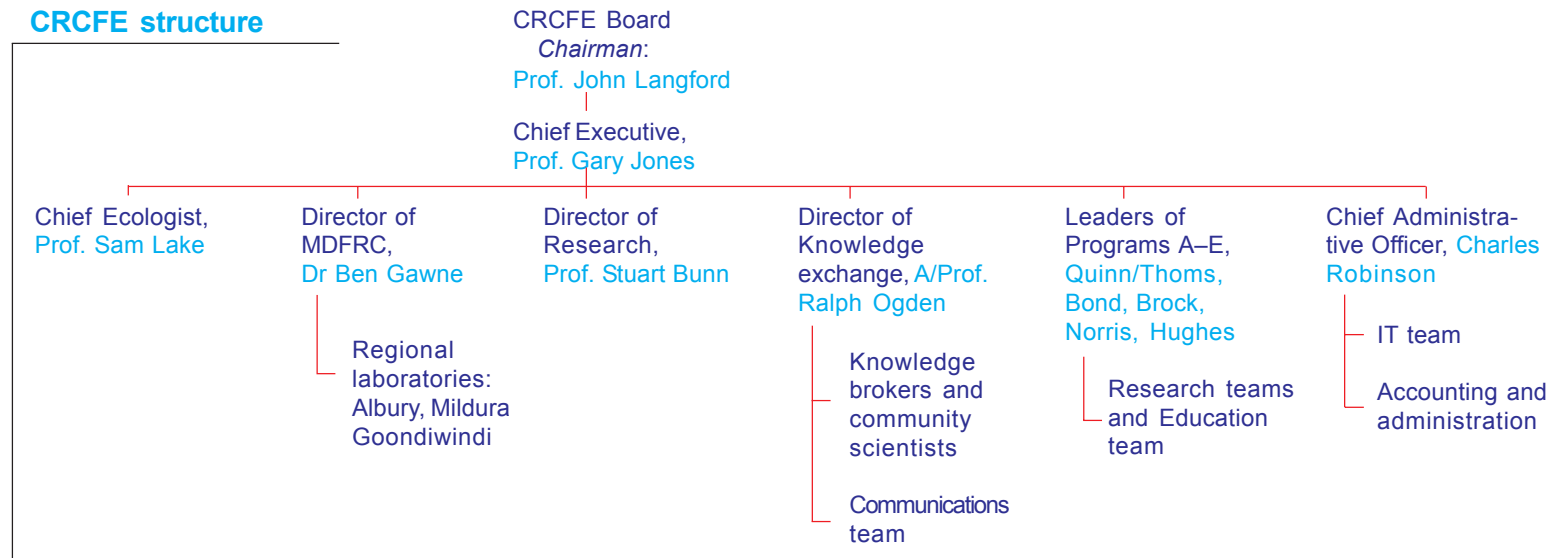
Organisational structure

The Chief Executive, Professor Gary Jones (University of Canberra), has carried executive responsibility for managing the CRCFE within the policy framework established by the Board. He has been

supported by the **Senior Management Team**, consisting of ten people:

- ▶ Chief Ecologist, Professor Sam Lake (Monash University)
- ▶ Director of Research, Professor Stuart Bunn (Griffith University)
- ▶ Director of Murray-Darling Freshwater Research Centre, Dr Ben Gawne (MDFRC, CSIRO Land & Water)
- ▶ Leaders of the four research programs and the education program
- ▶ Director of Knowledge Exchange, Associate Professor Ralph Ogden (University of Canberra)
- ▶ Chief Administrative Officer, Mr Charles Robinson.

CRCFE structure



The research staff of the CRCFE have been almost all provided by the five university partners (Adelaide, Canberra, Griffith, La Trobe, Monash) at labs in Adelaide, Canberra, Brisbane, Albury and Melbourne. Other researchers have been staff of CSIRO Land & Water through the Murray-Darling Freshwater Research Centre laboratories at Albury and Mildura, and state water agencies at Armidale and Goondiwindi. Staff and students at these laboratories have worked within any or several of the four research programs, according to expertise. See Chapter 2 for details of the research programs.

Research Program A — Ecological processes that are influenced by river flows — led by Assoc. Professor Gerry Quinn (Monash University, Melbourne). When Assoc. Professor Quinn moved to Deakin University early in 2005, Assoc. Professor Martin Thoms became program leader, taking the program through until the end of June 2005.

Research Program B — Ecology of river (and wetland) restoration — led by Dr Nick Bond (Monash University) during 2004–2005.

Research Program C — Conservation ecology and aquatic biodiversity — led by Dr Margaret Brock (DIPNR, Armidale).

Research Program D — Assessment of water quality and river condition — led by Professor Richard Norris (University of Canberra).

Program E — Education and training — led by Professor Jane Hughes (Griffith University).

Knowledge Exchange, led by its Director, Assoc. Professor Ralph Ogden, has involved researchers as well as a team of knowledge brokers and community scientists.

The Program Advisory Committees (PACs), through which representatives of public industry partners oversaw the planning of new research programs in CRCFE in the last few years, did not meet in 2004–2005 because the research projects were coming to an end.



Transitional arrangements for close of CRCFE and start of eWater CRC

All CRCFE research projects were formally concluded on 30 June 2005. From 1 July, transitioning staff have been involved in planning for the new eWater CRC research and product projects. The second half of 2005 has also provided staff with time to publish results from their CRCFE research projects, and for them to work with our transitioning industry partners on the application of their CRCFE findings in real-world management situations through a series of interim adoption projects.

All scholarship funds for remaining postgraduate students have been paid out to the CRC's University partners. Arrangements have been made with universities regarding mutual obligations for completion of the postgraduate student

training program. All final completion reporting will be to the eWater CRC.

Transitional funding has been provided for a small number of CRCFE post-doctoral fellows to allow them to participate in eWater planning, and to ensure they are not forced to find new jobs in the 6 month period before eWater projects commence on January 1, 2006.

Termination of the CRCFE will occur in January 2006 following completion of residual administrative activities, and completion of the final financial audit and its authorisation by the CRCFE Board.

All CRCFE outputs are being made available at an 'archive' web site (<http://freshwater.canberra.edu.au>), to be maintained and linked to the eWater CRC web site for the foreseeable future.



2. Research

Research in the CRCFE's portfolio has addressed five of the national ecological issues facing Australia's river and catchment managers:

- ▶ over-regulation of river systems, and the pressure for development of unregulated water resources
- ▶ ecological degradation of many urban and rural aquatic systems and the lack of knowledge about how to rehabilitate them
- ▶ loss of biodiversity and ecosystem function
- ▶ the need for detailed information about the condition (or health) of Australia's aquatic ecosystems
- ▶ the need to understand Australian inland aquatic systems — their biological communities, ecosystem processes and ecological function, and how human actions affect them.

Ten new core projects began in July 2003, taking over from the nine projects that had been the focus of core research during 2000–2003. Each core project integrated expertise from several of the CRCFE's research and management partners in several states. They tackled problems at a range of geographic and time scales, and combined field, laboratory and 'desk-top' research and development. Also, the Narran project, equivalent to a core project in size and integration of expertise, plus around 20 other ('associated') research projects, examined immediate management problems and related scientific knowledge-gaps. All core and 'associated' projects



are listed at the end of this chapter. Student research projects are listed in Chapter 3.

Program A — Flow-related ecosystem processes

Leaders: Assoc. Prof. Gerry Quinn (to early 2005) and Assoc. Prof. Martin Thoms

This program has investigated how flow affects ecological processes in rivers and their floodplains. It has examined fundamental ecological issues and management needs.

PROGRAM OBJECTIVES

- ▶ Determine the sensitivity of aquatic ecosystems to flow regulation and water abstraction.
- ▶ Determine how options for flow management will affect Australian aquatic ecosystems.
- ▶ Develop tools for assessing the success of environmental flow allocations.

Theme A1 — Role of flow in determining natural ecological processes in rivers and streams

Projects in Theme A1 have examined selected ecological processes in river channels and their floodplains and wetlands, and the transfer of materials between these parts of the landscape. The aim has been to understand how key components of flow (including flood and drought) interact with representative biota and ecological processes in rivers and their floodplains. Ultimately, the aim has been to predict what will happen to the ecology of rivers when flow regimes change.

Theme A2 — Flow manipulation in regulated lowland rivers

Projects within Theme A2 have studied the long-term effects of manipulating flow, both in winter-rainfall rivers in south-eastern Australia and in summer-rainfall rivers in northern NSW and southern Queensland. The team has measured the effects of different water-release regimes on various species, communities and processes, chosen to represent ecologically important 'response' groups. Fish, invertebrates, riparian- and floodplain-vegetation have been studied, as well as ecological processes such as fluxes of carbon and nutrients, nutrient spiralling and food-web dynamics.

PROGRAM SUMMARY

Program A has significantly improved our understanding of the way biota and ecological processes in rivers, floodplains and wetlands respond to changes and variability in flow.

Largely resulting from the CRC's research activities, significant variation in fish species richness, assemblage structure, and to some extent, fish abundance, can be explained by interactions between flow and other drivers (especially habitat structure, itself a function of flow interacting with geology, geomorphology, channel and floodplain morphology, woody material and aquatic vegetation). These interactions are demonstrably important at spatial scales ranging from small patches (e.g. logs and root masses, undercut banks, scour holes) to individual hydraulic units (e.g. riffles, pools, backwaters), to river reaches, and at whole of catchment scale. We have shown that flow–habitat

relationships are best viewed as operating in nested hierarchies of landscape patches, and that connectivity among patches (e.g. floodplains and river channels; waterholes and pools in intermittent streams) is vital for streams and rivers to be able to recover from drought or dry spells. Flows ranging from nearbed-flow to very large floods all play a part in maintaining habitat structure, heterogeneity and connectivity in the riverine landscape, and, hence, the integrity of fish assemblages in rivers with highly variable flow regimes. The findings of CRCFE research in minimally disturbed streams (SE Queensland) and floodplain rivers (Cooper Creek) are consistent with the principle that flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biotic composition.

PROGRAM HIGHLIGHTS

A240: Quantifying flow–habitat–biota relationships in riverine ecosystems

We hypothesised that rivers have particular zones that play important roles in the movement of carbon and organic matter through river food-webs and, therefore, overall ecological condition. Examples of such zones, which we term Functional Patches, have been identified in three river settings:

- ▶ surface flow type, in the Cotter (a high-energy, upland river);
- ▶ slackwaters (manipulated with sandbags) in the Broken (a medium-energy tributary of River Murray);
- ▶ littoral zones in the Murray weir pools (a low-energy, highly regulated lowland river system), compared to free-flowing river bends.

The results of this study suggest that rates of respiration and, to a lesser extent, productivity are highest in those patches associated with lower flow velocities and turbulence. The effect of high flow events on metabolism appears to be affected by antecedent conditions at a range of scales. At the scale of individual events, the length of the period of steady low flow prior to the event (the inter-pulse period) is likely to dictate the magnitude of the response in metabolism, as is the magnitude of the event itself. At longer timescales, the sequences of flow events appear to be linked to the river's existing responses to any major catchment disturbances. Some data are showing that flow releases shift the system towards autotrophy (i.e. producing energy from carbon via photosynthesis); however, this is counter to predictions based on overseas studies which suggest high flow events should lead to shifts to heterotrophy (obtaining energy by consuming carbon).

If flow releases are to be used to improve ecosystem health, our limited data suggest that both the character of the flow event itself and the flow history during the months prior to release, in particular the duration of the inter-pulse period, need to be considered. Given the limited amounts of water available for environmental releases, our results suggest that flows are likely to have more effect if fewer, higher magnitude flow releases are made instead of more closely spaced, lower magnitude releases. In addition, some flow events appear to produce a greater environmental diversity of patches than others and this may lead to enhancing biodiversity at the reach scale.

Benthic processes and structure vary widely between different flow types, and the links between them need to be understood further to help us predict the ecological consequences of flow management practices.

A250: Development of flow–ecological–response models

In project A250, in collaboration with CRC for Catchment Hydrology, we examined existing datasets to develop predictive relationships between flow change and the responses of particular biota, especially fish and macroinvertebrates.

We addressed the five management and five research questions below, particularly for fish in Queensland rivers.

Management:

1. How important is the natural flow regime as a major 'driver' of ecological structure and processes in eastern Australian rivers?
2. Which are the most and least important elements of the patterns of flows and floods in driving river ecology?
3. How are freshwater biota and ecological processes affected by water resource development (i.e. flow regulation) and river flow restoration?
4. In theory, given particular flow–ecological response models (e.g. for fish), how is an environmental flow allocation (e.g. a contingency volume stored in a dam) best used to achieve ecological outcomes for fish?
5. What biological responses should be measured when we attempt to assess the ecological benefits of environmental flows?

Research:

1. Are there any quantitative relationships between instantaneous and antecedent flow conditions, and ecological responses of fish and invertebrates, in eastern Australian rivers?
2. Can most of the variation in ecological responses of fish and/or invertebrates to flow be related to a few hydrological characteristics, or are many facets of the flow regime important?
3. At what spatial scale (e.g. hydraulic habitat unit, reach, basin, or bioregion) and temporal scale (e.g. daily to decadal) do these relationships become evident?
4. Can stronger relationships be established in rivers with relatively predictable flow regimes (e.g. wet tropics) compared to rivers with more variable flow regimes (e.g. south-east Queensland)?
5. How are production and decomposition in lowland rivers influenced by flow conditions?

From this project we have greater insight into the role of flow variability as a main factor driving ecological processes in streams and rivers. The project has tested various types of hydro-ecological modelling, assessing flow in comparison to other potential driving factors. Numerous publications have resulted from the project.



Program B — Restoration ecology

Leader: Dr Nick Bond

Many of Australia's streams, rivers and wetlands are in a degraded state and millions of dollars are being spent on restoration. To return value for money and be successful in the long term, restoration work needs a strong scientific base, and some measurement of the environmental benefits resulting from the restoration. Research by the CRC for Freshwater Ecology, particularly Program B, has helped provide the ecological knowledge that is essential to support and guide practical restoration measures.

PROGRAM OBJECTIVES

- ▶ Understand the processes that will make ecological recovery possible in disturbed river systems; determine the resilience of restored systems to subsequent disturbances.
- ▶ Develop innovative approaches for waterway restoration, integrating across conventional disciplines to maximise environmental outcomes.
- ▶ Establish case studies with relevant management groups as adaptive stream rehabilitation experiments.
- ▶ Facilitate the integration of river restoration practice into total catchment management.

Theme B1 — Physical habitat restoration

A key assumption of most river and riparian restoration activities is that if you rebuild or recreate habitat then organisms

will return and ecological condition will improve. This implies that recovery of degraded streams and rivers is largely constrained by the availability of suitable habitat.

Theme B2 — Mechanisms of recolonisation and recruitment

Successful stream and river restoration will not only depend on the availability of suitable habitat for aquatic organisms to survive, but also on the ability of organisms to reach the new habitat via dispersal. Physical restoration of stream habitats will be pointless if ecological recovery is constrained by the ability of aquatic plants and animals to recolonise disturbed sites. To be able to predict how quickly disturbed systems will recover, we need to know how aquatic organisms disperse (i.e. what mechanisms they use) and how far they can move.

Theme B3 — Indicators of success of restoration strategies

Much of the work aimed at developing and testing new methods for ecological assessment of the success of restoration is being undertaken in Program D. However, an important question being addressed in the Restoration Ecology Program is whether it is possible to restore key ecosystem processes (such as primary production, and nutrient cycling) without completely restoring all elements of the biological communities.

PROGRAM SUMMARY

Experimental projects in Program B have shown that restoring 'residential' habitat is not enough to ensure the long-term persistence of populations. Refuge habitats are also needed, for use in 'extreme' events. For example, populations of biota such as fish need deep permanent pools to survive in during drought. Further, simply returning a range of physical habitats to a stream does not guarantee improved ecological conditions in that stream. It is evident that catchment factors leading to the poor ecological conditions also have to be managed before rehabilitation can be successful, in urban and rural areas. Recent studies have begun to examine the effects of retrofitting elements of water-sensitive urban design in urban catchments. And an extensive survey of completed river-restoration projects in the USA and Victoria has generated a list of factors that need to be attended to before a rehabilitation project can be confirmed as a success or not, generating return to its investors.



PROGRAM HIGHLIGHTS

B240: Ecological responses and adaptive stream rehabilitation: Application to degraded rural streams

After installing large woody structures in sand-slugged stream reaches of the Granite Creeks (Victoria), the team assessed the degree of ecological rehabilitation that resulted. Fish, macroinvertebrates and stream metabolism (food webs and benthic primary production) were studied for several years. Overall the restoration project was successful. The structures survived floods and drought, resulting in organic matter being retained and stored in the stream reaches. Fish and micro-organisms responded positively to the restoration, but macroinvertebrate species richness and total abundance did not.

B250: Managing fragmentation and connectivity in river systems

This project team first assessed the distribution of species and populations of fish and macroinvertebrates among river reaches, tributaries and streams, under natural conditions. Then they used genetic analysis and analysis of ear-bones in fish (otoliths) to identify the species most likely to be disadvantaged when waterbodies become separated from each other by human activities. The team sampled the Sydney catchment area, the upper Darling, Warrego and Cooper rivers, and the Goulburn, Ovens and Campaspe rivers. High concordance has been found between the otolith and genetic data, making for a very strong analysis of fragmentation between fish populations at a range of time-scales.

B260: Rivers in landscapes: linking river ecosystems to catchment land-use

Project B260 aimed to link stressors and ecological responses across a range of ecologically relevant spatial scales with a particular focus on catchment-scale effects. Most other studies that have examined stressor-response relationships have worked at smaller scales.

We first distinguished between (a) driving factors, typically large-scale processes emanating from human actions, (b) stressors, which are consequences of driving factors, and (c) ecological responses, which result from the effects of the stressors. We classified landscapes in the entire Murray-Darling Basin (MDB) into sets of similar types based on structural and climatic variables and land-use variables. Classifications, which were done at stream orders 2 to 6, were scale-dependent, with the MDB “looking” very different depending upon the catchment level used. At many scales, there were significant mismatches between the classifications based on land-use, with similar land-uses regularly spanning physiographically distinct landscapes. Such interactions may help explain why apparently similar land-uses often lead to very different levels of stream degradation.

B270: Stream restoration through retrofit of catchment urban land use

The project examined options to reduce the area of impervious surfaces directly connected to waterways. These options included: rainwater tanks where the captured water is used to replace a portion of the mains supply; permeable pavements

that reduce runoff from roads; and swale drains and bioretention systems along roads. The traditional option is piped or channelled drainage direct to streams. Modelling showed that it is technically achievable to reduce drainage connection in an existing urban area, to a level predicted to improve the condition of the area’s creek. Pre-retrofit monitoring data shows that the main ecological indicators in the creek are stable relative to those in control and reference creeks, suggesting that changes post-retrofit will be detectable with confidence.



Program C — Conservation ecology

Leader: Dr Margaret Brock

Deputy Leader: Professor Jane Hughes

Degradation of habitat is considered to be the major cause of biodiversity loss, in freshwaters and estuaries as well as terrestrial ecosystems. This program has researched threats to biodiversity as a step towards conserving freshwater biota and ecosystems. The research aimed to guide decisions for restoring habitats and abating threats in a range of freshwater ecosystems.

PROGRAM OBJECTIVES

- ▶ Assess biodiversity and its distribution in freshwater ecosystems; gain insights into processes that regulate levels of biodiversity at various scales in space and time.
- ▶ Identify threats to biodiversity, measure their impacts on biodiversity, and research the mechanisms by which they act.
- ▶ Develop responses to these human-induced pressures, and monitor the effectiveness and outcomes of those responses.

PROGRAM SUMMARY

The Conservation Ecology program has addressed conservation concerns related to all inland aquatic ecosystems, with particular relevance to issues in the rivers and wetlands of eastern Australia. The agendas identified as highest priority for national-scale action were:

- (a) working towards the establishment of a national heritage system of rivers,
- (b) increasing and coordinating inventory effort and taxonomic work (including genetic) to support this,
- (c) protection and rehabilitation of nationally significant sites such as Ramsar sites, and
- (d) the need for national action on invasive species.

We now know more about threats to biodiversity and the mechanisms by which they act (second objective at left), and responses to human pressures (third objective), particularly where such pressures include alteration of ecological flows and habitat.

Specific work in the Conservation Ecology program has addressed the major threats of invasive species and salinity. These were identified in 2003 as being of high priority for partners.

PROGRAM HIGHLIGHTS

C240: The effects of increasing salinity on ecosystem function, resilience and diversity

This project examined the relationships between biological diversity and ecosystem process in freshwaters over a range of salinities. What are the effects of increasing salinity on aspects of primary and secondary production, nutrient dynamics, food web structure, and biodiversity, for microbes, algae, macro-invertebrates and freshwater plants? Sediments from sites in the Macquarie Marshes, NSW, were tested in mesocosm tanks.

The overall microbial community in the sediments was relatively resilient to salt additions — that is, an acute salt addition would take several months to have a major effect on the overall community. Where there is a prevalence of sulfate-reducing bacteria, there are implications for the way nutrients, particularly iron and phosphorus, are moved through the system, and for the potential for acid to be produced if the sediments undergo a cycle of wetting and drying. Phytoplankton biomass was larger at the higher salinities. There was also a change in phytoplankton community composition at the higher salinities but whether this was driven by the salinity differences or by resource availability or grazing pressure requires further analyses. Following an initial period of re-adjustment, all treatments ended up with quite similar respiration rates and primary-production (GPP) rates, except at 15,000 mg/L at which the GPP rate was substantially higher, driven largely by phytoplankton. The mesocosms went through an initial period of high respiration rates requiring a source of organic carbon that may have come from the sediments or been generated through photosynthesis. The capacity for this organic carbon to be used depended on salinity, with far lower respiration rates observed in the high salinity treatments. As salinity increases there is a corresponding decrease in the numbers and richness of wetland plants and zooplankton, as the team has found previously. The biotic community associated with the salinity of 15,000 mg/L was depauperate in numbers and species when compared with the less saline treatments.

C250: Role of refugia in maintaining biodiversity in dryland rivers

The flood early in 2004 enabled the team to sample for water chemistry and invertebrates and elements of the food web during a wet phase in the Cooper Creek. The team also estimated the diversity and abundance of fish, and the presence and identities of larval fish.

The very large amount of data collected has been entered into databases, and publications are being prepared. The databases include: geographic distributions of turtles, macroinvertebrates, fish and algae, and their changes through time; food webs, water chemistry, primary productivity; size structure and recruitment patterns for a number of taxa. Publications analyse effects of carp on primary production; the role of groundwater in dryland rivers; biodiversity patterns for fish, turtles and macroinvertebrates; life history and recruitment in mussels, fish and turtles; and possible impacts of water resource development on biodiversity in dryland rivers.

C260: Predicting the spread of invasive aquatic biota

This study developed a modelling approach which has the ability to incorporate the relative effects of the timing and frequency of floods and the size of founder populations — factors that may be of concern to managers. A range of plant or animal species can be modelled with the approach.

The model allowed a set proportion of the population to disperse passively downstream to the next river section each year. Environmental and demographic

stochasticity were built into the key life history parameters. The paucity of relevant species data led to the construction of a hypothetical species characterized as a one-stage, asexual, perennial organism for which the model outcomes were compared. Outputs from the model are statistical summaries of population size and location and a series of annual maps of the size, distribution and probability of occupancy in particular river sections. The latter can be animated.

The effects of the founder population size and flood frequency were seen in the time taken to spread downriver and this was related to the final population sizes. As floods were set to increase the reproductive rate, they had a major effect on population growth and hence number of individuals dispersing. The size of the founder population was varied by two orders of magnitude and this directly translated to larger populations and faster spread, with a reduced effect as the carrying capacity of a river section was approached. In order to model most aquatic and riparian invasive species, the model needs to be further developed to include a branched river system with the species having the capacity to disperse upstream and over long distances. Habitat suitability also needs to be better modelled because of its known effects on species establishment and survival.

C300: The Narran Lakes ecosystem project (continuing to 2006)

The Narran Lakes project was initiated in 2003 and postdoctoral staff commenced work at the start of 2004, coinciding with

the first major flooding event for the Narran Lakes in four years. Sampling trips during January–July focused on water chemistry, benthic productivity, zooplankton, phytoplankton, macroinvertebrates, fish, and mapping the pattern of inundation across the floodplain. Major surveys of vegetation have described the vegetation patterns (including lignum and trees) and ground-cover on the floodplain near each of the lakes. From soil samples, the seedbank and egg banks in various habitats have been examined via watering trials in mesocosms. Hydrologic data, remote sensing images and topographic data (including via LiDAR) have been collected and used in the hydrological model for the Narran Lakes ecosystem. The project has been reviewed by an International Scientific Review Panel.



Program D — Water quality and ecological assessment

Leader: Professor Richard Norris
Deputy Leader: Dr Chris Walsh

Biological assessment methods measure the effectiveness of management processes in rivers.

Ideal methods should provide rapid collection and analysis of data for management use, on a regional basis and in a timely manner. The methods should assess the degree of impact and present this in an easily interpretable form, using standardised methods of measurement and data presentation. Models underlying the assessment should respond in known ways to natural variability and be implemented with designs that meet statistical assumptions such as the need for independence of treatments being compared. Furthermore, for research managers to choose the most effective restoration and conservation strategies, ecological assessment should also assess degrading processes and determine causal links between the damaging agents and observed ecological condition. Projects within Program D's three themes have addressed these needs.

PROGRAM OBJECTIVES

- ▶ Determine how the ecology of rivers and related wetlands responds to stress factors.
- ▶ Develop and test ecological risk assessment (ERA) procedures for application to freshwater systems.
- ▶ Develop ecologically sound reference conditions for use as benchmarks

when measuring ecological damage or change.

- ▶ Determine the effectiveness of various bioassessment approaches in providing information on the condition of aquatic communities and ecosystem processes.
- ▶ Determine the relationships between ecological features and processes and outputs from bioassessment methods.

Theme D1 — Ecological response to damaging agents

Rivers and related wetlands generally demonstrate an ecological response to damaging agents, both physical and chemical. Experiments have studied responses to nutrient cycles, particularly of nitrogen and phosphorus, and to pesticides and herbicides, land-use, habitat degradation and flow regulation, in winter- and summer-rainfall river systems.

Theme D2 — Innovative bioassessment methods

The effectiveness and relative costs of various bioassessment methods have been compared, for robustness to geographic changes in environmental variables, and for particular situations.

Theme D3 — Ecological risk assessment

Ecological risk assessment procedures have been augmented and tested in situations where several human-induced disturbances are operating in combination, focusing on defining damaging agents in the Australian context and combining them in ERA models.

PROGRAM SUMMARY

The program has advanced knowledge on several separate fronts. Rapid biological assessment methods have been compared and papers describing the outcomes are being published in a special issue of *Hydrobiologia*. In urban areas, effective imperviousness (EI: the proportion of a catchment covered by impermeable surfaces that are directly connected to a stream) is now recognised as a strong predictor for the ecological condition of urban streams (to a threshold of maximum degradation above 5–10% EI). Most recently, trials of retrofitting urban catchments to minimise EI have begun. An innovative framework has been developed for assessing multiple lines and levels of evidence feeding into research or management projects. Also, Ecological Risk Assessment (ERA) has been expanded as a technique and begun to be an accepted tool for waterway management.

PROGRAM HIGHLIGHTS

D240: Assessment methods: environmental flows and biological diversity
The pilot study assessing MLE (Multiple Lines and Levels of Evidence) was completed successfully, and presented at, and published in the proceedings of, the Australian Stream Management Conference in Launceston in October 2004. A presentation was also invited for a special session of the North American Benthological Society conference in New Orleans in May 2005. The MLE approach was adopted as part of the CRCFE Flows Monitoring Forum study design, and is included in the Environmental Flow

Monitoring and Assessment Framework (see report on CRCFE website). A full-scale trial involving the Queensland Dept of Natural Resources & Mines at Goondiwindi, the Victorian Environmental Protection Authority and University of Canberra has also been completed. The reference condition component has used General Additive Models, with collaboration from Lester Yuan of the USEPA, who visited Australia as part of the project early in 2005. Local versus regional species richness (using the 26 catchments in Victoria as regions) has been analysed using multiple regression, and strong conclusions can now be drawn about regional and local biodiversity.

D250 Predicting ecological condition of streams in response to stormwater management

Macroinvertebrate data and classifications of imperviousness were collated for Melbourne, Canberra and Brisbane. They are information assets for partner agencies in these cities, quite apart from their value to this project. Macroinvertebrate assemblages in Brisbane and Melbourne respond to stormwater impacts in remarkably similar ways. This suggests



that similar remedial actions may be applicable, despite the cities' different climates. Predictive models using these data have been completed. The patterns and thresholds shown by models for Canberra and Brisbane were similar to those observed in east Melbourne. The project was enhanced by parallel work being conducted by the stormwater unit of the NSW Department of Environment and Conservation, which developed three models for different areas of the Sydney region. This allowed a comparison of urban impacts in all major cities of S-E Australia.

Five journal papers are in preparation from this project.

RESEARCH PROJECTS active or being written-up during 2004–2005

Core and associated research projects that were active or being written-up during the financial year are listed below.

Project	Project Name
<i>Core</i>	
A240	Quantifying flow–habitat–biota relationships in riverine ecosystems
A250	Development of flow–ecological-response models
B200	Restoration ecology in degraded rural streams
B240	Ecological responses and adaptive stream rehabilitation: application to degraded rural streams
B250	Managing fragmentation and connectivity in river systems
B260	Rivers in landscapes: linking river ecosystems to catchment land use
B270	Stream restoration through retrofit of catchment urban land use
C220	Conservation ecology and systematics of the mountain galaxias
C240	The effects of increasing salinity on ecosystem function, resilience and diversity
C250	Role of refugia in maintaining biodiversity in dryland rivers
C260	Predicting the spread of invasive aquatic biota
D200	Assessment and delivery of methods for determining river health
D220	Development of a catchment-based ecological risk assessment framework for aquatic systems
D240	Assessment methods: environmental flows and biological diversity
D250	Predicting ecological condition of streams in response to urban stormwater management
C300	Narran Lakes integrated research project

Project Project Name

Non-core projects

A708	The effect of water regime on wetland ecology
A716	Fish habitat protection in the Darling and Paroo Rivers
B704	River rehabilitation through re-snagging
B708	National Riparian Lands Program (II): In-stream ecological issues
B709	A synthetic analysis of the scientific basis of ecological restoration of stream ecosystems
B710	Effectiveness of riparian zone restoration in the streams of the Murray-Darling Basin
C702	Systematics of the Australian mayflies (Ephemeroptera) of the families Baetidae and Caenidae
C710	Long-term monitoring of the littoral fauna of Lake Pedder
C711	Sustainable management of on-farm biodiversity in the rice growing industry: vertebrate wildlife resources
C712	The ecology, distribution and abundance of green and golden bell frogs on the Molonglo River floodplain
C713	Predicting ecological consequences of increasing salinity on wetland sustainability
C714	An ecological approach to reestablishing trout cod in the Murrumbidgee River
C715	Biodiversity of riverine landscapes: the role of patches and connectivity
D724	Tooma River study
D725	Robust procedures for measuring metal speciation and bioavailability
D726	Ecological risk assessment of irrigation schemes
D727	Development of ecosystem guidelines for sedimentation and suspended particulate matter for rivers and streams
D728	Delivering sustainability through risk management
D730	Development of risk-based approaches for managing contaminants in catchments



TABLE OF RESEARCH OUTCOMES

Major outcomes from the four research programs during July 1999–June 2005 are shown in the table on the next pages. The first column shows the outcomes projected in the Centre's Commonwealth Agreement. The second column shows the milestones agreed in the Commonwealth Agreement. The third column shows the situation at the end of year 6.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>PROGRAM A</p> <p>Better understanding of the links between flows, ecological processes and biodiversity in a range of river types</p>	<p>PROGRAM A</p> <p>3-year Improved conceptual and empirical understanding of the role of flow (floods and droughts) as a disturbance affecting ecological processes in rivers and streams.</p> <p>5–7 year Improved understanding of the links and exchange of biotic and abiotic materials, including organic matter and nutrients, between river channels and their floodplains.</p>	<p>PROGRAM A</p> <ul style="list-style-type: none"> • Low flows in rivers (with the correct timing, variability, frequency, etc.) are critical features that should be protected. • Summer low flows are particularly important for native fish recruitment (low flow recruitment hypothesis; Humphries et al. 1999). • Slackwater areas in lowland rivers (such as backwaters and macrophyte beds) are important as hot spots for productivity, macroinvertebrate diversity and abundance, and fish recruitment. • Australian river function differs from that predicted by existing conceptual models developed overseas, such as the Flood Pulse Concept and the River Continuum Concept. • Biota of floodplain wetlands are strongly affected by wetting and drying cycles (comparing permanent versus temporary wetlands) and there is strong evidence that these differences are driven by nutrient dynamics in wetland sediments responding to inundation after a dry phase. • The connection between floodplain wetlands (billabongs) and the river channel serves two purposes — recharging of billabongs, and the transfer of beneficial material from the wetlands to the main river channel (A702). • The CRCFE held a very successful international symposium on the ecological effects of drought (Albury, Feb 2001). Proceedings of this conference have been published in <i>Freshwater Biology</i> (Humphries & Baldwin 2003), and a synopsis is published on the CRCFE web site (http://freshwater.canberra.edu.au > publications > technical reports > 2003). • The Narran Lakes Ecosystem Project (C300) continues to examine the responses of a large terminal wetland complex to flow variability in the Narran River. • The Dryland River Refugia Project (C200) has also examined the role of connectivity between the river channel and floodplain waterholes in the Cooper Creek and the Warrego River in arid Australia (see Program C).
<p>New tools that will lead to improved recommendations for, and evaluations of, environmental water allocations.</p>	<p>3-year Ecological characterisation of flow regimes in rivers in Eastern Australia including both winter and summer rainfall systems.</p>	<ul style="list-style-type: none"> • FLOWS method now applied to stream flow management plans in Victoria. • Sustainable Diversion Limits process used to protect ungauged streams in Victoria from over-extraction. • Numerous scientific panel studies of the water requirements for regulated rivers, such as those supporting environmental flow provisions in bulk water entitlements in Victoria. • Murray Flow Assessment Tool developed with CSIRO, for determining flow requirements for key sites along River Murray. • Implemented and refined Before-After-Control-Impact (BACI) designs for monitoring environmental water allocations to rivers (the Campaspe) and floodplain wetlands (Barmah-Millewa forest on the Murray). • Robust and effective indicators of ecological response to environmental flows identified. • Generic decision framework for monitoring environmental flows being devised, including using multiple lines and levels of evidence from project D240. • Sensible characterisation of flow regimes depends on our ability to identify ecologically meaningful flow variables and relate these to changes in biota and ecological processes. The core CRCFE project A250, working with hydrologists from CRCCH, has analysed existing ecological and flow datasets to develop predictive models of ecological response to flow change. User-friendly software for calculating a range of flow parameters from flow gauge data has been developed as a joint project between CRCCH and CRCFE and is now available.
<p>Outcomes (from Schedule)</p>	<p>Milestones (from Schedule)</p>	<p>Situation at end of CRCFE</p>

<p>Program A continued</p> <p>Ability to predict the sensitivity of aquatic ecosystems to varying levels of flow regulation (or water abstraction) from models relating biotic patterns and ecological processes with flow attributes.</p>	<p>3-year Assessment and development of designs for:</p> <ul style="list-style-type: none"> • monitoring the effects of environmental water allocations (environmental flows) to rivers, floodplains and wetlands, and • experimentally testing, at realistic spatial and temporal scales, the causal links between attributes of flow regimes and specific ecological processes. <p>5–7 year Implementation and analysis of</p> <p>(i) monitoring designs for assessing the effects of environmental water allocations to rivers, floodplains and wetlands, and</p> <p>(ii) multi-scale experiments testing the causal links between attributes of flow regimes and specific ecological processes.</p>	<ul style="list-style-type: none"> • Review of refereed and grey literature, focusing on Australian studies, shows unequivocal evidence for ecological responses to altered flow regimes in 87% of 'flow–ecology' studies reviewed. Strengths of responses and nature of relationships were variable (Lloyd et al. 2003). • International workshop held in conjunction with Ninth International Symposium on Regulated Streams in 2003 and collaboration is now on-going with Prof. LeRoy Poff from Colorado State. • Project A250 is using existing detailed datasets and robust statistical techniques to develop predictive models relating flow change to both fish and macroinvertebrate diversity and composition. • 'Measuring the Effectiveness of Environmental Water Allocations' (A703) showed that a BACI design could detect responses of wetland plants to targeted environmental flows in Barmah-Millewa forest. • A240 (Quantifying Flow–Habitat–Biota Relationships In Riverine Ecosystems) has experimentally tested the hypotheses about ecological responses to flow change developed in projects A100, A200 and A210. • A718 determined that BACI designs are not always appropriate for assessing environmental flows and recommended tracking trends through time as flows are gradually implemented. • CRCFE hosted the Ninth International Symposium on Regulated Streams in 2003. Over 250 delegates from 18 different countries attend the meeting, which was held in Albury, NSW. • Two special issues of <i>River Research and Applications</i> were published and Martin Thoms was guest editor of these. Manuscripts in the first special issue were essentially those presented at the Ninth International Symposium on Regulated Streams. These covered an array of topics dealing with the impact and management of regulated rivers. The second special issue contained manuscripts that dealt with variability in riverine environments.
<p>Develop and promote the adoption of flow restoration recommendations that could lead to measurable ecological benefits in degraded rivers.</p>	<p>3-year Development of interim flow restoration guidelines for lowland rivers that will lead to measurable ecological benefits in the main channel, the floodplain and associated wetlands.</p> <p>5–7 year Quantifying the benefits of environmental flows on key biota and ecological processes in winter- and summer-rainfall regulated rivers.</p>	<ul style="list-style-type: none"> • Program A research on ecological responses to flow change, both natural flow variability and flow modification due to regulation of various forms, has resulted in adoption of numerous developments by our partner agencies. Four key examples: <ul style="list-style-type: none"> – a new decision support system, the Murray Flow Assessment Tool, developed with CSIRO to evaluate different environmental flow scenarios for the River Murray. – being part of project teams to develop (i) the FLOWS method for setting environmental flows in rivers and streams in Victoria, and (ii) the Sustainable Diversion Limits method for determining sustainable extraction limits for unregulated streams. – advising Environment ACT and ACTEW on, first, setting environmental flows in the Cotter River (ACT), and then managing those environmental flows under extreme drought conditions and after severe bushfires that resulted in large amounts of sediment entering storages. – Setting of environmental flow rules in the Barwon-Darling River.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>PROGRAM B</p> <p>An improved understanding of the constraints to recovery of disturbed aquatic ecosystems and the processes that can facilitate rehabilitation.</p>	<p>PROGRAM B</p> <p>3-year Development and validation of innovative and practical monitoring tools so that the success of rehabilitation of streams and rivers can be quantified in ecological terms.</p> <p>5–7 year Identify important factors that constrain ecological recovery of degraded aquatic ecosystems and guide rehabilitation strategies to overcome such constraints.</p>	<p>PROGRAM B</p> <ul style="list-style-type: none"> • Sampling techniques for monitoring recovery of wood habitat restoration projects have been developed and tested in several projects on degraded lowland streams (e.g. B200, B706, B240, A100). • Ecosystem health indicators have been identified for streams in south-eastern Queensland as part of the Regional Water Quality Management Strategy (D721). • Availability of suitable in-stream and riparian habitat is a major constraint to recovery of disturbed streams. Habitat rehabilitation can be successful; e.g. <ul style="list-style-type: none"> – provision of wood habitat in streams and rivers affected by sand slugs or de-snagging can be successful in restoring fish populations, such as trout cod (B704) and other smaller species (e.g. B706) – however, provision of residential habitat alone is not sufficient for recovery if there are no refugia for extreme events such as drought (B706, B240) – fish can be patchily distributed through meanders in large rivers and this information can be used to determine where to put wood for re-snagging (B704) – in the case of urban streams, simple re-instatement of physical habitat such as riffles will not work if other catchment scale parameters such as water quality constrain recovery (B705) – manipulation of effective imperviousness in rural/urban catchments may lead to improved stream ecosystem health (D210) – riparian rehabilitation of small streams can mitigate extreme temperature regimes (B708) and lead to the recovery of important ecosystem processes such as benthic metabolism (B708, D721). • Recovery of populations of some species, however, may be constrained by their ability to disperse: e.g. <ul style="list-style-type: none"> – some fully aquatic taxa (including some species of fish) show highly fragmented populations and limited dispersal capability (B250) – reach-scale habitat restoration may be important in preventing populations of such taxa from local extinction and loss of genetic diversity – translocation of individuals from other subcatchments to enhance recovery of disturbed populations may lead to undesirable outcomes. • Population studies, such as these, should be undertaken before major investments are made in habitat restoration. • Preliminary work suggests that there may be some redundancy in the relationship between community composition and important ecosystem processes: rates of denitrification did not change in response to drought even though the species responsible did change (B220, B240).

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>Program B continued</p> <p>To ensure that public funds invested in restoration of degraded ecosystems result in the maximum environmental benefit possible. This will be achieved by:</p> <ul style="list-style-type: none"> Developing guidelines for rehabilitation of streams, rivers and floodplain wetlands in both rural and urban settings, based on sound ecological principles. Establishing demonstration sites to showcase ecologically-sensitive rehabilitation methods. 	<p>3-year</p> <p>Initiate demonstration sites aimed at showcasing practical, cost-effective and ecologically sound methods for the rehabilitation of rivers and wetlands.</p> <p>Contribute to the development of best management practice for the cost-effective and ecologically sound rehabilitation of rivers and wetlands.</p> <p>5–7 year</p> <p>Promote and assist with</p> <p>(i) adoption of monitoring tools and protocols into restoration programs undertaken by stakeholders.</p> <p>(ii) adoption of best practice methods for rehabilitation of rivers and wetlands by stakeholders.</p>	<ul style="list-style-type: none"> The experimental work on wood habitat restoration in the Granite Creeks region (B200, B240, B706) was developed in collaboration with the Goulburn-Broken Catchment Management Authority, Goulburn-Murray Water, and the Granite Creeks and Nagambie and Molka-Miepoll Landcare Groups. Research on the effectiveness of riparian restoration in SE Queensland (B708, D721 and CRCCH 6.4) was undertaken as part of the Echidna Creek riparian re-vegetation project in collaboration with the Maroochy Shire Council and local landcare groups. A large-scale demonstration project has examined the effectiveness of riparian rehabilitation on the River Murray, in an adaptive management experiment (B710), funded by the Murray-Darling Basin Commission. In addition to providing opportunities for quantification of the effectiveness of restoration activities, these demonstration sites have provided an important knowledge exchange opportunity for the CRC. A practical and cost-effective monitoring program for assessing ecosystem health in streams and rivers in southeast Queensland has been developed as part of Program D (D721; Smith and Storey, 2001) and subsequently implemented by the Moreton Bay and Catchments Healthy Waterways Partnership. The project team conducted specific training sessions for community groups and government staff and additional field training. Much of this regional monitoring has now been handed over to the Queensland Dept of Natural Resources & Mines. Further development of ecosystem health tools to measure the success of restoration efforts has occurred within Program D (e.g. D200, SRA Pilot Study). The development of specific technical guidelines, and associated presentations at workshops, conferences and seminars, were all aimed at promoting the adoption of best practice methods for rehabilitation. Large rehabilitation trials (e.g. riparian vegetation in the Murray, B710; urban stream restoration in the Yarra) have had an experimental, adaptive context, supported by CRCFE research. Local and state authorities have adopted recommended methods for monitoring stream ecosystem health. Technical guidelines have been prepared for riparian rehabilitation and the management of wood (logs) in streams. Technical advice on priorities for riparian management has been adopted into regional management strategies (e.g. SEQ Regional Water Quality Management plan). Plain-English summaries of research outcomes in natural resources management publications and brochures (see list of publications). Riparian rehabilitation projects have been undertaken with stakeholders as adaptive management experiments; for example, Echidna Creek riparian restoration project (with CRCCH and the Healthy Waterways partnership) and a large-scale project at several sites in the Murray-Darling Basin (B710). In addition to physical habitat restoration projects, flow manipulation experiments have been undertaken in Program A.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>PROGRAM C</p> <p>New knowledge on the distribution, life history and conservation ecology of threatened freshwater biota</p>	<p>PROGRAM C</p> <p>3-year Organisation of a national forum on conservation of biodiversity in freshwater ecosystems, bringing together the range of perspectives from science and management</p> <p>5–7 year Significant contribution to understanding of biodiversity, its regulation in natural and disturbed systems, its measurement and its distribution within the Australian freshwater landscape.</p> <p>Decision-making tools for biodiversity conservation, provided in a form that can be readily used by managers.</p>	<p>PROGRAM C</p> <ul style="list-style-type: none"> • Fenner Conference on the Environment 2001, 'Biodiversity Conservation in Freshwaters' (see Georges & Cottingham 2002), focused on the nature of decision making for Australian freshwater biodiversity, and recognised the need for an adaptive approach, where intervention and research, including monitoring and evaluation, are used to improve conservation outcomes and improve knowledge. • A special issue of <i>Aquatic Ecosystem Health and Management</i>, called Freshwater Biodiversity in Australia (Volume 6(1) 2003), Arthur Georges, Angela Arthington and Pierre Horwitz as guest editors, published eight papers from the Fenner Conference. They cover a broad cross-section of perspectives on freshwater biodiversity in Australian freshwaters, from single species approaches to taxonomic groups to special habitats and ecosystems, wetland restoration, river degradation, modifications to hydrology and protective measures for rivers. • The endangered species survival decision tool ESSENTIAL (C709) is available by web delivery. • The Biodiversity Knowledge Project and the Biodiversity Forum agreed to develop a framework for assessing biodiversity in consultation with managers. • Report: 'Assessing and monitoring aquatic biodiversity: What have we learnt?' at CRCFE website (O'Connor and Kotlash 2005) reports accumulated knowledge from CRCFE researchers as developed through the CRCFE Biodiversity Forum.
<p>Principles and recommendations for assessing the biodiversity values of freshwater systems</p>	<p>3-year Design of experimental protocols for testing hypotheses on the processes that regulate biodiversity in natural and modified freshwater ecosystems</p> <p>5–7 year Principles and recommendations for assessing the biodiversity values of freshwater systems and recommendations for management options.</p>	<ul style="list-style-type: none"> • The Biodiversity Knowledge Project and the Biodiversity Forum have facilitated the generalisation of principles and recommendations in a form that is of real use to managers. • Biodiversity values have emerged from the studies of dryland river waterholes (C200/250). Experimental protocols have been developed within the dryland refugium project (C250) and the project on sustainable management of on-farm biodiversity in the rice growing areas (C711). • Principles for assessing biodiversity were developed for the Sydney Catchment Authority long-term monitoring program and published in a major report to the SCA (F663).

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>Program C continued</p> <p>Advice on the likely impacts of various human-induced disturbances on biodiversity in freshwater ecosystems and the spatial scales over which they are likely to have effect</p>	<p>3-year Development of principles for the assessment of biodiversity in freshwater ecosystems</p> <p>5–7 year Direct involvement in policy and decision-making through established government processes for implementing policy on biodiversity and threatened species conservation</p>	<ul style="list-style-type: none"> • Advice on salinity, invasives and threatened species is now available, including via a series of fact sheets. • Genetic techniques, being applied to study the distributions of taxonomic groups, are finding cryptic species (which differ genetically but not in morphology) with high genetic diversity. • Scientists from CRCFE continue to be members of state Threatened Species Scientific Committees (Prof Jane Hughes (QLD), Dr Margaret Brock (NSW), Dr Will Osborne (ACT)) and have had input to the design and revision of the legislation for Commonwealth and state Acts. Professor Angela Arthington participates in an international program of biodiversity science, DIVERSTAS. Increased awareness for the need for freshwater biodiversity conservation and a heritage river system have been derived from the Fenner Conference and from other CRCFE publications such as <i>Conserving Natural Rivers: A Guide for Catchment Managers</i> (Cullen 2002) and <i>Biodiversity in Inland Waters — Priorities for its Protection and Management</i> (Georges and Cottingham 2002). Our research on adaptive management in restoration ecology (C210) and in fish recovery (C220, C715) has also fed into policy implementation.
<p>Advice on the possible ecological effects of invasive species on native flora and fauna.</p>	<p>3-year Identification of primary threatening processes for aquatic biodiversity.</p>	<ul style="list-style-type: none"> • Our ability to influence the management of aquatic invasive species has increased as our understanding of the process of invasion has increased. Much of the relevant knowledge has been developed through student projects. • Project C260, 'Predicting the spread of invasive aquatic biota', has developed a model which can incorporate the effects of timing and frequency of floods on founder populations. This model needs further development for a range of aquatic and riparian invasive species in branched river systems and for different short-term and long-term dispersal patterns.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at end of CRCFE
<p>PROGRAM D</p> <p>Improved scientific knowledge on the ecological effects of damaging agents (including nutrients and pesticides) in Australian freshwater systems.</p>	<p>PROGRAM D</p> <p>3-year Development of priority areas for research in ecological response to agents that damage freshwater ecosystems</p> <p>5–7 year Understanding of cause and effect links between ecological features and processes and methods of assessment</p>	<p>PROGRAM D</p> <ul style="list-style-type: none"> • Increased knowledge about how catchment impermeability affects the health of urban streams. • Investigation of the impacts on Tooma River from leachate from a waste rock dump showed changes in stream chemistry but not biota. • Further understanding of sediment dynamics during storm events and base flow: <ul style="list-style-type: none"> (1) from the relationship between storm hydrograph, sediment concentration and particle size in transportation; (2) from the relationship between sedimentation and aquatic diatom, algae and macroinvertebrate communities; (3) from levels at which sedimentation induces mortality of Australian native fish eggs. • Nitrogen found to be the primary limiting nutrient in SE Queensland streams. Nitrate and organic carbon are important for controlling denitrification, and rates are insufficient to deal with current loads. Shading from the riparian zone important for controlling stream productivity (D722).
<p>Improved and robust bioassessment methods that provide information on ecosystem health and assist in identifying the degrading processes (including habitat modification).</p>	<p>3-year Integration of AUSRIVAS with other techniques for assessment of river condition.</p> <p>5–7 year</p> <ul style="list-style-type: none"> • Understanding of the effects of natural variability on bioassessment methods • Evaluation of bioassessment techniques in an experimental process • Integration of bioassessment methods into agency assessment programs 	<ul style="list-style-type: none"> • D200: DIAR2 index and new macrophyte index developed. AUSRIVAS more robust as a result of outcomes from sub-sampling comparison and replication trials. D722: some nutrient processes shown to have potential as ecological indicators. • D727: Aquatic diatoms, algae and macroinvertebrates used to develop ecosystem guidelines for sediments. • Biological assessment has become an important component of the Victorian State Environmental Protection Policies, Index of Stream Condition, Queensland Water Allocation Management Plans, NLWRA, the NSW Blueprints for catchment targets and catchment management plans. • Workshops held on design for comparison of methods, habitat assessment and information needs of partners for integration of biological methods into monitoring programs (D200). • Eight different biological approaches (three macroinvertebrate methods, one macrophyte method, two diatom methods and two benthic metabolism methods) were assessed using an explicit framework also developed in the study. This gave information on both the usefulness of the framework and on the RBA methods.
<p>New ecological risk assessment procedures and associated tools for use by water industries.</p>	<p>Bring in expertise in ecological risk assessment (biota and processes with inputs to ecological risk assessment over a range of scales up to catchment level).</p>	<ul style="list-style-type: none"> • Development of Bayesian approaches in risk assessment. • STREAMS DSS refined for Melbourne Water; algal models for Lake Yarrunga developed for SCA. • Models for impact of sediment on biota.

3. Education and training

Leader: Professor Jane Hughes

The overarching focus of the Education Program has been to broaden the CRCFE's students' education and training experience, particularly in graduate programs. This has been achieved through initiatives such as the active involvement of researchers from outside the higher education system, and by enhancing the employment prospects of students through involvement in our user-oriented research program.

Our first objective has been the training of postgraduates to produce ecologists and aquatic scientists with high-level research skills who are sought after to work in the water industry. The objective has been achieved through the activities of the CRCFE's staff at its partner universities, collaborating with personnel from our industry partners and the Education Program team.

The CRCFE's Commonwealth Agreement had four other education & training objectives:

- ▶ contribution to the continuing development of professionals working in the water industry through continuing education programs that update their knowledge and skill-bases;
- ▶ contribution to undergraduate education programs to ensure graduates have sound ecological knowledge and an appreciation of its application to



water management, and that graduates are aware of opportunities and are employable within the water industry;

- ▶ assisting community groups to understand water-related issues, and help equip them to take an active role in land and water management;
- ▶ building community awareness of water ecology and related environmental issues through a program of public and school-based education.

These four areas have been handled largely by researchers and knowledge exchange staff.

In meeting these five objectives, CRCFE has aimed to provide the water industry with:

- (a) well-trained graduates who have keen academic, communication and technological expertise, as well as
- (b) opportunities for professional development among freshwater managers,
- (c) support for ecologically-aware management, among members of the community, and
- (d) a continuing supply of new recruits to freshwater science.

Summary of progress

POSTGRADUATE STUDENTS

The CRCFE has attracted postgraduate students through a combination of applied research opportunities, scholarships and operating funds, and value-adding professional training.

APA Industry Level scholarships and top

up scholarships have been offered through the CRCFE, except in 2004–2005. The scholarships encouraged students to take up PhD projects that are relevant to the water industry. The most recent recipients of top-up scholarships also have had a mentor from the water industry, with whom they have met regularly.

At 1 June 2005, the CRCFE had five postgraduate students on full scholarships (4 full-time, 1 part-time); 16 on top-up scholarships; 7 working on associated (non-scholarship) projects (including 1 on a collaborative write-up scholarship); 7 privately supported (funding had finished); plus 1 PhD and 1 MSc suspended: 37 in total (see table on pages 27–29).

A scheme of collaborative write-up scholarships was offered to all students during 2004–2005 for students who had recently submitted their PhDs. One student, Patricia Bowen, applied and was eligible for a scholarship. Patricia therefore has worked half time for industry partner the Murray Wetlands Working Group, and has spent the rest of the time completing her PhD thesis.

Training workshops and professional development courses have been offered to CRCFE postgraduate students during 2004–2005. Basic GIS courses were offered to students in their capital cities who had not previously been exposed to GIS training; also, a course on advanced statistics. A mid-year workshop in July 2004 on two themes — Writing successful grant applications, and Effective conference presentations —

was enthusiastically received by the students. The workshops were interactive, giving students opportunities to demonstrate their skills in these areas. They were so successful that students asked for a student forum where they could share PhD experiences and further enhance their presentation skills. A student forum was therefore held in conjunction with the Annual General Meeting in late June 2005.

Postgraduate student statistics

During 2004–2005, the CRCFE has had a total of 41 full-time and part-time PhD students, including those who have submitted and taken time off. The following students have submitted PhD theses or had them accepted between July 2004 and June 2005:

- ▶ Giovannella Carini, 'The role of flooding in the maintenance of genetic diversity in four floodplain invertebrates' (Griffith University)
- ▶ Dale McNeil, 'Fish, zooplankton and algae dynamics in Murray River billabongs' (La Trobe University)
- ▶ Amy George, 'Population dynamics and recruitment of eucalypts on the Lower Murray Floodplain' (University of Adelaide)
- ▶ Jason Nicol, 'The ecology and management of arid deflation basin lakes' (University of Adelaide)
- ▶ Benjamin Smith, 'Carp spawning dynamics and early growth in the River Murray, South Australia' (University of Adelaide)
- ▶ Kelly Vanderkruk, 'Biogeochemistry of nutrients in a sand slug stream,

Creightons Creek, Victoria' (Monash University)

- ▶ Claudette Keller, 'Factors regulating faunal assemblages in freshwater temporary ponds' (Monash University)
- ▶ Claire McKenny, 'The relationship between ecosystem processes and community structure in south east Queensland rivers' (Griffith University)
- ▶ Carol Conway, 'Reactivity of organic carbon under anaerobic conditions and its role in sediment nutrient dynamics' (University of Canberra)
- ▶ Mark Kennard, 'A quantitative basis for the use of fish as indicators of river condition' (Griffith University).

The following students graduated at ceremonies during 2004–2005:

- ▶ Kelly Vanderkruk
- ▶ Benjamin Smith
- ▶ Jason Nicol
- ▶ Giovannella Carini
- ▶ Julia Howitt
- ▶ Amy George
- ▶ Dale McNeil

Two new associated projects began in 2004–2005. Anne Jensen began work on 'The lower Murray floodplain seedbank: status and response to flooding', working at the University of Adelaide with Associate Professor Keith Walker and Associate Professor David Paton. And in July 2004, Mark Southwell began his studies with Associate Professor Martin Thoms (University of Canberra) and Dr Jon Olley at CSIRO Land & Water, on

'Inland river floodplains: the role of sediment and nutrient exchanges'.

Conference/workshop attendance and travel

During 2004–2005 CRCFE has supported postgraduate students to travel to and present papers and posters at the following national and international conferences and workshops:

- ▶ 43rd Annual ASL Congress (four students)
- ▶ Fifth International Symposium on Ecohydraulics, Madrid, Spain (one student)
- ▶ 29th Conference of the International Association of Limnology, Finland (one student)
- ▶ North American Benthological Society Annual Meeting, New Orleans (one student)
- ▶ Evolution 2005 Society for the Study of Evolution, Fairbanks, USA (one student)
- ▶ 2004 Royal Australian Chemical Institute Conference, Gold Coast (one student)
- ▶ Ecological Society of Australia conference (one student)
- ▶ American Society for Limnology and Oceanography summer meeting, Spain (one student)
- ▶ 36th International Binghamton Geomorphology Symposium, 'Geomorphology and Ecosystems', Buffalo, New York State (one student).

Students have been able to attend up to two national conferences and one international conference during their

candidature, with the proviso that they present their work as a paper or poster at the conference and produce a short article suitable for publication in the news section of *Watershed* or CRCFE News (the internal emailed newsletter) upon return.

In addition, all students have been funded to attend the CRCFE Annual General Meeting, the associated workshops and the student forum. This has encouraged interaction between students from the different university campuses, as well as introducing them to other researchers and managers in the water industry.

Destination surveys

Graduates from the CRCFE PhD program have been surveyed to follow the progress of past students. The purpose of the survey was to provide feedback to the CRCFE from former graduates, with a focus on mentoring and general experiences, and suggestions for changes. Of 31 past students (theses completed 1997–2004) who could be contacted, 25 completed the survey. They recorded these strengths of the CRCFE postgraduate program:

- ▶ the opportunities given for networking with scientists and other students during their candidature
- ▶ the industry contact and the chance to have professional mentoring and work experience in industry
- ▶ the professional development offered as workshops and courses,
- ▶ the financial support (scholarships, operating funds, travel allowances).

Young Water Scientist of the Year

The CRCFE has managed the 2004 and the 2005 CRC Water Forum Young Water Scientist of the Year Award program. In both years, the awards have been hosted by the *Riverfestival Riversymposium* in Brisbane in early September. The candidates presented their talks during the conference sessions most related to their subject matter, rather than in a separate session as in previous years. They have since commented on the welcome interest shown by the audiences, and on the good exposure to the industry and other scientists in their particular fields

The CRC Water Forum's high profile Young Water Scientist of each year is selected by a panel of eminent judges at a major water conference, from finalist postgraduates selected from water-focused CRCs. Until 2005, only the Water Forum CRCs had been involved, but in 2005 the contest was widened to include water-focused PhD candidates from any CRC. Selection criteria, which are applied to both a written and a spoken paper from each candidate, in 2005 were: (i) the quality of the scientific research



approach, (ii) the personal role the student has played in developing the topic and overcoming difficulties along the way, and (iii) the student's skill and initiative shown in communicating their subject matter. An underlying criterion is also the relevance of the work to industry, but this year that was given lower priority than in previous years. The award is intended to showcase students working on water-focused research.

Amy George (from the University of Adelaide; now working with Dept of Water, Land and Biodiversity Conservation in Adelaide, SA, and a knowledge broker with CRCFE until June 2005) has been our candidate for the 2005 Young Water Scientist of the Year; Dale McNeil (from La Trobe University; working at DIPNR at Forbes, NSW) was our finalist for 2004. Winner for 2005 was Cara Beal (CRC for Coastal Zone, Estuary and Waterway Management), and for 2004 it was Sara Lloyd (CRC for Catchment Hydrology).

Judges for 2005 were:

- ▶ Professor Ian Rae, professorial fellow in the history and philosophy of science at the University of Melbourne;
- ▶ Dr Barbara Baginska, Senior Environmental Scientist, Waters and Catchment Science Section, NSW Department of Environment and Conservation;
- ▶ Mr Harley West, Secretary of the Granite Borders Landcare Committee, and a founding member of the Stanthorpe Water Assessment and Monitoring Project, south-east Qld.

Awards to postgraduate students

Tim Page (Griffith University) won Best Student paper at the Australian Society for Limnology's 43rd Annual Congress, Adelaide, in November–December 2004.

Ben Smith (University of Adelaide) was awarded the Australian Society for Fish Biology's 2004 International Travel Scholarship (worth \$5000), on the basis of his technical publications.

Craig Boys (University of Canberra) has just won the John Holliday Student Conservation Award, presented annually by NSW Fisheries, part of NSW Dept of Primary Industries, for his PhD studies on fish habitats in the Barwon-Darling River, NSW.

Mark Kennard (Griffith University), with co-authors Brad Pusey and Angela Arthington, also of Griffith University, has just been awarded the Whitley Award for zoological publishing, from the Zoological Society of NSW, for their book *Freshwater Fishes of North-eastern Australia*.

TRAINING FOR WATER INDUSTRY PROFESSIONALS

CRCFE researchers and knowledge exchange staff ran and/or supported several courses for water industry professionals during 2004–2005.

The AUSRIVAS Online training course was delivered each semester during 2004–2005, particularly to water industry personnel. The course consists of four modules that are self-paced and accessed via the Internet, and also an

optional four-day face-to-face practical workshop module. The modules teach participants about assessing river health using the methods and predictive models of AUSRIVAS (Australian River Assessment System).

The success of online and blended face-to-face delivery has led to a new set of courses, 'Watercourses Online', being offered from 2004–2005, via the same CRCFE University of Canberra team. Watercourses Online is a growing set of online training courses designed primarily to support personnel in water management, natural resources management, environmental education and ecological consulting. The courses available now are:

- ◆ Ecology and river function
- ◆ Waterway assessment
- ◆ Catchments: their character, waters & chemical composition.

Details are available from <http://freshwater.canberra.edu.au/WatercoursesOnline.nsf>.

John Hawking has again run 'Train the trainer' sessions for Waterwatch staff in Victoria, South Australia and ACT. The sessions teach sampling methods (hands-on in local rivers) for macroinvertebrates, the ecology of stream macroinvertebrates, and the identification of aquatic freshwater invertebrates in the laboratory, using an Internet-based guide to the identification and ecology of aquatic freshwater invertebrates. John developed the web guide at the request of the Australian Government Dept of Environment and Heritage.

UNDERGRADUATE EDUCATION

Undergraduate teaching takes place at Monash University, University of Canberra, La Trobe University, Griffith University, the University of Adelaide, and at other CRC sites, or at the request of other institutions.

The following undergraduate freshwater ecology and water-science-related units are offered at university partners as part of an associated degree. These often encourage students to further their studies by MSc or PhD in the water field within the CRCFE. Students are exposed to CRCFE research and researchers as much as possible, especially during their final year.

Summer scholarships and work experience

Summer scholarships were undertaken for a period of 8 weeks from November 2004 through to February 2005, with a stipend of \$4000 each. Short projects were completed under the supervision of CRCFE staff at the various institutions. The scholarships were provided to:

Monash University (2),
Monash Water Studies Centre (1),
University of Canberra (3),
Griffith University (3),
MDFRC Mildura Lab (2, each sponsored half by CRCFE and half by the local community),
MDFRC Albury Lab (1).

Mark Carey (one of the MDFRC summer scholarship students in 2003–2004) was awarded the North-east CMA Prize at the Annual Presentation of Awards and Prizes Ceremony at La Trobe University in July 2004.

COMMUNITY EDUCATION

Community and school-based education activities have been managed and performed mainly by knowledge brokers and scientific staff.

We worked with Waterwatch and Greening Australia, in particular, and interacted with the broader community via presentations, forums, field events and working groups.

- ▶ A member of CRCFE staff has been working with Waterwatch Victoria to develop quality assurance methods for use by community members of Waterwatch; and CRCFE staff helped set up the ACT Waterwatch Campfire program for post-fire freshwater monitoring.
- ▶ Specialist groups have held discussions with CRCFE staff about training that can be set up to train them in particular areas (e.g. CMAs).
- ▶ Occasionally, targeted fact sheets have been produced in response to requests for information from community members and local state agency staff; e.g. on anabranch channels of the Macintyre River, and on connectivity and its role in promoting biodiversity.
- ▶ Presentations and interaction have been invited by a wide range of community groups, including art project teams, wetland groups, the wetlands education network, bird observers, field naturalists, Rotary and Lions Clubs, eco-tourism groups, wetland community groups, Landcare.

SCHOOL-BASED EDUCATION & ASSISTANCE TO THE GENERAL PUBLIC

In April 2005 again, students from years 9 to 11 attended the two very popular annual freshwater schools run by the Murray-Darling Freshwater Research Centre, and Rotary.

The annual 'Health of the River System' youth forum, run from Mildura each April, attracts students in years 9–10 from south-west NSW, South Australia and Victoria. Each year, students investigate the biology of fish, water bugs and plants at Lake Cullulleraine, as well as some of the social and economic aspects of water management. They also work with catchment managers and scientists. Student presentations at the end of the forum are always excellent, and demonstrate good understanding of issues in river ecology.

Also in April, the Rotary Murray-Darling School of Freshwater Research introduces year 11 students to freshwater ecology. They work in teams with leading scientists from La Trobe University, the MDFRC and Charles Sturt University.



Students experience both work in the MDFRC laboratories and field-work at Wonga Wetlands, and always give excellent presentations at the end of the week to a group of scientists and Rotarians.

During 2004–2005, CRCFE staff (particularly knowledge brokers and scientists based at the regional laboratories) visited schools and colleges (pre-primary to tertiary), led excursions of school-students, worked with students in preparation for MyRiver sessions, and produced plays (primary school) on ecological themes. Presentations have been tailored to the particular groups but often focused on river health issues, salinity, aquatic food webs, aquatic plants, ecological sampling, work of the regional labs, stormwater education, flow alteration, flooding, native fish and introduced fish.

For the general public, CRCFE staff also have answered questions, identified biota, supplied general CRCFE written material, including brochures, reports, newsletters (e.g. *Watershed*, *The Narran News*) and run stands at displays and field days (e.g. World Wetlands Day; Water Week).

CRCFE postgraduate students active at June 2005

The CRCFE's postgraduate students are listed on the next three pages, by name and expected degree, project title, supervisors/ mentors and institutions, and source(s) of funds.

CRCFE postgraduate students active at June 2005

Name and expected degree	Project title	Supervisor and institution	Source(s) of funds
Aldridge, Kane PhD	Structure and function of Mediterranean creeks along a rural-urban gradient: influence on phosphorus dynamics	George Ganf, Justin Brookes, University of Adelaide; Michael Burch, SA Water (industry)	APA + CRCFE Top-up scholarship
Atkinson, Bonnie PhD	Ecosystem function responses to stream rehabilitation in the Granite creeks	Barry Hart, Mike Grace, Monash University; Wayne Tennant, Goulburn Broken CMA (industry)	APA + CRCFE Top-up scholarship
Barrett, Melissa PhD	Distributions and implications of C3, C4, CAM/SAM species in the Murray-Darling Basin as a response to resources/stress limitations of water, nutrients and salinity	Keith Walker, George Ganf, the University of Adelaide	APA + CRCFE Top-up scholarship
Bowen, Trish PhD	Flow effects on cycling of carbon from lowland river macrophytes	David Williams, University of Canberra	Land and Water Australia Associated Project, Collaborative write-up scholarship
Boys, Craig PhD	Habitat used by riverine fish communities in semi-arid regions during low flow	Martin Thoms, University of Canberra	CRCFE full scholarship
Bryce, Cassandra PhD	The ecology and systematics of the Australian Eustjemiidae (Insecta: Phlecoptera) and the implications of climate change on their conservation status	Phil Suter, La Trobe University; John Hawking, MDFRC	CRCFE top-up Associated Project
Cook, Ben PhD	Recovery and recruitment of aquatic fauna to rehabilitated streams in south-eastern Australia	Jane Hughes, Stuart Bunn, Griffith University	APA + CRCFE Top-up scholarship
Cooper, Karen PhD	How are aquatic ecosystems affected by different configurations of landscape-scale drivers?	Gerry Quinn and Ralph MacNally, Monash University; Leon Metzeling, EPAV (industry)	Associated Project + Land & Water Australia scholarship, UC top-up
Curmi, Tim MSc (deferred)	Determining the health of the Lachlan River	Phil Suter, La Trobe University; Richard Norris, University of Canberra	Associated Project
Davis, Nicole PhD	Fate and environmental effects of ammonia	Bill Maher, University of Canberra	Associated Project
Francis, Cathy PhD	The effects of flow regulation on carbon and nutrient cycles in temporary wetlands of the Murray River	Martin Thoms, University of Canberra; Ben Gawne, MDFRC	APA + CRCFE Top-up scholarship
Gehrig, Susan PhD	The ecology of riparian willows on the River Murray	Keith Walker, University of Adelaide	APA + CRCFE Top-up scholarship
Hammer, Michael PhD	Setting a framework for conservation: molecular systematics and conservation biology of small fishes of the Murray-Darling Basin	Keith Walker, University of Adelaide	APA + CRCFE Top-up scholarship

Name and expected degree	Project title	Supervisor and institution	Source(s) of funds
Harbott, Ernestine PhD	Use of enzyme activity for characterising organic carbon in Australian freshwater streams	Barry Hart, Mike Grace, Monash University	APA + CRCFE Top-up scholarship
Hughes, Victor PhD	Hydraulic habitat of inland rivers: the role of large woody debris	Martin Thoms, University of Canberra	CRCFE Top-up Scholarship expired, now self-funded
Hunter, David PhD	Life history of declining and non declining frogs in the Southern Highlands of NSW	Will Osborne, University of Canberra	Now self-funded
Jensen, Anne PhD	The Lower Murray Floodplain seedbank: status and response to flooding	Keith Walker and David Paton, the University of Adelaide	Associated project, Land & Water Australia scholarship
Kelly, Nadine PhD	Quantifying flow–habitat–biota relationships in riverine ecosystems	Keith Walker + Trevor Daniell and Martin Lambert, (School of Civil and Environmental Engineering), the University of Adelaide; Shaun Meredith, MDFRC	Associated project + CRCFE top up scholarship
Linke, Simon PhD	New approaches in biodiversity assessment for conservation purposes	Richard Norris, University of Canberra; Leon Metzeling, EPAV (industry)	CRCFE top up scholarship
Loo, Sarina PhD	Intercontinental analysis and modelling of invasive species	Ralph MacNally, Sam Lake, Dennis O'Dowd, Monash University; Sabine Schreiber, DSE (industry)	CRCFE top up scholarship
MacKay, Stephen PhD	Flow requirements of aquatic macrophytes in south-east Queensland streams	Angela Arthington, Thorsten Mosisch, Griffith University	CRCFE full scholarship
McGinness, Heather PhD	Connectivity and fragmentation of floodplain-river exchanges in a semi-arid, anabranching floodplain river system	Martin Thoms, University of Canberra	APA + CRCFE Top-up scholarship
Medeiros, Elvio PhD	Variation on diet composition of fish in dryland refugia	Angela Arthington, Griffith University	International Scholarship and Associated Project
Oswald Louisa PhD	Development of in-situ protocols for the assessment of water quality using macroinvertebrates	Richard Norris and Bill Maher, University of Canberra	CRCFE Top-up (expired), now self-funded
Page, Timothy PhD	The role of vicariance and dispersal in the evolution of atyid shrimps in Australasia	Jane Hughes, Stuart Bunn, Griffith University	APA + CRCFE Top-up scholarship
Perryman, Shane PhD	Nitrogen cycling and bacterial bio-diversity in urban Australian streams	Barry Hart, Mike Grace, Monash University	CRCFE full scholarship (extension)
Price, Amina PhD	Influence of hydrology on the recruitment of native fishes to the Narran Lakes, north-western NSW	Martin Thoms, University of Canberra	CRCFE full scholarship
Reid, David PhD	Effects of riparian zone degradation and restoration on ecological processes in freshwater streams	Gerry Quinn, Sam Lake, Monash University; Wayne Tennant, Goulburn-Broken CMA (industry)	CRCFE top-up scholarship

Name and expected degree	Project title	Supervisor and institution	Source(s) of funds
Sellens, Claire PhD	Defining the reference condition: implications for biological assessment	Richard Norris, University of Canberra	CRCFE full scholarship, part-time student, now self-funded
Sharma, Suman PhD	Genetic structure of aquatic fauna in coastal streams in SE Queensland: evidence for past drainage changes	Jane Hughes, Griffith University	CRCFE full scholarship (expired), now self-funded
Southwell, Mark PhD	Inland river floodplains: the role of sediment and nutrient exchanges	Martin Thoms, University of Canberra; Jon Olley, CSIRO Land and Water	Associated project, Land and Water Australia, UC top-up scholarship
Stojkovic-Tadic, Slobodanka PhD	Interactions between nutrient status and UVB in microalgae	John Beardall, Monash University	Monash Graduate Scholarship + CRCFE Top-up scholarship, now self-funded
Thomas, Colette PhD	Ecological risk assessment of land derived contaminants to coastal ecosystems	Barry Hart, Mike Grace, Monash University	Associated Project
Troy, Aaron PhD	Quantification of ecological benefits associated with wetland rehabilitation along the Murray River Floodplain	Phil Suter, Terry Hillman, La Trobe University; Keith Ward, DSE and NECMA (industry)	APA + CRCFE Top-up scholarship
Watkins, Susan PhD	Effects of flooding and drying cycles on ecological processes in river-flood plain systems	Gerry Quinn, Monash University; Ben Gawne, MDFRC; Deb Nias, NSW Murray Wetlands Working Group (industry)	CRCFE top-up scholarship

4. Collaboration and Knowledge exchange

To ensure that CRCFE research and services meet the short- and long-term knowledge needs of the CRC's partners, and that new knowledge is applied by our partner management agencies and by policy-makers and researchers all over the world and others, we use *collaborative linkages* within and beyond the CRCFE, and particularly a process we call '*knowledge exchange*'.

Collaborative linkages between CRCFE partners

The CRCFE is a cooperative assemblage of 19 research and management institutions, as listed in Chapter 1. In this cooperative working environment, it is easy to forget that research in freshwater ecology, and communication between water professionals, was different before the CRCFE was set up first in 1993. It is very important that the good cooperative linkages between the CRCFE's core participants are maintained, and developed further where possible.

Several mechanisms have operated to build mutual trust between the groups, across sites and disciplines.

- ▶ One strong mechanism has been the cross-institutional collaboration that has existed among our research-provider partners and between them and our water-industry partners. The

CRCFE's research teams worked across disciplines and organisations. Program and project meetings, field-work and joint supervision of PhD students all offered opportunities for face-to-face interaction among team members from different institutions and states, reinforcing email and phone contact.

- ▶ The cross-institutional collaboration has been led by the senior management team structure, which brought together representatives from five of the research sites, eight times per year.
- ▶ Important collaborative linkages have been maintained at Board level, with four meetings per year plus committee and other interactions between meetings. The Board consists of senior representatives of the core participants (both industry partners and research providers) that make the largest financial contributions to the CRCFE.
- ▶ The CRCFE's knowledge exchange (KE) team has also aimed to help maintain trust between groups. In part of their work, the KE team members have assembled forums and steering committees consisting of industry and research staff, and they have also been an important contact point for the CRCFE's other stakeholders.
- ▶ All CRCFE staff have been invited to contribute news items to the fortnightly internal e-newsletter. Staff have also been emailed *Research Highlights*, which notes progress in current research projects, and *Watershed*, the CRCFE's public

newsletter/magazine.

- ▶ The Annual General Meeting, a busy two–three day meeting, brings together staff and students from all sites and programs. The 2005 AGM was held in Sydney. Postgraduate students from all sites also have met at least once per year, usually during the AGM.

External collaborative linkages

Beyond the CRCFE partners, collaborative links have been established with:

- ▶ policy-makers, natural resource managers, government officials from non-partner organisations
- ▶ community groups; parliamentarians
- ▶ non-partner members of the water industry, including small-to-medium-size enterprises
- ▶ the four other water-related CRCs in the Water Forum: viz. the CRC for Catchment Hydrology; the CRC for Water Quality and Treatment; the Environmental Biotechnology CRC; and the CRC for Coastal Zone, Estuary and Waterway Management; this collaboration operated at a project level, and in giving policy advice, and in running the CRCs' Young Water Scientist of the Year Award
- ▶ non-partner research institutions and water agencies overseas.

International linkages

CRCFE's researchers (staff and students) have established international linkages and reputations partly by:

- ▶ working with relevant research groups overseas and attending international conferences,
- ▶ running international conferences here,
- ▶ accepting invitations to join international scientific steering committees and editorial boards,
- ▶ publishing work that is relevant to water management issues everywhere.

Also, in 2004–2005, staff of the CRCFE were again invited to join, or elected members of, committees, working groups and editorial boards overseas; including:

- ▶ Australian–Japanese ‘Predictions in Ungauged Basins’ Working Group (D. Baldwin, CSIRO)
- ▶ Steering Committee for the 2nd International Symposium on Riverine Landscapes, Sweden 2004 (S. Bunn, Griffith U.)
- ▶ Scientific Committee of DIVERSITAS crosscutting network on freshwater biodiversity (A. Arthington, Griffith U.)
- ▶ Ramsar Convention’s Scientific and Technical Review Panel (A. Arthington, Griffith U.)
- ▶ Global Water Systems Project, Scientific Steering Committee (a joint project of Diversitas, the IGBP, the IHDP and the WCRP) (S. Bunn and A. Arthington, Griffith U.)
- ▶ North American Benthological Society Executive Committee (S. Bunn, Griffith U., R. Norris, U. Canberra). Norris became Chair in May 2005.

- ▶ North American Benthological Society Awards of Excellence Committee (S. Bunn, Griffith U.)
- ▶ North American Benthological Society International Planning Committee (S. Bunn, Griffith U.)
- ▶ *Hydrobiologia* Editorial Board (R. Norris, U. Canberra)
- ▶ *River Research and Applications* Editorial Board, based in the United Kingdom (K. Walker, U. Adelaide; M. Thoms, U. Canberra)
- ▶ *Freshwater Biology* Editorial Board, based in UK (Sam Lake, Monash U.)
- ▶ *Geomorphology* Editorial Board (M. Thoms, U. Canberra)
- ▶ *Environmental Biology of Fishes* Editorial Board (A. Arthington, Advisory Editor).

Staff and students have visited, worked overseas or worked collaboratively with overseas research groups; e.g.:

- ▶ Gary Jones was part of a delegation that visited Korea to establish working relations with Korean water authorities
- ▶ Gary Jones was invited to give one of a series of presentations at the MDBC to the visiting Director and staff of the Yellow River Conservancy Commission, from China
- ▶ Simon Linke (PhD student, U. Canberra) worked for three months with Professor Bob Bailey in northern Canada, from April 2005, as part of his PhD fieldwork)
- ▶ leading researchers in river health assessment in N. America and Canberra have ongoing collaboration,

running workshops, exchanging students, and publishing jointly (Norris, U. Canberra)

- ▶ CRCFE staff are invited overseas to give presentations, and attend overseas conferences (see Chapter 7).

Knowledge exchange: ensuring that CRCFE research outputs are used and applied

In CRCFE, knowledge exchange is defined as two-way interaction between end-users and CRCFE staff — usually scientists, but also our particular team of ‘knowledge brokers’ and ‘community scientists’. Members of the KE team have all been science graduates with communication skills and postgraduate degrees or experience — at levels reflected in the two job titles.

Our aim has been to provide our end-users with available ecological information, based on CRCFE research, and supply it in a most useful form. Our knowledge-exchange staff interacted with partner agencies and water managers and the community to determine their needs and learn how best to deliver knowledge to them. Scientists and members of the KE team have synthesised tacit and explicit knowledge from the CRCFE research providers. They have made knowledge products available in the form of decision tools, guidelines, summary booklets, web pages, and so on.

During 2004–2005, the knowledge exchange team has been led by its director, Associate Professor Ralph Ogden. He has been supported by a chief knowledge broker in Melbourne (Peter Cottingham, based at Melbourne Water), knowledge brokers in Sydney (Amanda Kotlash, based at Sydney Catchment Authority), Mildura (Michelle Bald & Sylvia Zukowski), Goondiwindi (Janey Adams) and Albury-Wodonga (John Hawking), at those MDFRC labs, and in Canberra (Ruth O’Connor and Bronwyn Rennie) backed up by the communications group (Ann Milligan and Bronwyn Rennie), all three based at University of Canberra. In October 2004, Amy George began work with the CRCFE partners in Adelaide, SA, funded by and based at the SA Dept of Water, Land and Biodiversity Conservation. Amy had just completed her PhD with the CRCFE.

Scientific and public communication

CRCFE research staff disseminate scientific information via seminars, conferences, journal papers, technical reports.

CRCFE research is also publicised by newsletters, fact sheets, brochures, web sites and media articles. CRCFE publications have been handed out to visitors to the laboratories, and at public events and agricultural shows, particularly near the regional laboratories. The communications group also receives numerous requests for copies of publications.

This year, there have been three bumper size issues (one of 16 pages and two of 24 pages) of our newsletter *Watershed* (normally 12 pages per issue), which maintains a circulation of around 2500 copies per issue. Also, three issues of the Narran Lakes newsletter have been sent to 200 stakeholders and landholders in the Narran Lakes area.

All new publications are made available on the CRCFE web site. The two interactive web sites — for the Narran Lakes project (<http://mooki.canberra.edu.au/narran>), and for the CRCs' Water Forum (<http://mooki.canberra.edu.au/waterforum>) have continued to operate. Both are available via <http://freshwater.canberra.edu.au>.

Media representatives contact the CRCFE for comment from Professor Gary Jones and other senior staff. At least 24 staff have been interviewed or mentioned in the media this year. Our media releases generally focus on events and outcomes, rather than research findings.

In press, TV and radio, CRCFE staff and CRCFE work have been mentioned or featured in over 50 media items during 2004–2005 (38 press, 2 TV, 5 radio, 8 online), and eWater CRC has been foreshadowed, in connection with Gary Jones in 12 items (7 press, 1 TV, 1 radio and 3 online).

Technical and consultancy publications, public presentations and non-refereed (communication) publications are listed in Chapter 7. There have been 26 technical reports (printed and or on-web), 32 consultancy reports, 75 public notable

presentations or conference presentations, 31 published or accepted conference papers, and 40 non-refereed publications.

Refereed journal papers (97) and chapters in books, or whole books (26), are also listed in Chapter 7.

Knowledge exchange interactions with the community, general public and schools, and training courses for water industry personnel, run by CRCFE research and knowledge exchange staff, are outlined in Chapter 3.

Summarised below are significant outcomes of knowledge exchange activities and ongoing interactions between the KE staff and industry end-users and policy-makers at all levels of government, during 2004–2005.

Highlights of the knowledge exchange program

▲ The CRCFE's framework for monitoring and assessing the ecological effects of environmental flows has been published as a report (*Environmental Flows Monitoring and Assessment Framework*, see <http://freshwater.canberra.edu.au> > publications > technical reports). The framework was developed by a panel representing 14 water agencies across eastern Australia (including Tasmania), many of which were CRCFE partner institutions. A web tool to assist users has been prepared and is being reviewed.

*The Dept of Sustainability and Environment, Victoria, has based an

environmental flows monitoring program for the Thomson-Macalister Rivers on the CRCFE environmental-flows monitoring framework.

*The Dept of Water, Land and Biodiversity Conservation, SA, is applying the basis of the framework to streams in the Mt Lofty ranges.

*Cottingham P., Stewardson M. and Webb A. (2005), Victorian Environmental Flows Monitoring and Assessment Program — Stage 1: Statewide Framework, is a joint CRC for Freshwater Ecology and CRC for Catchment Hydrology report to the Victorian Department of Sustainability and Environment. It applies the Environmental Flows Monitoring and Assessment Framework to Victoria.

▲ 'Recent lessons on river rehabilitation in eastern Australia' is a management guide (in press) that captures recent lessons that have emerged from CRCFE's rehabilitation research and from practitioners' on-ground experience. The guide should be useful to river managers for the planning, implementation and evaluation of the success of rehabilitation projects.

▲ *Assessing and monitoring aquatic biodiversity: what have we learnt?*, by Ruth O'Connor and Amanda Kotlash, is a compilation of knowledge gained, largely by the CRCFE, in the measurement of aquatic biodiversity. It is available on the CRCFE web site at <http://freshwater.canberra.edu.au>.

▲ A framework or schema for organising and examining evidence for causality between environmental

factors has been developed from a model in use in epidemiological studies. It complements other approaches for water quality monitoring. The 'Multiple Lines and Levels of Evidence' schema consists of software and a manual, and is at present being rigorously tested. Presentations and a paper have been produced for the Australian Stream Management Conference and for a special session of the Conference of the North American Benthological Society.

▲ CRCFE was contracted to undertake review of the ACT's Environmental-Flow Guidelines, for the ACT Government. A report, 'Review of the 1999 ACT Environmental Flow Guidelines' by Ralph Ogden, Peter Davies, Bronwyn Rennie, James Mugodo and Peter Cottingham, was submitted by the CRCFE to Environment ACT in November 2004.

▲ CRCFE scientists continued to work regularly with ACTEW, the ACT water managers, to devise the best active adaptive management for environmental flows during the drought and the after-effects of bushfire in Canberra's main water supply catchments. This work has won a University of Canberra Vice-Chancellor's Distinction Award for Innovation and Creativity in Research and Enterprise (2005), and has been presented at the 8th International Riversymposium in September 2005.

▲ Williams, D. and Roberts, J. (2005), *Riparian vegetation diversity in the Sydney Catchment Authority's area of operations*, describes the vegetation

biodiversity work that was part of a larger biodiversity study. It is published on the CRCFE web site, at <http://freshwater.canberra.edu.au>.

- ▲ A joint CRCFE–CRCCH industry report, *Urban stormwater and the ecology of streams*, by Chris Walsh, Alex Leonard, Anthony Ladson and Tim Fletcher, has been published on the CRCFE website (link from front page) and in print. Derivative publications are planned. Other KE outputs underway or planned are: incorporation of the design guidelines into MUSIC (urban stormwater software), industry workshops, and possibly the development of educational on-line modules.
- ▲ Wetlands knowledge relevant to the Lower Murray swamps has been compiled and provided to the DWLBC, to help identify natural wetlands that have ecological conservation value, and that are amenable to ecological rehabilitation, as a guide for assigning priority to restoration works.
- ▲ A wetland management “checklist” has been developed for managers to use in collecting and applying the information that they need to consider when monitoring and managing wetlands.
- ▲ A Waterwatch training workshop was held by the CRCFE in the ACT, and specialist theory and training sessions were delivered by three CRCFE staff at the Waterwatch conference in Adelaide.
- ▲ Working with CRCFE, Waterwatch Victoria has produced a report guiding

the use of community-collected data in natural resources management.

- ▲ The CRCFE team that works on the Narran project contributed an article to the Jan/Feb '05 *Western Division Newsletter* (a DIPNR production) on the Narran project. Readers (landholders and NRM managers) commented very favourably.
- ▲ Three newsletters were sent out about the Narran Project (nos. 6, 7, 8) during the year and received favourably, according to comments during a successful field day with stakeholders at the Nature Reserve in May.
- ▲ The Narran Lakes oral history project continues to collect valuable information from the Narran River community. The collection is expected to be completed later in 2005. eWater CRC will continue to deliver the Narran Lakes project, which is already informing government and community decision-makers about the ecology of the Narran Lakes ecosystem and communicating new knowledge of the ecological functioning of the ecosystem to the national and international scientific community.
- ▲ The CRCFE facilitated a workshop on the importance of floodplain-wetland habitat for native fish at the Australian Society for Fish Biology annual conference (20–21 September 2004). The workshop explored what is known of flow–wetland–native fish interactions for the Living Murray significant ecological asset sites,

consistent with activities proposed by the MDBC Native Fish Strategy. The workshop objectives were established following discussions between the Murray-Darling Basin Commission, the Arthur-Rylah Institute, the University of Adelaide and the CRCFE.

- ▲ CRCFE staff (Lintermans, O'Connor, Cottingham) have edited the proceedings of a workshop they facilitated on 'Fish Habitat Rehabilitation and Management in the Murray-Darling Basin' for MDBC in February 2004. Papers from the workshop are to serve as a benchmark.
- ▲ Graham, R. and Harris, J. (2005) *Floodplain inundation and fish dynamics in the Murray-Darling Basin: Current concepts and future research: a scoping study*, has been published on the CRCFE website at <http://freshwater.canberra.edu.au>.
- ▲ A technical report, 'Reestablishment of Macquarie Perch in Queanbeyan river NSW', by Mark Lintermans, will soon be available at <http://freshwater.canberra.edu.au>.
- ▲ Explorers' diary accounts of fish in rivers of the Murray-Darling Basin show abundance and distribution of fish species in the early 1800s. A new report (in press) summarising the accounts is a useful resource for researchers and local communities.
- ▲ The CRCFE was well represented at the Second International Symposium on Riverine Landscapes in Sweden, with invited papers from Jane Hughes, Sam Lake and Stuart Bunn. Ben Cook (PhD student), Nick Bond

and Paul Reich also attended and presented posters on their research. The Third Symposium is planned to be held in Australia in 2007.

- ▲ Gary Jones has coordinated and led the development of the Inland Waters Theme for the 2006 Australian State of the Environment report. A workshop was organised in July 2004 to provide input on the appropriate indicators and conceptual model.
- ▲ CRCFE was contracted to conduct an ecological risk assessment of ACT's water source options for ACTEW as a result of earlier activities. A report 'Ecological Risk Assessment of ACT Water Source Options: Workshop Report for ACTEW Corporation' by Ruth O'Connor was submitted by the CRCFE to ACTEW in October 2004.
- ▲ CRCFE facilitated (Ogden), and contributed to (Brock, Nielsen, Schreiber), a session at LIMPACS (Human Impacts on Lake Ecosystems) workshop 'Salinity, Climate and Salinisation working group — setting research priorities 2005–2010' in October 2004 at Mildura, Victoria. The objective of the session was to review the latest science related to salinity impacts on aquatic systems, and determine if there is enough new science to improve on existing aquatic management guidelines. Daryl Nielsen attended and presented results from core project C240 in the workshop, and also the CRCFE session. The CRCFE was also represented by Sabine Schreiber of Arthur Rylah Institute (DSE).

- ▲ Rob Vertessy and Gary Jones led an official Australian delegation of business people (from the water consulting industry) and scientists from CSIRO and the CRC for Catchment Hydrology to the Republic of Korea in October 2004. The aim of the visit was to develop a joint R&D program with the Korean Sustainable Water Resources Research Centre, and with the national water management authority, KOWACO. This has been flagged as a key international relationship for the eWater CRC. CRCCH has an MOU with SWRRC, signed in August 2003.
- ▲ Targets and indicators for healthy working rivers — a project begun in CRCFE and being developed in eWater CRC — is a framework designed for stakeholder groups involved in river management. It provides a process for groups to ensure targets are (i) informed by the best available scientific information so ecological trade-offs are explicit; and (ii) directly linked to management actions.
- ▲ Rapid biological assessment: a project begun in CRCFE and being completed in eWater CRC is collating information on techniques for rapid biological assessment, for a decision framework useful to managers. Scientific papers discussing the methods are in press with the international journal *Hydrobiologia*.
- ▲ Watercourses Online (see Education, p.25) is a growing set of online training courses designed primarily to support personnel in water management, natural resources management, environmental education and ecological consulting. Three courses have been on offer in 2004–2005.
- ▲ ‘The Tooma River Project: interdisciplinary probes into ill-defined and capricious pollution’, by Harris, J., Bowling, L., Keller, R., Kress, J., Lake, S., McPhail, B. and Simpson, J. is in press as a CRCFE technical report. It describes a study of water quality in the Tooma River, NSW, associated with a spoil dump and occasional fish kills.
- ▲ The report from core project A100, ‘Ecological functioning of the Murray River’, by Ben Gawne et al., is in press. The project extensively investigated the productivity of the River Murray, at Albury, Barmah and Hattah.
- ▲ Six representatives of CRCFE (Jones, Ogden, Norris, Meredith, Rayburg and Kelly) had productive interaction with 11 parliamentarians at the Science Meets Parliament meeting in February 2005 in Canberra.
- ▲ The CRCFE (via the MDFRC) continued to contribute to the SA Wetlands Baseline Monitoring project, run with the River Murray Catchment Water Management Board and DLWBC, via demonstrations and by running community training days. The project was completed in October 2004.
- ▲ The 7th International Riversymposium was held in Brisbane on 1–3 September 2004, with nearly 500 delegates from 38 countries. The CRCFE ran the Young Water Scientist of the Year Award at Riversymposium (on behalf of the CRC Water Forum), and Gary Jones chaired a lively debate on the costs and benefits of building dams. The 8th International Riversymposium has also hosted the Young Water Scientist of the Year Award 2005 for CRCFE.

CRCFE maintained cooperative interaction with the Cotton RDC, Cotton Australia, the Rice Growers Association, and several community-based management groups, particularly the Mallee CMA, North-East CMA, Border Rivers CMA and Goulburn-Broken CMA, as well as other catchment management groups, and the community reference panel for the Narran Lakes area of the Lower Balonne Floodplain, on the Queensland–NSW border. These groups all operate at the interface between fresh-water ecology and floodplain land-use. It is important to the CRCFE that we cooperate together to achieve common goals.

Table of knowledge exchange with end-users during 2004–2005

The table that follows summarises exchanges of knowledge and information between CRCFE staff and end-users in 2004–2005. Knowledge exchange activities usually result in outputs in the form of:

- (i) guidelines, handbooks or manuals, software including decision support tools, collaborative research partnerships, consultancies, reports or literature reviews,

and *outcomes* such as:

- (ii) end-users having more comprehensive knowledge,
- (iii) decisions,
- (iv) action (or policy for action), and, ultimately,
- (v) solutions to the underlying issues.

End-users for the CRCFE’s research findings have been our partners (all of whom are ‘core participants’) in particular, but we also have key end-users among other public water industry organisations and government bodies, and among small–medium-size enterprises in the private water industry, including consultants, irrigation businesses

and catchment management groups, and among natural resource management committees, education groups and the community.

Conference presentations, also a form of knowledge exchange, are listed with publications at the end of the annual report.

Topics information has been exchanged about	Activities involved and outputs	Locations and/or species involved	End-users (immediate): core participants (P) and others. C = consultancy	CRCFE staff involved (from KE team and research providers)
algal management: blue-green algae	Input to planning committee; invited briefing	Lake Hume; Lower Basin Lab (Mildura) area of operations	Catchment management/producer body; EPA Victoria (P), Mallee CMA	Ogden; Bald
biodiversity: threatened species listing, recovery plans, survey of aquatic species	Input to advisory committees; articles in <i>Watershed</i>	Various; corroboree frog; turtles; trout cod	DIPNR (P); DSE (P); Griffith University (P); University of Canberra (P); Environment ACT (P), state and federal government responsible committees; <i>Watershed</i> readers	Brock, Hughes, Crook, Koehn, Lintermans, Osborne; Georges and team; Milligan
biodiversity: assessment of	compilation of research findings; discussions; publication; <i>Watershed</i> articles	eastern Australia	DIPNR (P), EPAV (P), QNRM (P), SCA (P), Environment ACT (P), DSE (P), UC (P), Monash U (P), Griffith U (P); <i>Watershed</i> readers	O'Connor, Kotlash
biodiversity: management of factors in	Input to meeting; Biodiversity Forum briefings; consultancy report; <i>Watershed</i> articles	Sites in connectivity and dispersal research projects; general biodiversity; mussels in Cattinach Canal; Murray cod	Griffith University (P); DIPNR (P); SCA (P); QNRM (P), Environment ACT (P); Lower Murray Urban and Rural Water Authority (P C); University of Canberra (P); <i>Watershed</i> readers	Kotlash, Hughes; Mildura lab; Jones; Hawking; Milligan
catchment assessment:	Advice on priority-setting; input to ASL congress sessions (Chair, judge); workshop for NLWRA2	Queensland; Australia;	Qld EPA; Aquatic researchers and managers; CRC for Catchment Hydrology; Coastal Zone CRC; Land & Water Australia; CSIRO Water for a Healthy Country	Adams, Wilson; O'Connor; Ogden, Norris
catchment management	Input to responsible groups advice; provision of publications; review of research programs; input to assessment panel for funding; Chairing management committee; media hit	Toowoomba; Goulburn River; Victoria; Nepal; water catchments for Sydney; Border Rivers; ACT water supply catchments; Queensland Murray-Darling Basin; Border Rivers	Qld Murray-Darling Committee; Melbourne University; Melbourne Water (P); Goulburn Murray Water (P); DSE (P); Nepalese local government; SCA (P); Border Rivers CMA/Landcare; ACT Government (P); Queensland Murray-Darling Committee; Border Rivers CMA	Adams; Cottingham; Rennie; Ogden; Jones; Kotlash
collaborative partnerships: development of; success of	Inputs to planning groups and advisory committees; 2-day forum of managers and researchers; workshop facilitation; discussions; media hits; newsletter articles (<i>Watershed</i>); publication drafting (brochure); presentations; briefings	Mildura; northern Murray-Darling Basin; Moree; River Murray near Mildura; wetlands along lower Murray; Wodonga; Albury area; cotton area, Narrabri; River Recovery program, MDFRC research; north-eastern Victoria; Border Rivers industry	Murray-Darling Association; QNRM (P), DIPNR (P), Griffith University (P), CSIRO L&W (P), CSIRO Entomology; University of Canberra (P); catchment and regional managers, community stakeholders; MDBC (P) Community Advisory Committee; Riverwatch committee (P via DIPNR); Queensland EPA; Mallee CMA; La Trobe University (P), MDFRC; Condamine Alliance; eWater CRC partners, Border Rivers CMA/Landcare; Queensland Murray-Darling Committee; Cotton CRC, NSW Agriculture; Greening Australia; Dept of Agriculture, Fisheries and Forestry; NECMA; Albury Water; NE Water; Border Rivers Food and Fibre; Queensland Government; Dept of Environment and Heritage; SCA (P); Melbourne Water (P), Goulburn-Murray Water (P); EPA Victoria (P); Waterwatch	Bald; all Northern Basin Lab staff; O'Connor; Adams, Wilson; Zukowski; Keating; Jones; Baldwin; Nielsen, Rees; Gawne, Sinclair; Williams; McNeil; Brennan, Milligan; Cottingham, Rooney; Kotlash; Meredith; Hawking

Topics of exchange	Activities and outputs	Locations, species	End-users	CRCFE staff involved
ecological education and training	Publications (including conference poster); online courses; input to planning meetings with marketing collaborators; presentations (conferences, schools); training camps (2); work experience training; media hits; discussions; scoping; review of training; workshops	Mildura; Albury; NECMA prize; CMA training needs; wetland training module; ACT	Catalyst Interactive, catchment managers; stream managers; Mildura Youth Centre; North-East CMA; DIPNR; DWLBC; Queensland Murray-Darling Committee, Torrens CWMB, Condamine Catchment NRM Corp Ltd; Waterwatch; school communities from south-west NSW, north-west Victoria and SA	Rennie, Ogden, Nichols, Barlow, Norris; Zukowski; Gigney; Adams, Wilson; Hawking, O'Connor; Keating
ecological risk assessment: risk management for sustainability	Input to ASL congress session on "Linking environmental baselines with policy" (Chair); Media hit; advice, discussions; review of assessment;	Australia; Lower Loddon catchment; ACT; Granite Belt (Qld)	Aquatic researchers and managers; DSE (P); ACTEW (P); Queensland EPA	Adams; O'Connor, Norris, Lintermans, Barlow
environmental flows: monitoring of effects	Development of framework for monitoring and assessment; presentations; adoption by management authority; review of monitoring plans; construction of monitoring plans; <i>Watershed</i> articles; compilation, report on flow-ecology relationships	CRCFE monitoring and assessment framework; Thomson-Macalister rivers; Victoria; Mt Lofty Ranges; Wimmera-Glenelg Rivers	DSE (P); DIPNR (P), Metropolitan Water Directorate; SCA (P); Environment ACT (P); DPIWE; MDBC (P); Goulburn-Murray Water (P); QNRM (P); Melbourne Water (P); Monash University; Thomson-Macalister stakeholders; DWLBC (P); Glenelg-Hopkins CMA; Wimmera CMA; <i>Watershed</i> readers	Cottingham; Quinn; King; Norris; Chessman; Marshall; Webb; Scott; Milligan
environmental flows: setting and management	review of guidelines; media hits; presentations; input to committee	River Murray; Cotter River; Sydney area	River stakeholders; MDFRC; University of Canberra (P); online readers; Environment ACT (P); ACTEW (P); SCA (P)	Ogden, Rennie, Cottingham, Mugodo, Sellens, Liston; Gawne; Norris; Lintermans;
fish management; habitats management	TV news report (ABC), newsletter articles (<i>Watershed</i>); sponsorship, facilitation/running of workshops (various); media hits; literature reviews; production of publications; presentations	Murrumbidgee River NSW (trout cod); carp, golden perch, Broken River; billabong species; Cooper Creek; Warrego R; River Murray; Murray-Darling Basin; Native Fish Strategy; Murray cod; flooded floodplains; diaries in 1800s; Lindsay Island	Environment ACT (P), MDBC (P); NSW Fisheries; Charles Sturt University; fish researchers and managers, Australian Society for Fish Biology; MDBC (P); La Trobe University; South Mildura Rotary Club; Lions Club Mildura; Lower Murray CMA; QNRM (P); southern Queensland community; <i>Watershed</i> readers	Ebner, Lintermans, Thiem; Crook, Humphries; Milligan; McNeil; Cottingham, Koehn, Ogden, O'Connor; Zukowski, Matveev; Harris; Scott; Meredith; Sheldon, Georges, Arthington, Balcombe, Bunn
floodplains management/research	Input to planning workshop, policy group	River Murray (SA)	DWLBC (P), RMCWMB, SARDI, EPA of SA, DEH of SA	George
habitats in streams/rivers	Media hits	Frogs; turtles; Snowy Mts; rice-growing area	University of Canberra (P)	Hunter; Osborne; Rennie, Milligan
identification of biota	Online ID guide; photo	Macroinvertebrates; dragonfly	Dept of Environment and Heritage; Melbourne Living Museum	Hawking; Gawne; Rennie
invasive species	Input to management group; media hit; briefing; advice; <i>Watershed</i> article	Carp; invasive spp.; weeds	CRC for Pest Animals; Expert Consultation Panel hosted by Global Invasive Species Programme (at Smithsonian, USA); SCA (P); DSE (P); <i>Watershed</i> readers	O'Connor; Koehn; Arthington; Kotlash; Schreiber, Williams

Topics of exchange	Activities and outputs	Locations, species	End-users	CRCFE staff involved
knowledge exchange within other organisations (not CRCFE)	Seminar; discussions on research and information needs; advice, briefing; input to planning		Bureau of Resource Sciences, Dept of Agriculture, Fisheries and Forestry; DWLBC (P); Weeds CRC; Centre for Research in Women's Health; SCA (P); Greening Australia	Ogden; George; Cottingham; Kotlash; O'Connor
Narran Lakes freshwater ecology	Discussions; input to responsible groups; newsletters (3); magazine article; workshop; field day; conference presentations; oral history interviews Oct 04-Jun 05; invited article in <i>Western Division Newsletter</i> ; establishment of 'joint discovery' KE process	Lower Balonne floodplain; Walgett, Goodooga, Brewarrina, Lightning Ridge; Narran Lakes area	MDBC (P), DIPNR (P), QNRM (P), Narran Lakes Community Reference Panel, Queensland Murray-Darling Committee; landholders and managers in Western Division NSW; NSW NPWS (part of DEC (P)); University of Canberra (P); Griffith University (P), MDFRC (P)	Ogden, Adams, Quinn, Murray, Thoms, Rayburg, Brandis, Capon, Milligan, Mesley, Cossart, James, White; O'Connor
National Water Initiative	Coordination of R&D linkages	National Water Commission	NWC, researchers	Jones
Rewetting sediments: effects of grazing on ecology	Consultancy	Thegoa Lagoon	NSW Murray Wetlands Working Group (C)	Nicol
river condition / ecological function: assessment	Advice, workshops on methods and approaches; media hit; article in <i>Watershed</i> ; discussions; report	Melbourne; Lower Basin Lab; Australia; Hawkesbury-Nepean R; River Murray	Melbourne Water (P); Aquatic researchers and managers; DIPNR (P), QNRM (P), EPAV (P), MDBC (P); Hawkesbury-Nepean CMA; <i>Watershed</i> readers	Cottingham; Adams; Bald; Norris, Milligan; Mugodo, O'Connor, Sellens; Kotlash; Gawne, Baldwin, Rees, Williams, Oliver and MDFRC team
river condition / ecological function: development and delivery of training in	Theory and practical training sessions (2) on identification & sampling; AUSRIVAS training (2); media hit	Macroinvertebrates, ACT; macroinvertebrates Australia	ACT and Sydney Waterwatch coordinators, SCA (P); Environment ACT (P); University of Canberra (P)	Hawking, O'Connor, Linke; Nichols, Barlow, Norris
river management via flows	Presentations; input to committee; media hit; report	Campaspe R; Mulcra Island; Yarra R; River Murray	Goulburn-Broken CMA; NE CMA; Mallee CMA; Melbourne Water, Monash University; MDBC (P); Murray-Darling Basin Community Advisory Committee; DIPNR (P), Riverwatch	Humphries; Cook; Zukowski; Walsh; Cottingham; Gawne; Keating
river management for multiple uses	Advice: reference condition, benchmarking, monitoring terms of reference; media hits (including live interview); framework for working towards Healthy Working Rivers; running Yarra Forum; developing decision support tools	Urban streams in Melbourne; Broken River, River Murray; Macquarie R; Yarra R., MFAT software, BLACKWATER software; MLE software	Melbourne Water (P); Goulburn-Broken CMA; river stakeholders; general public; ABC; DIPNR (P); Monash U (P); DSE (P); State Water (NSW); MDBC (P); Barmah-Millewa Forest Forum; partner agencies (P);	Cottingham; Tennant; Gawne; Baldwin; Mitchell; Oliver; Hawking; Humphries; O'Connor, Nichols, Norris; Rennie; O'Connor; White; Baldwin, Howitt, Rees; Mugodo, Norris, project team;
river rehabilitation	Compilation, report, <i>Watershed</i> articles; advice	Granite Creeks; eastern Australia; wood for resnagging; Victorian CMA projects; USA projects	DSE (P); Melbourne Water (P); Monash U (P), <i>Watershed</i> readers	Lake, Bond; Cottingham; Koehn; Brooks
salinity effects on ecology (wetlands)	assessment and reporting, discussions with managers; media hit; workshop, factsheets	Albury; Australia; Border Rivers region, major eastern Australian wetlands, zooplankton, wetland vegetation	DIPNR (P); Ecological Society of Australia; QNRM (P); DSE (P); various management bodies	Brock, Nielsen; Kotlash; Rees; Schreiber, Ogden

Topics of exchange	Activities and outputs	Locations, species	End-users	CRCFE staff involved
urban waters: management and rehabilitation, rural-urban gradient	Publications; newsletter articles; media and online hits (several), workshop planning; advice; organisation of 2-day workshop	Yarra River, Melbourne urban streams; Sydney urban streams; international urban waters; Canberra; ACT suburban wetland;	Monash University (P); Melbourne Water (P); NSW Stormwater Trust (P C); the University of Melbourne; Canberra Urban Parks and Places; SCA (P), University of Canberra (P)	Walsh (and team), Cottingham, Kotlash, Milligan; O'Connor; Lintermans
Vegetation: riparian, macrophytes; invasive spp	input to monitoring planning workshop, steering committee for River Recovery, and criteria for red gum rescue; report of large vegetation survey; media hits; review of management priorities for riparian zone; advice; <i>Watershed</i> articles	Eastern Australia; South Australia; Sydney catchments; red gums and blackbox; azolla, Broken Creek;	DWLBC (P); Greening Australia; SCA (P); Dept of Environment and Heritage; <i>Watershed</i> readers	Williams; George; Ogden; Bunn; Gawne
water quality: management, assessment, policy	review of report; review of monitoring program; input to task force; compilations of methods and knowledge; report; review of knowledge gaps;	Tallowa Dam; ACT; Tooma R; Cotter R; Victoria; eastern Australia; cotton areas of northern Murray-Darling Basin; rice-growing area, pesticides	SCA (P); South Coast CMA; ACT Waterwatch 'campfire' program; Waterwatch Victoria; DSE (P); DIPNR (P); ACTEW (P); Environment ACT (P); Cotton CRC; U New England; Border Rivers community; RIRDC, rice-growers	Nichols, Norris, Barlow; Kotlash; O'Connor; Harris; Johnson; Thoms; Lutton; Hyne
water resources management, policy	Articles (including <i>Watershed</i>); input to research forum; media hits (ABC TV, radio; capital city press, eco-press, Korean cable TV); discussions; publications drafting; assessment and reporting of ecological risk; planning; chairing discussions; reports; coordination of State of Environment theme; development of assessment framework and software	Lake Burley Griffin; Victoria; Molonglo River, ACT; water catchments south of Sydney; ACT water source options; River Murray; National Water Initiative; Korean water resources; SE Queensland; Australia; eastern Australia; MLE	University of Canberra (P), Melbourne Water (P), Goulburn Murray Water (P); DSE (P); General public; SCA (P); ACTEW (P C); MDBC (P); Korean water authorities/agencies; federal parliamentarians; QNRM (P), Moreton Bay Waterways and catchments partnership; Dept of Environment and Heritage; <i>Watershed</i> readers	Jones; Kotlash, Norris; O'Connor; Bunn; Gawne; Lawrence; Rayburg, Kelly, Meredith, Ogden; Sellens; Mugodo
waterbody management, policy: lakes, storages, waterholes, weir pools	Consultancy; input to advisory committee report	Lake Mulwala; Lake Eyre Basin	Goulburn-Murray Water (P); Lake Eyre Basin Ministerial Forum	Baldwin, Howitt, Hawking; Bunn, Cullen
wetlands: monitoring, management, salinity issues; rehabilitation; community education	media hits; public field days (2); input to planning groups; presentations to catchment managers; input to assessment methods; compilations of knowledge, report, checklist; input to prioritisation; brochure drafting	Goondiwindi, Border Rivers, Narran wetlands; Kings Billabong (Mildura); Lower Murray wetlands; Murrumbidgee wetlands; Australia; Living Murray wetlands	Border Rivers CMA/Landcare; Brenda Park RMCWMB; DWLBC (P); Murrumbidgee Wetlands Working Group, DIPNR (P), Wetlands Care; SKM; River Murray CWMB; community, Mallee CMA	Adams, Wright; Bald; George, Nicol, Smith; Baldwin; Zukowski; Ogden; Butcher; Keating

5. Operations and Staff matters

Buildings

The Murray-Darling Freshwater Research Centre at Albury-Wodonga moved premises in February 2005. The labs are now on the La Trobe University campus in Wodonga, having been on the Charles Sturt University's Thurgoona campus in Albury for several years.

Equipment purchases

No major equipment was purchased during this final year of CRCFE operations.

Specified personnel

Early in 2005, Associate Professor Gerry Quinn left Monash University and the CRCFE to take up a Chair at Deakin University. He was replaced by Associate Professor Martin Thoms (University of Canberra) for the last few months of the CRCFE. Specified personnel at the end of June 2005 are shown in the table at right.

Staff movements: comings

Amy George, Knowledge Broker, Adelaide.

and goings

Michelle Bald, Sylvia Zukowski (MDFRC, Mildura),
Gerry Quinn (Monash University),
Debbie Heck (Griffith University),
Paul Humphries (MDFRC, Albury).

Specified personnel at 30 June 2005

Prof. Gary Jones U. Canberra	CEO	100%
Prof. Stuart Bunn Griffith U.	Director (research)	85%
Dr Ben Gawne MDFRC	Director (regional labs)	100%
Prof. Sam Lake Monash U.	Chief Ecologist	75%
Prof. Richard Norris U. Canberra	Program leader	75%
A/Prof. Martin Thoms U. Canberra	Program leader	75%
Dr Margaret Brock DIPNR	Program leader	30%
Dr Nick Bond Monash U.	Program leader	60%

Awards and honours to staff and associates during since June 2004

Professor John Langford (Board Chairman) was made a Member of the Order of Australia (AM) in the Queen's Birthday Honours, 'for service to water resource management, particularly through organisations that regulate and research water supply, quality and usage'.

Professor *Peter Cullen* was awarded the 'Einar Naumann–August Thienemann' Medal by the Societas Internationalis Limnologiae, 'for exemplary scientific leadership and extraordinary efforts to communicate complex limnological and water resources issues to colleagues and decision-makers'.

Professor *Sam Lake* (Monash University) was awarded one of three inaugural L&WA Senior Research Fellowships (\$100,000 in total), which he will use to review drought effects on freshwater ecosystems.

Professor *Richard Norris* (University of Canberra) and his research team were awarded one of two Vice-Chancellor's Distinction Awards for Creativity and Innovation in Research and Enterprise, at the University of Canberra. Their innovative studies on the Cotter River, ACT, before and since the 2003 bushfires, have supported active adaptive management by Canberra's water managers, benefiting the environment and the Canberra community.

Dr *Sabine Schreiber* (Arthur Rylah Institute, Victoria) was elected the President of the Australian Society of Limnology in early 2005, and Professor *Stuart Bunn* was elected Vice President.

In May 2005, Professor *Richard Norris* became Chair of the Executive Committee of the North American Benthological Society. Professor *Stuart Bunn* (Griffith University) is also a member of the Executive Committee.

Professor *Stuart Bunn* has been invited to join the inaugural Scientific Steering Committee of the Global Water Systems Project (a joint project of DIVERSITAS, the International Geosphere-Biosphere Program, the International Human Dimensions Program and the World Climate Research Program, under the auspices of the Earth System Science Partnership).

Professor *Angela Arthington* (Griffith University) remains an invited member of the Scientific Committee of the DIVERSITAS Freshwater Cross-cutting network.

Professor *Angela Arthington* has been appointed an Advisory Editor to the international journal 'Environmental Biology of Fishes'.

Associate Professor *Martin Thoms* (University of Canberra) has been appointed to the Editorial Board of the international journal 'Geomorphology'.

Dr *Will Osborne* (University of Canberra) has been appointed as Chair of the ACT Flora and Fauna Committee.

Mark Carey (MDFRC summer scholarship student) was awarded the North-east CMA Prize at the Annual Presentation of Awards and Prizes Ceremony at La Trobe University in July 2004.

Tim Page (Griffith University) won Best Student paper at the Australian Society for Limnology's 43rd Annual Congress, Adelaide, in November–December 2004.

Ben Smith (University of Adelaide) was awarded the Australian Society for Fish Biology's 2004 International Travel Scholarship (worth \$5000), on the basis of his technical publications.

Craig Boys (University of Canberra) has just won the John Holliday Student Conservation Award, presented annually by NSW Fisheries, part of NSW Dept of Primary Industries, for his PhD studies on fish habitats in the Barwon-Darling River, NSW.

Mark Kennard (Griffith University), with co-authors Brad Pusey and Angela Arthington, also of Griffith University, has just been awarded the Whitley Award for zoological publishing, from the Zoological Society of NSW, for their book *Freshwater Fishes of North-eastern Australia*.

At the final Annual General Meeting of the CRC for Freshwater Ecology, the following special awards were presented.

Best Support Person: *Rhonda Sinclair* (MDFRC).

Best published paper with a postgraduate student as lead author: *David Crook, Alistar Robertson, Alison King and Paul Humphries*, for 'The influence of spatial scale and habitat arrangement on diel patterns of habitat use by two lowland river fishes' (*Oecologia* **129**, 525–533).

Best published paper with a CRCFE scientist as lead author: *Paul Humphries, Alison King and John Koehn*, for 'Fish, flows and floodplains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia' (*Environmental Biology of Fishes* **56**, 129–151).

Best multidisciplinary team research project: 'D210, Urbanization and the ecological function of streams', led by *Chris Walsh* (Monash University).

Best knowledge exchange activity or project: 'The Assessment of River Condition: an audit of the ecological condition of Australian rivers', led by *Richard Norris* (University of Canberra) and *Ian Prosser* (CSIRO).

Special Achievement Awards were made to *John Langford* (our Board Chairman), *Barry Hart* (Monash University), *Ben Gawne* (MDFRC, Albury-Wodonga) and *Peter Cullen*, in recognition of their outstanding contributions to the CRCFE.



6. Performance indicators

Cooperative arrangements

Activities of the centre seen by stakeholders as making a difference to water management, July 1999 – June 2005

During 2004–2005:

- ▲ the CRCFE's framework for monitoring and assessing the ecological effects of environmental flows has been published as a report (*Environmental Flows Monitoring and Assessment Framework*, see <http://freshwater.canberra.edu.au> > publications > technical reports). The framework was developed by a panel representing 14 water agencies across eastern Australia (including Tasmania), many of which were CRCFE partner institutions. A web tool to assist users has been prepared and is being reviewed. Three projects are already either completed or in progress, based on the framework: monitoring programs for the Thomson-Macalister Rivers (DSE) and streams of the Mt Lofty Ranges (DWLBC); and a Victoria-wide monitoring program (DSE).
- ▲ 'Recent lessons on river rehabilitation in eastern Australia' is a management guide (in press) that captures recent lessons that have emerged from CRCFE's rehabilitation research and from practitioners' on-ground experience. The guide should be useful to river managers for the planning, implementation and evaluation of the success of rehabilitation projects. In the same area, a database and assessment of on-ground rehabilitation works across Victoria and USA is being prepared in an international project that CRCFE is part of (via Brooks and Lake). The team has recently published a list of characteristics that signify successful ecological restoration.
- ▲ *Assessing and monitoring aquatic biodiversity: what have we learnt?* by Ruth O'Connor and Amanda Kotlash, is a compilation of knowledge gained, largely by the CRCFE, in the measurement of aquatic biodiversity. It is available on the CRCFE web site at <http://freshwater.canberra.edu.au>.
- ▲ A framework or schema for organising and examining evidence for causality between environmental factors has been developed from a model in use in epidemiological studies. It complements other approaches for water quality monitoring. The 'Multiple Lines and Levels of Evidence' schema consists of software and a manual, and is at present being rigorously tested.
- ▲ CRCFE reviewed the ACT's Environmental Flow Guidelines, on contrast to the ACT Government. A report, 'Review of the 1999 ACT Environmental Flow Guidelines' by Ralph Ogden, Peter Davies, Bronwyn Rennie, James Mugodo and Peter Cottingham, was submitted to Environment ACT in November 2004.
- ▲ CRCFE scientists continued to work regularly with ACTEW, the ACT water managers, to devise the best active adaptive management for environmental flows during the drought and the after-effects of bushfire in Canberra's main water supply catchments. This work has won a University of Canberra Vice-Chancellor's Distinction Award for Innovation and Creativity in Research and Enterprise (2005), and has been presented at the 8th International Riversymposium in September 2005.
- ▲ Williams, D. and Roberts, J. (2005), *Riparian vegetation diversity in the Sydney Catchment Authority's area of operations* describes the vegetation biodiversity work that was part of a larger biodiversity study. It is published on the CRCFE web site, at <http://freshwater.canberra.edu.au>.
- ▲ A joint CRCFE–CRCCH industry report, *Urban stormwater and the ecology of streams* by Chris Walsh, Alex Leonard, Anthony Ladson and Tim Fletcher, has been published on the CRCFE website (link from front page) and in print. Derivative publications are planned.
- ▲ Wetlands knowledge relevant to the Lower Murray swamps has been compiled and provided to the DWLBC, to help identify natural wetlands that have ecological conservation value, and that are amenable to ecological rehabilitation, as a guide for assigning priority to restoration works.

- ▲ A Waterwatch training workshop was held by the CRCFE in the ACT, and specialist theory and training sessions were delivered by three CRCFE staff at the Waterwatch conference in Adelaide.
 - ▲ The CRCFE team that works on the Narran project contributed an article to the Jan/Feb '05 *Western Division Newsletter* (a DIPNR production) on the Narran project. Readers (landholders and NRM managers) commented very favourably.
 - ▲ The CRCFE facilitated a workshop on the importance of floodplain-wetland habitat for native fish at the Australian Society for Fish Biology annual conference (20–21 September 2004). The workshop explored what is known of flow–wetland–native fish interactions for the Living Murray significant ecological asset sites, consistent with activities proposed by the MDBC Native Fish Strategy. The workshop objectives were established following discussions between the Murray-Darling Basin Commission, the Arthur-Rylah Institute, the University of Adelaide and the CRCFE.
 - ▲ CRCFE staff (Lintermans, O'Connor, Cottingham) have edited the proceedings of a workshop they facilitated on 'Fish Habitat Rehabilitation and Management in the Murray-Darling Basin' for MDBC in February 2004. Papers from the workshop are to serve as a benchmark.
 - ▲ The CRCFE was well represented at the Second International Symposium on Riverine Landscapes in Sweden, with invited papers from Jane Hughes, Sam Lake and Stuart Bunn. Ben Cook (PhD student), Nick Bond and Paul Reich also attended and presented posters on their research. The Third Symposium is planned to be held in Australia in 2007.
 - ▲ Gary Jones has helped to coordinate the development of the Inland Waters Theme for the 2006 Australian State of the Environment (SoE) report, as a mentor of the SoE committee. A workshop was organised in July 2004 to provide input on the appropriate indicators and conceptual model.
- During 2003–2004:*
- ▶ the conclusions and report of the Scientific Reference Panel for the Living Murray initiative were widely considered to have contributed both to the National Water Initiative confirmed in June 2004 and to the first-step decision of the Murray-Darling Basin Ministerial Council, in November 2003, to adjust the management of the Murray system's water over the next five years so that an estimated average extra 500 GL per year can be devoted to environmental needs.
 - ▶ The Goulburn River Scientific Panel for the Living Murray, and its report, 'Environmental flow recommendations for the Goulburn River below Lake Eildon', contributed to the Living Murray initiative above.
 - ▶ Public talks by Gary Jones and Ben Gawne contributed to community understanding of the Living Murray initiative, and therefore indirectly to river management.
 - ▶ CRCFE scientists are working regularly with the ACT water managers to devise strategies for Canberra's main water supply catchments.
 - ▶ CRCFE has devised a monitoring design specifically for DSE for assessing ecological responses to future environmental flows in the Wimmera and Glenelg Rivers, western Victoria.
 - ▶ The CRCFE has established a multi-state working group to develop a generic framework for monitoring environmental flows, following on from the project above that highlighted the challenges in designing monitoring programs for environmental flows in lowland rivers with naturally variable flow regimes. The framework is expected to be complete in late 2004.
 - ▶ City water managers in Melbourne, Canberra, Brisbane and Sydney have accepted CRCFE's advice on storm-water drainage connection with urban streams, and have begun to collect the information on infrastructure that they need to be able to apply the advice.
 - ▶ A risk-based approach formulated by CRCFE is to be incorporated into guidelines for suspended sediments, by EPA Victoria.
 - ▶ CRCFE (MDFRC), with the River Murray Catchment Water Management Board, and DLWBC, is contributing to the SA Wetlands Baseline Monitoring project that is expected to make a difference to SA wetland management.
 - ▶ Outcomes from workshops and research on ephemeral wetlands and deflation basins have been incorporated into management guidelines for ephemeral deflation basin lakes for the MDBC.
 - ▶ CRCFE ran the Ninth International Conference on River Research and Applications in early July 2003 at Albury, NSW. Together with a pre-conference forum on flow ecology and environmental flows, the conference brought together managers and national and international researchers.
 - ▶ CRCFE helped organise, and facilitated, a workshop attended by ~80 scientists and aquatic managers to discuss the current status of knowledge on fish-habitat rehabilitation and management issues. Papers from the workshop are to serve as a benchmark.
 - ▶ The Narran Project (joint CRCFE-MDBC) is involving key members of the Lower Balonne Floodplain community via the Lower Balonne Community Reference Group and the Narran Community Reference Panel. Leading irrigators and pastoralists in the area are collaborating in the project.
 - ▶ CRCFE staff have run or helped run three international and national conferences and 12 major training workshops or courses for scientists and water industry personnel, two freshwater schools for school students, and 14 other workshops or seminar series during 2003–2004.

During 2002–2003:

- ▶ the CRCFE conducted the assessment of three environmental flows scenarios for the River Murray, under the Living Murray Initiative for its partner the Murray-Darling Basin Commission, and for the Murray-Darling Basin Ministerial Council, which is widely seen to have influenced river management in 2003–2004.
- ▶ Scientific knowledge generated by the CRCFE was part of the basis for environmental flow recommendations for the Goulburn River, Victoria. The Low Flow Recruitment hypothesis for fish and wetland macroinvertebrate responses to inundation, and CRCFE work on the microbial processing of carbon and nutrients in relation to ‘seasonal flow inversion’ below Lake Eildon, and the FLOWS methodology, to which CRCFE research contributed strongly, have been used for this and other environmental flow studies in Victoria.
- ▶ In regular discussions, the CRCFE advised and assisted its partner water authorities for Canberra in devising environmental flows for the Cotter River (Canberra’s main water supply) during the drought of spring/summer 2002 and summer/autumn 2003, and in managing water quality and environmental flows in the Cotter River since the bushfires of January 2003.
- ▶ CRCFE collaborated with the Department of Sustainability and Environment (Victoria) to develop Sustainable Diversion Limits for Victorian rivers.
- ▶ CRCFE was invited to be part of the Victorian Technical Audit Panel to review groundwater management plans and streamflow management plans.
- ▶ A team from CRCFE reviewed Melbourne Water’s Waterway Management Strategy and their decision support system STREAMS. CRCFE identified opportunities for further refinement.
- ▶ CRCFE contributed to the development of a long-term monitoring program for Melbourne Water. This included liaising with Melbourne Water staff and arranging for the project to be undertaken by researchers from Monash University.
- ▶ CRCFE continued to collaborate with SCA, DIPNR and NSW EPA on researching the ecological consequences of reduced connectivity and increased fragmentation of rivers in the Sydney region using genetic techniques.
- ▶ At the Murray Unregulated River Management Committee meeting, CRCFE staff gave advice on the stream flow management plan for Billabong Creek.
- ▶ CRCFE provided DIPNR with input to the Darling Anabranched Management Plan and has advised on environmental flows.
- ▶ The Lower Basin Laboratory of the Murray-Darling Freshwater Research Centre (CRCFE) is helping manage environmental flows for the Mallee CMA in western Victoria.
- ▶ The CRCFE undertook a literature review of the aquatic ecological

condition of the Keepit Dam and its immediate surroundings, at DIPNR’s request.

During 2001–2002:

- ▶ CRCFE convened and led the Expert Reference Panel on Environmental Flows and Water Quality Requirements for the River Murray System, for the MDBC. The CRC provided a key technical report supporting the April 2002 Ministerial Council decision to continue development of River Murray environmental flows allocations.
- ▶ Described the environmental health of the rivers of the Murray-Darling Basin in a report to the MDBC titled *Snapshot of the Condition of the Rivers in the Murray-Darling Basin*.
- ▶ Coordinated Scientific Panel assessments for Victoria’s Ovens River and Broken River, and produced a technical report reviewing the Scientific Panel approach to determining environmental flows for DNRE Victoria.
- ▶ Undertook a major Aquatic Biodiversity Assessment Pilot Study on behalf of the Sydney Catchment Authority.
- ▶ Facilitated a whole-of-water cycle benchmarking study workshop for ACTEW Corporation.
- ▶ Undertook assessment of proposed management scenarios for the Lower Balonne River system for DNRM Queensland.
- ▶ Produced two river management guides for regional catchment management organisations that were

distributed to over 3500 stakeholders. There has been strong demand for these guides.

During 2000–2001:

- ▶ CRCFE provided First National Assessment of River Condition, through the NLWRA, as a basis for large-scale decision making about improving river condition across Australia.
- ▶ Developed a framework which will provide for a comprehensive annual review of the condition of the Basin's waterways — the Sustainable Rivers Audit — for the MDBC.
UPDATE, JUNE 2004: 'After a highly successful pilot trial in four rivers, a new \$11 million six-year program' called the Sustainable Rivers Audit will 'audit the health of the Murray-Darling Basin's rivers and streams' in 23 river valleys: announced on 10 June 2004 by Murray-Darling Basin Commission (MDBC) President Ian Sinclair. (See <http://www.mdbc.gov.au/commcentre/elist/eletter/Issue32-july04.htm>)
- ▶ The National Water Quality Management Strategy guidelines for water quality (and sediments) and for water-quality monitoring and reporting, completed and published. Both guidelines have had large input from CRCFE staff over several years, and Bill Maher was a principal writer of the monitoring and reporting guidelines and the sediment quality guidelines. These guidelines are now the basis for water quality measurements and reporting, nationally.

- ▶ Reviewed progress made towards the definition, measurement and reporting of Ecologically Sustainable Development as it is applied to Queensland's water resources, in a 2-day workshop with QDNR.
- ▶ Provided scientific input to, and oversaw, several riverine environmental flows assessment expert panels.

During 1999–2000:

- ▶ the CRCFE's ability to improve water management was recognised by a wide range of stakeholders as shown by the high demand for the CRCFE's expertise from community groups, the water industry, politicians, the media and the general public.
- ▶ Many of the CRCFE's recommendations were adopted via consultancies.

Research undertaken in large multi-disciplinary projects is managed in an integrated way, 1999–2005

Large multi-disciplinary projects have formed the core of the CRCFE's research portfolio. These projects use expertise from across the CRCFE to focus on problems at an appropriate field scale (preferably at landscape scale), and are managed in an integrated way.

The CRC's research portfolio has been guided by a conviction that if truly multi-disciplinary and collaborative research is to be undertaken, the researchers and managers must be involved from the start in developing the projects. We have invested in leadership training to help staff work in these integrated projects,

and each project has had input from industry via the Program Advisory Committees and other collaborations.

Of 35 active core- and associated-research projects in 2004–2005, 18 involved staff from several partner institutions. Eight of the 11 phase-2 core projects were cross-institutional, and also 10 associated projects. The staff interact via frequent phone and email contact and regular program and project meetings. Phase I research teams (2000–2003), now disbanded, combined staff across sites in a similar way.

Maintaining a strong partner base, 1999–2005

The CRCFE consisted of 19 partners at June 2005, since two partners — Lower Murray Water and Sunraysia Rural Water Authority — amalgamated into one in 2004–2005. The partners comprised six research providers and 13 public and private water-industry agencies.

The Senior Management Team and the Knowledge Exchange team have been in regular contact with members of the CRCFE's partner organisations, discussing their requirements and supplying advice and information. The Senior Management Team members were staff members in four of our partner research providers.

Wherever possible, CRCFE has ensured that the involvement of partner organisations in CRCFE work has been acknowledged in publicity about the Centre.

During 2004–2005, the success of the CRCFE's rebid, jointly with the CRC for Catchment Hydrology, was announced. The new CRC will have over 40 participants, about one-third of which have not been participants in the two former CRCs. The new partners comprise representatives from private industry, including small-medium size enterprises (SMEs), as well as public industry and research providers.

Research and researchers

Research portfolio appropriate to short- and longer-term issues for the water industry

Our research portfolio has targeted both short and long-term issues facing the water industry. CRCFE projects have ranged from large integrated three- to five-year projects looking at scientific questions underpinning sustainable water resources management, to short-term 6–12 month projects addressing immediate needs and knowledge gaps. Up till 2004–2005, additional targeted funding has been provided through government and industry research grants.

We believe that most benefit is gained if research projects are developed as collaborative partnerships between researchers and managers. Program Advisory Committees (PACs), established for each research program, formalised the involvement of industry staff in research planning and activities.

Industry personnel have continued to be involved directly with many of the latest post-graduate students, as mentors (see

below), ensuring that the students' research topics have continued relevance to water industry issues.

Research is of an excellent standard and is published in refereed literature

All research projects undertaken within the CRCFE have undergone a rigorous review process to ensure excellent quality science which is relevant and of benefit to our partners. To reinforce this, we have had a quality assurance review process that all research projects have undergone. It had three levels:

- internal review of the science (by management committee);
- external review of the science (by peers); and
- review of management relevance (by PACs).

All research projects were approved by the CRCFE's Board.

The list of articles accepted by, or published in, refereed journals has varied from year to year. In total the CRCFE has published approximately 450 papers since mid-1999, though the number appears higher in the yearly figures, because there is some overlap with papers in press at the ends of financial years:

- 97 articles in 2004–2005;
- 104 articles in 2003–2004;
- 67 in 2002–2003;
- 50 in 2001–2002;
- 94 in 2000–2001;
- 43 in 1999–2000.

Number of postgraduate students enrolled and working with the CRCFE, and degrees conferred

	2004–2005	2003–2004	2002–2003	2001–2002	2000–2001	1999–2000
PhD	41	48	51	47PhD+MSc	41	51
MSc	1	1	1	na	1	12
Conferred	7	10	4	8	na	11
Associated projects	10	10	6	na	90	25

na = information not available

One of the ways in which the CRCFE has ensured its research is world-class has been through international collaborations with selected institutions and researchers. These linkages have enriched the research generated by both parties and benefited the broader water science community in Australia as CRCFE researchers have shared their knowledge. Several key researchers in CRCFE have been on international committees (e.g. DIVERSITAS, and editorial boards) by invitation (see page 31).

Effective project management with regular reporting to Board

The CRCFE Project Management System has tracked the achievement of milestones for individual projects. All staff accessed the Project Management System through the secure CRCFE intranet web site. Reasons for missed milestones were provided by the Project Leader and these formed part of the Exceptions Report to the Board.

Education and training

Involvement of non-university staff in teaching postgraduate courses and research supervision

Nine CRCFE postgraduate students have had non-university staff as co-supervisors in 2004–2005. In 2003–2004, 2002–2003, 2001–2002, 2000–2001 and 1999–2000, the numbers were 9, 10, 10, 1 and 22, respectively. Additionally, each year the CRCFE has had several students involved in collaborative projects with non-university partners of the CRCFE and benefiting from feedback and advice they receive from them.

The industry mentoring scheme for postgraduate students, introduced in 2003, has continued this financial year, 2004–2005. Recipients of CRCFE top-up and APA scholarships have had industry mentors, as well as supervisors, to ensure that the students' training produces new scientists with a sound understanding of the water industry.

Short courses and workshops developed and presented

During 2004–2005, CRCFE personnel have run, or jointly run 11 professional training courses, and five short courses and interactive workshops or forums for industry staff, managers and researchers.

Three conferences and 28 courses or interactive workshops were run in 2003–2004; 13 research planning, joint problem solving or communications workshops were organised in 2002–2003, 17 in 2001–2002, 17 in 2000–2001 and 3 in 1999–2000.

Applications of research

Adoption of research by partners, 1999–2005

- Environmental flow monitoring and assessment framework (MDBC, DSE, DWLBC)
- River health assessment methods (Sydney Catchment Authority (SCA), MDBC, QNRM, DSE, DIPNR, EPA NSW, EPAV, Environment ACT)
- Waterway condition assessment (National Land & Water Resources Audit)

- ▶ Integrated urban land and water management (ACT Government, Melbourne Water)
- ▶ Urban stream rehabilitation (ACT Government, Melbourne Water, NSW EPA (DEC), SCA,)
- ▶ Biodiversity assessment methods and management (SCA, EPAV)
- ▶ Environmental flows assessment and setting (MDBC, DSE, SCA, QNRM, ACT Government, ACTEW, Melbourne Water, Goulburn-Murray Water)
- ▶ Environmental flow effects — monitoring (DSE, EPAV, Melbourne Water, MDBC, DIPNR, QNRM, Environment ACT, DWLBC)
- ▶ Taxonomic guides (DSE, QNRM, DIPNR, EPAs)
- ▶ Fish management (MDBC, DWLBC, DIPNR, QNRM)
- ▶ Lake, reservoir, wetland management (Lower Murray Water, DIPNR, Environment ACT, MDBC, SCA, DWLBC, ACTEW Corporation)
- ▶ Stream rehabilitation (DSE, QNRM, SCA, MDBC)
- ▶ Ecological risk assessment (Melbourne Water, EPAV, Goulburn-Murray Water, DSE, SCA)
- ▶ CRCFE research staff have worked as consultants for partner agencies (e.g. DWLBC, DIPNR, MDBC, Goulburn-Murray Water, DEC, DSE).

Technical publications produced, 1999–2004

	2004–2005	2003–2004	2002–2003	2001–2002	2000–2001	1999–2000
Technical reports	26	14	11	16	17	25
Consultancy reports	32	54	21	17	44	58
Software	1	3	2	-	-	-
ID guides	0	6	2	7	10	7
Tech memos and electronic publications	na	1	3	1	1	1

Advice and consultancies provided to industry partners and others & Applied research, investigation and consulting contracts with non-participating agencies

CRCFE staff completed or were engaged in six consultancies generating income of \$250,000 during 2004–2005, and provided advice, continuing input, training or assistance to all 13 of our industry partners as well as our six research providers, plus numerous non-partner groups (see table at end of Chapter 4). ('Consultancies' include all external contracts, including contract research.)

In 2003–2004, 20 or more consultancies generated \$715,000 in income. During 2002–2003, 2001–2002, 2000–2001, 1999–2000, there were 19 consultancies (\$576,000 income), 28 consultancies (\$780,000 income), 16 consultancies (\$1.1 million income) and 36 consultancies (\$1.4 million income), respectively. In 1999–2000, staff provided advice and assistance on more than 250 occasions to industry partners and others.

Production of technical publications appropriate for end-users and development of other vehicles for reaching these groups

To broaden access to CRCFE research findings, technical reports are now made available in PDF format on the CRCFE website, and non-technical descriptions of research findings are also produced, often via *Watershed*, our newsletter/magazine.

The CRC uses a variety of communication strategies to reach end-users, including one-on-one knowledge exchange, web placement of information and reports, seminars, workshops, conferences, consultative and business meetings, international visits, advisory committees and training sessions.

Centre staff involvement in government and other advisory bodies

CRCFE staff have been members of at least 34 committees and advisory bodies to government agencies and natural resources management groups, at local, state, national and international level,

during 2004–2005, and chair or deputy chair of 10 of those bodies. They include:

- ▶ NSW Scientific Committee for the Threatened Species Conservation Act
- ▶ Queensland threatened species scientific committee
- ▶ ACT Flora and Fauna Committee (Chair)
- ▶ ACT Environment Advisory Committee
- ▶ Australian Government State of the Environment Committee
- ▶ ACT Water Supply Catchments Management Committee (Chair)
- ▶ DSE Technical Advisory Panel on environmental flows (Chair)
- ▶ Gippsland Lakes Task Force
- ▶ Gippsland Integrated Natural Resource Forum (Chair)
- ▶ Australian Society for Limnology (President and Vice-President)
- ▶ Australian Society for Fish Biology (President)
- ▶ Victorian Catchment Management Council

- ▶ Gippsland Water Technical Review Committee (Chair)
- ▶ EPA Victoria Scientific Advisory Panel
- ▶ Board of EPA Victoria
- ▶ Board of Wetland Care Australia
- ▶ Murray Wetland Working Group
- ▶ Environment ACT/ACTEW environmental flows technical working group
- ▶ Task Force on Declining Amphibian Populations
- ▶ Lindsay Wallpolla Environmental Flows Steering Committee (Chair of meetings)
- ▶ Technical Audit Panel for Streamflow and Groundwater Management Plans, DSE
- ▶ Scientific Reference Panel for Lower Snowy River Rehabilitation Trial
- ▶ Scientific Advisory Group, Moreton Bay Waterways and Catchments Partnership (Deputy Chair)
- ▶ Scientific Expert Panel, Ecosystem Health Monitoring Program, Moreton Bay Waterways and Catchments Partnership (Deputy Chair)
- ▶ Scientific Expert Panel, Moreton Region Water Resource Planning, Moreton Bay Waterways and Catchments Partnership (Chair)
- ▶ Lake Eyre Basin Ministerial Council Scientific Advisory Panel.
- ▶ 2nd International Symposium on Riverine Landscapes, Scientific Committee
- ▶ Australian–Japanese ‘Predictions in Ungauged Basins’ Working Group (D. Baldwin, CSIRO)

- ▶ Scientific Committee of DIVERSITAS crosscutting network on freshwater biodiversity
- ▶ Ramsar Convention’s Scientific and Technical Review Panel
- ▶ Global Water Systems Project, Scientific Steering Committee (a joint project of Diversitas, the IGBP, the IHDP and the WCRP)
- ▶ North American Benthological Society Executive Committee (Chair)
- ▶ North American Benthological Society Awards of Excellence Committee
- ▶ North American Benthological Society International Planning Committee

During the first five years of this CRCFE, staff were members of 38 committees (chairing 6) in 2003–2004, 10 committees in 2002–2003, 17 committees (chairing 3 of them) plus 3 expert advisory panels in 2001–2002, 59 committees (chairing 8 of them) plus 23 expert advisory panels in 2000–2001, and more than 56 committees and advisory bodies (chairing 11 of them) in 1999–2000.

Media exposure by centre

Each year the CRCFE’s work is covered by a range of mass media outlets as well as industry newsletters. In 2004–2005, staff and students of the CRCFE generated over 50 media hits that we know of, with another 12 foreshadowing eWater CRC, in connection with Gary Jones. Comparable numbers in 2003–2004, 2002–2003, 2001–2002, 2000–2001, 1999–2000 were >200, 104, 150, 130 and 103 media hits, respectively.

Management and budget

Effectiveness of Board in setting research directions and providing overall policies for the centre

The Board has been very involved with developing the research portfolio and with setting other policies for the CRCFE. The Board’s Research Committee has enabled timely feedback on research project matters to the Senior Management Team and other senior research staff.

Reporting progress to the Board and to the Commonwealth

The CRCFE Board received financial information on a quarterly basis and research-progress reports at each Board meeting.

The Australian Government has been advised of the financial position of the CRC each quarter.

Accurate monitoring of agreed performance indicators

The CRCFE has a project management system in place, which has tracked the completion of milestones for the research component. Other performance indicators have been monitored through the CRCFE Information Management System.

Deliver induction program so that all new entrants to the centre have an understanding of the organisation, its operations and resources

An induction program is carried out annually as part of the project management course for new students and staff. The postgraduate student manual outlines funding opportunities, applications, and other administrative procedures.

Provide appropriate staff development opportunities within the centre

Staff have been given opportunities to expand their scientific and managerial skills through CRCFE-funded attendance at national and international conferences and workshops, plus national scientific and managerial development training courses. The CRCFE provides substantial annual funding (in excess of \$50,000) for this purpose.

Significantly increase revenues from outside sources during the life of the centre

The CRCFE was paid \$250,000 during 2004–2005 for consultancies, including contract research. Income from consultancies in earlier years is reported above.

7. Publications and presentations

Books and chapters in books

- Abal, E.G., Bunn, S.E. and Dennison, W.C. (eds) (2005). *Healthy Waterways, Healthy Catchments: Making the connection in south east Queensland. Moreton Bay and Catchments Partnership, Brisbane Queensland*. 222 p.
- Abal, E.G., Bunn, S.E., Dennison, W.C., Greenfield, P.F. and Tarte, D. (2005) The way forward. In: Abal, E.G., Bunn, S.E. and Dennison, W.C. (eds) (2005). *Healthy Waterways, Healthy Catchments: Making the connection in south east Queensland. Moreton Bay and Catchments Partnership, Brisbane Queensland*, pp. 209–216.
- Abal, E.G., Dennison, W.C. and Bunn, S.E. (2005) Setting. In: Abal, E.G., Bunn, S.E. and Dennison, W.C. (eds) (2005). *Healthy Waterways, Healthy Catchments: Making the connection in south east Queensland. Moreton Bay and Catchments Partnership, Brisbane Queensland*, pp. 35–68.
- Arthington, A.H., Baran, E., Brown, C.A., Dugan, P., Halls, A.S., King, J.M., Minter-Vera, C.V., Tharme, R.E. and Welcomme, R.L. (2005) Water requirements of floodplain rivers and fisheries: existing decision-support tools and pathways for development. In: *Comprehensive Assessment of Water Management in Agriculture*. International Water Management Institute, CGIAR. 59 pp.
- Bunn, S.E., Balcombe, S.R., Davies, P.M., Fellows, C.S. and McKenzie-Smith, F.J. (in press). Productivity and aquatic food webs of desert river ecosystems. In: R.T. Kingsford (ed.) *Changeable, Changed, Changing: The Ecology of Desert Rivers*. Cambridge University Press.
- Freudenberger, D. and Norris, R. (2004) Angling after the fires. *The Flyfisher* **9**, 81–84.
- Jarman, P.J. and Brock, M.A. (2004) The evolving intent and coverage of legislation to protect biodiversity in New South Wales. In: *Threatened Species Legislation: Is It Just An Act?* Eds Hutchings, P., Lunney, D. & Dickman, C. Royal Zoological Society of New South Wales. Mosman, NSW, Australia, pp. 1–19.
- Kennard, M.J. (2004) Appendix H: Freshwater fish. In: *Mary Basin Water Resource Plan (WRP) — Environmental Conditions Report*. Eds S. Brizga, A.H. Arthington, S. Choy, L. Duivendoorden, M. Kennard, R. Maynard, and W. Poplawski. Queensland Department of Natural Resources, Brisbane.
- Kennard, M.J. (2005) Appendix H. Freshwater fish. In: *Logan–Albert Basin Water Resource Plan (WRP) — Environmental Conditions Report*. (Ed. S. Brizga). Queensland Department of Natural Resources and Mines, Brisbane.
- Lintermans, M. and Phillips, B. (eds) (2005) *Management of Murray Cod in the Murray-Darling Basin*. Statement, recommendations and supporting papers from a workshop held in Canberra, 3–4 June 2004. Murray-Darling Basin Commission, Canberra. 128 pp.
- Lintermans, M., Cottingham, P. and O'Connor, R. (eds) (2005) *Fish Habitat Rehabilitation and Management in the Murray-Darling Basin*. Statement, recommendations and supporting papers from a workshop held in Albury, 10–11 February 2004. Murray-Darling Basin Commission, and CRC for Freshwater Ecology. Canberra.
- Mitchell, A.M., Baldwin, D.S. and Rees, G.N. (2005) Alterations to potential phosphorus release processes from anaerobic freshwater sediments with additions of different species of labile carbon. In: L. Serrano and H.L. Golterman (eds) *Phosphate in Sediments*. Backhuys: Netherlands.
- Mitchell, A.M. and Baldwin, D.S. (2005) Interactions between organic phosphorus in aquatic nutrient cycles. In: B.L. Turner, E. Frossard and D.S. Baldwin (eds) *Organic Phosphorus in the Environment*. CAB International: Oxfordshire, UK.
- Oliver, R., Grace, M., Olley, J. and Cooper, B. (2004) Water quality. Chapter 13. In: Breckwoldt, R., Boden, R. and Andrew, J. (eds) *The Darling. Murray-Darling Basin Commission, Canberra*, 298–329.
- Pusey, B.J., Kennard, M.J. and Arthington, A.H. (2004) *Freshwater Fishes of North-eastern Australia*. CSIRO Publishing, Melbourne, 684 pp.
- Sheldon, F. and Thoms, M.C. (2004) River corridors. In: Breckwoldt, R., Boden, R. and Andrew, J. (eds) *The Darling. Murray-Darling Basin Commission, Canberra*.
- Smith, M., Carruthers, T. and Bunn, S.E. (2005) Aquatic habitats. In: Abal, E.G., Bunn, S.E. and Dennison, W.C. (eds) (2005) *Healthy Waterways, Healthy Catchments: Making the Connection in South-east Queensland. Moreton Bay and Catchments Partnership, Brisbane Queensland*, pp. 13–34.
- Thoms, M.C., Hill, S.M., Spry, M.J., Chen, X.J., Mount, T.J. and Sheldon, F. (2004) The geomorphology of the Darling River. In: Breckwoldt, R., Boden, R. and Andrew, J. (eds). *The Darling. Murray-Darling Basin Commission, Canberra*.
- Thoms, M.C., Sheldon, F. and Crabb, P. 2004. A hydrological perspective of the Darling River. In: Breckwoldt, R., Boden, R. and Andrew, J. (eds) *The Darling. Murray-Darling Basin Commission, Canberra*.
- Thoms, M.C., Terrill, P., Crabb, P., Maher, S., Harris, J. and Sheldon, F. (2004) Environmental flows in the Darling Basin. In: Breckwoldt, R., Boden, R. and Andrew, J. (eds) *The Darling. Murray-Darling Basin Commission, Canberra*.
- Thoms, M.C. (in press) An interdisciplinary and hierarchical approach to the study and management of river ecosystems. In: *International Perspectives on the State of the Art and Pathways Forward*. International Association of Hydrological Sciences.
- Thoms, M.C., Beyer, P. and Rogers, K.H. (in press) Variability, complexity and diversity — the geomorphology of river ecosystems in dryland regions. In: Kingsford, R.T. (ed.) *The Ecology of Desert Rivers*. Cambridge University Press, pp. 47–75.
- Tockner, K., Bunn, S.E., Gordon, C., Naiman, R.J., Quinn, G.P. and Stanford, J.A. (in press). Floodplains: critically threatened ecosystems. In: N. Polunin (ed.) *Future of Aquatic Ecosystems*. Cambridge University Press.
- Turner, B., Frossard, E. and Baldwin, D.S. (eds) (2005) *Organic Phosphorus in the Environment*. ABI Publishing, Wallingford, UK. 399 p.
- Welcomme, R.L., Bene, C., Brown, C.A., Arthington, A.H., Dugan, P., King, J.M. and Sugunan, V. (2005) Predicting the water requirements of river fisheries. In: *Wetlands as an Ecological Resource (Vols 1 and 2)*. Ecological Studies, Springer.

Refereed journal articles

- Arthington, A.H., Balcombe, S.R., Wilson, G.A., Thoms, M.C. and Marshall, J. (2005) Spatial and temporal variations in fish assemblage structure within isolated waterholes during the 2001 dry season of an arid-zone floodplain river, Cooper Creek, Australia. *Marine and Freshwater Research* **56**, 25–35.
- Baker, A.M., Hughes, J.M., Dean, J.C. and Bunn, S.E. (2004) Mitochondrial DNA reveals phylogenetic structuring and cryptic diversity in Australian freshwater macroinvertebrate assemblages. *Marine and Freshwater Research* **55**, 629–640.
- Balcombe, S.R. and Closs, G.P. (2004) Spatial relationships and temporal variability in a littoral macrophyte fish assemblage. *Marine and Freshwater Research* **55**, 609–617.
- Balcombe, S.R., Bunn, S.E., Davies, P.M., and McKenzie-Smith, F.J. (in press) Variability of fish diets between dry and flood periods in an arid zone floodplain river. *Journal of Fish Biology*.
- Baldwin, D.S., Mitchell, A.M., Rees, G.N., Watson, G.O. and Williams, J.L. (in press) Nitrogen processing by biofilms along a lowland river continuum. *River Research and Applications*.
- Baldwin, D.S., Rees, G.N., Mitchell, A.M. and Watson, G.O. (in press) Spatial and temporal variability of nitrogen dynamics in an upland stream before and after a drought. *Marine & Freshwater Research*.
- Ballinger, A., Mac Nally, R. and Lake, P.S. (2005) Immediate and longer-term effects of managed flooding on floodplain invertebrate assemblages in south-eastern Australia: generation and maintenance of a mosaic landscape. *Freshwater Biology* **50**, 1190–1205.
- Barlow, A.J., Marchant, R. and Norris, R. (in press) The effect of dams on macroinvertebrate recolonization in the Cotter River, Australia. *Verh. Internat. Verein. Limnol.* **29**.
- Bernhardt, E., Bunn, S.E., Hart, D.D., Malmqvist, B., Muotka, T., Naiman, R.J., Pringle, C., Reuss, M. and van Wilgen, B. (in press). The challenge of ecologically sustainable water management. *Water Policy*.
- Bernhardt, E.S., Palmer, M.A., Allan, J.D., Alexander, G., Barnas, K., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad-Shah, J., Galat, D., Gloss, S., Goodwin, P., Hart, D., Hassett, B., Jenkinson, R., Katz, S., Kondolf, G.M., Lake, P.S., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, L., Powell, B. and Sudduth, E. (2005) Synthesizing U.S. river restoration efforts. *Science* **308**, 636–637.
- Bond, N. and Lake, P.S. (2005) Ecological restoration and large-scale ecological disturbance: the effects of drought on the response of fish to a habitat restoration experiment. *Restoration Ecology* **13**, 39–48.
- Boys, C.A. and Thoms, M.C. (in press) A large-scale, hierarchical approach for assessing habitat associations of fish assemblages in large dryland rivers. *Hydrobiologia*.
- Brock, M.A., Nielsen, D.L. and Crosslé, K. (2005) Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. *Freshwater Biology* **50**, 1376–1390.
- Brookes, J.D., Aldridge, K., Wallace, T., Linden, L. and Ganf, G.G. (in press) Multiple interception pathways for resource utilisation and increased ecosystem resilience. *Hydrobiologia*.
- Brooks, A.J., Haeusler, T., Reinfelds, I. and Williams, S. (2005) Hydraulic microhabitats and the distribution of macroinvertebrate assemblages in riffles. *Freshwater Biology* **50**, 331–344.
- Bunn, S.E., Thoms, M.C., Hamilton, S.K. and Capon, S.J. (in press). Flow variability in dryland rivers: boom, bust and the bits in between. *River Research and Applications*
- Capon, S.J. (2005) Flood variability and spatial variation in plant community composition and structure on a large arid floodplain. *Journal of Arid Environments* **60**(2), 283–302.
- Carini, G. and Hughes, J.M. (2004) Population structure of *Macrobrachium australiense* (Decapoda: Palaemonidae) in Western Queensland, Australia: the role of contemporary and historical processes. *Heredity* **93**, 350–364.
- Carini, G. and Hughes, J.M. (in press) Population genetic structure and phylogeography of an endangered freshwater snail *Notopala sublineata* (Gastropoda: Viviparidae). *Biological Journal of the Linnean Society*.
- Choquenot, D., Nicol, S. and Koehn, J. (2004) Bioeconomic modelling in the development of invasive species policy. *New Zealand Journal of Marine and Freshwater Research* **38**, 419–428. (in press 2004)
- Churchill, R.C., Meathrel, C.E. and Suter, P.J. (2004) A retrospective assessment of gold mining in the Reedy Creek sub-catchment, northeast Victoria, Australia: residual mercury contamination 100 years later. *Environmental Pollution* **132**, 355–363.
- Close, P.G., Pusey, B.J. and Arthington, A.H. (2005) Larval description of the sympatric species, *Craterocephalus stercusmuscarum stercusmuscarum* (Pisces: Atherinidae) and *Mogurnda adspersa* (Pisces: Eleotridae) from tropical streams of north-east Queensland, Australia. *Journal of Fish Biology* **66**(3), 668–684.
- Crook, D.A. (2004) Movements associated with home range establishment by two species of lowland river fish. *Canadian Journal of Fisheries and Aquatic Sciences* **61**, 2183–2193.
- Davis, J., Horwitz, P., Norris, R.H., Chessman, B., McGuire, M. and Sommer, B. (in press) Are river bioassessment methods using macroinvertebrates applicable to wetlands? *Hydrobiologia*.
- Doody, J.S., Georges, A. and Young, J.E. (2004) Determinants of reproductive success and offspring sex in a turtle with environmental sex determination. *Biological Journal of the Linnean Society* **80**, 1–16.
- Douglas, M.M., Bunn, S.E. and Davies, P.M. (2005) River and wetland food webs in Australia's wet-dry tropics: general principles and implications for management. *Marine and Freshwater Research* **56**, 329–342.
- Dyer, F. and Thoms, M.C. (in press) Managing river flows for hydraulic diversity. *River Research and Applications*.
- Fellows, C.S., Clapcott, J.E., Udy, J.W., Bunn, S.E., Harch, B.D, Smith, M.J. and Davies, P.M. (in press) Benthic metabolism as an indicator of stream ecosystem health. *Hydrobiologia*.
- Feminella, J.W. and Walsh, C.J. (2005) Urbanization and stream ecology: an introduction to the series. *Journal of the North American Benthological Society* **24**, 585–587.
- Hamilton, S.K., Sippel, S.J and Bunn, S.E. (2005) Separation of algae from detritus for stable isotope or ecological stoichiometry studies using density fractionation in colloidal silica. *Limnology and Oceanography Methods* **3**, 149–157.

- Hamilton, S.K., Bunn, S.E., Thoms, M.C. and Marshall, J. (2005) Persistence of aquatic refugia between flow pulses in a dryland river system (Cooper Creek, Australia). *Limnology and Oceanography* **50**, 743–754
- Hammer, M.P. and Walker, K.F. (2004) A catalogue of South Australian freshwater fishes including new records, range extensions and translocations. *Transactions of the Royal Society of South Australia* **128**, 85–97.
- Harbott, E.L. and Grace, M.R. (2005) Extracellular enzyme response to bioavailability of dissolved organic C in streams of varying catchment urbanization. *Journal of the North American Benthological Society* **24**, 588–601.
- Harbott, E.L., Grace, M.R., Webb, J.A. and Hart, B.T. (2005) Small-scale temporal variation and the effect of urbanisation on extracellular enzyme activity in streams. *Journal of Environmental Monitoring* **7**(9), 861–868.
- Hatt, B.E., Fletcher, T.D., Walsh, C.J. and Taylor, S.L. (2004). The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management* **34**, 112–124.
- Howitt, J.A., Baldwin, D.S., Rees, G.N. and Hart, B.T. (2004) Facilitated heterogeneous photodegradation of dissolved organic matter by particulate iron. *Environmental Chemistry* **1**(3), 197–205.
- Huey, J., Baker, A.M. and Hughes, J.M. (in press) Patterns of connectivity and gene flow in two species of eel-tailed catfish, *Neosilurus hyrtlilii* and *Porochilus argenteus* (Siluriformes: Plotosidae), in western Queensland's dryland rivers. *Biological Journal of the Linnean Society*.
- Hughes, J., Baker, A.M., Bartlett, C., Bunn, S., Goudkamp, K. and Somerville, S. (2004) Past and present patterns of connectivity among populations of four cryptic species of freshwater mussels *Velesunio* spp. in central Australia. *Molecular Ecology* **13**, 3197–3212.
- Hyne, R.V., Pablo, F., Aistrop, M., Leonard, A. and Ahmad, N. (2004) Comparison of time-integrated pesticide concentrations determined from field deployed passive samplers with daily river water extractions. *Environ. Toxicol. Chem.* **23**, 2090–2098.
- Jackson, J.E., Raadik, T.A., Lintermans, M. and Hammer, M. (2004) Alien salmonids in Australia: impediments to effective impact management, and future directions. *New Zealand Journal of Marine and Freshwater Research* **38**, 447–455.
- Kennard, M.J., Arthington, A.H., Pusey, B.J. and Harch, B.D. (2005) Are alien fish a reliable indicator of river health? *Freshwater Biology* **50**, 174–193.
- Kennard, M.J., Harch, B.D., Pusey, B.J. and Arthington, A.H. (in press) Accurately defining the reference condition for summary biotic metrics: a comparison of four approaches. *Hydrobiologia*.
- Kennard, M.J., Pusey, B.J., Arthington, A.H., Harch, B.D. and Mackay, S.J. (in press) Utility of a multivariate modelling method for prediction of freshwater fish assemblages and evaluation of river health. *Hydrobiologia*.
- King, A.J. (2004) Density and distribution of potential prey for larval fish in the main channel of a floodplain river: the role of pelagic and epibenthic meiofauna. *River Research & Applications* **20**(8), 883–897.
- King, A.J. (2004) Niche overlap between larvae of exotic and native fish in a lowland river. Abstract only. *New Zealand Journal of Marine and Freshwater Research* **38**, 563.
- King, A.J. (2004) Ontogenetic patterns of habitat use of fish in an Australian lowland river. *Journal of Fish Biology* **65**, 1582–1603.
- King, A.J. (2005) Ontogenetic dietary shifts of fishes in an Australian floodplain river. *Marine and Freshwater Research* **56**, 215–225.
- Koehn, J.D. (2004) Rehabilitating fish habitats in Australia: improving integration of science, management and the community. *Ecological Management and Restoration* **5**(3), 211–213.
- Koehn, J.D. and Harrington, D.J. (2005) Collection and distribution of early life stages of the Murray cod (*Maccullochella peelii peelii*) in components of a regulated river system. *Australian Journal of Zoology* **53**, 137–144.
- Koehn, J.D. and Mackenzie, R.F. (2004) Priority management actions for alien freshwater fish species in Australia. *New Zealand Journal of Marine and Freshwater Research* **38**, 457–472.
- Koehn, J.D. and McDowall, R.M. (2004) Invasive species: fish and fisheries. A workshop overview, then and now. *New Zealand Journal of Marine and Freshwater Research* **38**, 383–389.
- Koehn, J.D., Nicol, S.J. and Fairbrother, P.S. (2004) Spatial arrangements and physical characteristics of structural woody habitat in a lowland river in south-eastern Australia. *Aquatic Conservation: Marine and Freshwater Ecosystems* **14**, 457–464.
- Lake, P.S. (in press) Perturbation, restoration and seeking ecological sustainability in Australian flowing waters. *Hydrobiologia*.
- Lamb, D.W., Bunganaen, Y., Louis, J., Woolsey, G.A., Oliver, R.L. and White, G. (2004) Fibre evanescent field absorption (FEFA): an optical fibre technique for measuring light absorption in turbid water samples. *Marine and Freshwater Research* **55**, 533–543.
- Linke, S., Norris, R.H., Faith, D.P. and Stockwell, D. (2005) ANNA: A new prediction method for bioassessment programs. *Freshwater Biology* **50**(1), 147–158.
- Lintermans, M. (2004) Human-assisted dispersal of alien freshwater fish in Australia. *New Zealand Journal of Marine and Freshwater Research* **38**, 481–501.
- Lloyd, N.J., Mac Nally, R. and Lake, P.S. (2005) Spatial autocorrelation of assemblages of benthic invertebrates and its relationship to environmental factors in two upland rivers in southeastern Australia. *Diversity and Distributions* **11**, 375–386.
- Lloyd, N.J., Mac Nally, R. & Lake, P.S. (in press) Spatial scale of autocorrelation of assemblages of benthic invertebrates in two upland rivers in south-eastern Australia and its implications for biomonitoring and impact assessment in streams. *Environmental Monitoring and Assessment*.
- Madsen, B.L., Boon, P.J., Lake, P.S., Bunn, S.E., Dahm, C.N., Langford, T.E. and Zalewski, M. (in press). Ecological principles and stream restoration. *Verhandlungen für internationalen Vereinigung Limnologie*.
- Marshall, J.C., Steward, A.L. and Harch, B.D. (in press) Taxonomic resolution and quantification of freshwater macroinvertebrate samples from an Australian dryland river: the benefits and costs of using species abundance data. *Hydrobiologia*.
- Marshall, N.A. and Bailey, P.C.E. (2004) Impact of secondary salinisation on freshwater ecosystems: effects of contrasting, experimental, short-term releases of saline wastewater on macroinvertebrates in a lowland stream. *Marine and Freshwater Research* **55**, 509–523.

- Meathrel, C.E., Suter, P.J. and Reid, S. (2004) Habitat and dietary preferences of freshwater turtles in ephemeral billabongs on the Ovens River, north-east Victoria. *The Victorian Naturalist* **121**(1), 4–14.
- Metzeling, L., Tiller, D., Newall, P., Wells, J. and Reed, J. (in press) Biological objectives for the protection of rivers and streams in Victoria, Australia. *Hydrobiologia*.
- Metzeling, L., Robinson, D. and Perriss, S. (in press) Can the detection of salinity and habitat simplification gradients using rapid bioassessment of benthic invertebrates be improved through finer taxonomic resolution or alternative indices? *Hydrobiologia*.
- Mugodo, J., Kennard, M., Liston, P., Nichols, S., Linke, S., Norris, R. and Lintermans M. (in press) Local stream habitat variables predicted from catchment scale characteristics are useful for predicting fish distribution. *Hydrobiologia*.
- Newall, P. and Walsh, C.J. (2005) Response of epilithic diatom assemblages to urbanization influences. *Hydrobiologia* **532**, 53–67.
- Nichols, S.J., Robinson, W.A. and Norris, R.H. (in press) Sample variability influences on the precision of predictive bioassessment. *Hydrobiologia*.
- Nicol, S.J., Lieschke, J., Lyon, J. and Koehn, J.D. (2004) Observations on the distribution and abundance of carp and native fish and their responses to a habitat restoration trial in the Murray River, Australia. *New Zealand Journal of Marine and Freshwater Research* **38**, 541–551.
- Orr, P.T., Jones, G.J. and Hamilton, G.R. (2004) Removal of saxitoxins from drinking water by granular activated carbon, ozone and hydrogen peroxide — implications for compliance with the Australian drinking water guidelines. *Water Research* **38**(20), 4455–4461.
- Page, T.J., Sharma, S. and Hughes, J.M. (2004) Deep phylogenetic structure has conservation implications for the ornate rainbowfish (*Rhadinocentrus ornatus*) in Queensland, eastern Australia. *Marine and Freshwater Research* **55**, 1–8.
- Page, T.J., Choy, S.C. and Hughes, J.M. (2005) The taxonomic feedback loop: symbiosis of morphology and molecules. *Biology Letters* **1**, 139–143.
- Page, T.J., Baker, A.M., Cook, B.D. and Hughes, J.M. (2005) Historical transoceanic dispersal of a freshwater shrimp: the colonization of the South Pacific by the genus *Paratya* (Atyidae). *Journal of Biogeography* **32**, 581–593.
- Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C.N., Follstad Shah, J., Galat, D.L., Gloss, S., Goodwin, P., Hart, D.D., Hassett, B., Jenkinson, R., Kondolf, G.M., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, L. and Sudduth, E. (2005) Standards for ecologically successful river restoration. *Journal of Applied Ecology* **42**, 208–217.
- Parsons, M.E., Thoms, M.C. and Norris, R.H. (2004) Development of a standardised approach to river habitat assessment in Australia. *Environmental Monitoring and Assessment* **98**, 109–130.
- Parsons, M., Thoms, M.C. and Norris, R.H. (2004) Using hierarchy to select scales of measurement in multiscale studies of stream macroinvertebrate assemblages. *Journal of the North American Benthological Society* **23**, 157–170.
- Peat, M., Chester, H. and Norris, R. (2005) River ecosystem response to bushfire disturbance: interaction with flow regulation. *Australian Forestry* **68**, 153–161.
- Pusey, B.J., Burrows, D., Arthington, A.H. and Kennard, M.J. (in press) Translocation and spread of piscivorous fishes in the Burdekin River, north-eastern Australia. *Biological Invasions*.
- Rees, G.N., Baldwin, D.S., Watson, G.O., Perryman, S. and Nielsen, D.L. (2004) Ordination and significance testing of microbial community composition derived from terminal restriction fragment length polymorphisms: application of multivariate statistics. *Antonie van Leeuwenhoek International Journal of Microbiology* **86**, 339–347.
- Rees, G.N., Beattie, G., Bowen, P.M. and Hart, B.T. (in press) Heterotrophic bacterial production in the lower River Murray, south eastern Australia. *Marine and Freshwater Research*.
- Rees, G.N., Bowen, P.M. and Watson, G.O. (in press) Variability in benthic respiration in three south eastern Australian lowland rivers. *River Research and Applications*.
- Rees, G.N., Watson, G.O., Baldwin, D.S. & Mitchell, A.M. (in press) Variability in the sediment microbial communities in a semi-permanent stream: impact of drought. *J. North American Benthological Society*.
- Reid, M.A. and Ogden, R.W. (in press). Trend, variability or extreme event? The importance of long-term perspectives in river ecology. *River Research and Applications*.
- Reid, M.A. and Quinn, G.P. (2004) Hydrological regime and macrophyte assemblages in temporary floodplain wetlands: implications for detecting responses to environmental water allocations. *Wetlands* **24**, 586–599.
- Rutherford, J.C., Marsh, N.A., Davies, P.M. and Bunn, S.E. (2004) Effects of patchy shade on stream water temperature: how quickly do small streams heat and cool? *Marine and Freshwater Research* **55**, 737–748.
- Sheldon, F. and Thoms, M.C. (in press) Geomorphic in-channel complexity: the key to organic matter retention in large dryland rivers? *Geomorphology*.
- Sheldon, F. and Thoms, M.C. (in press) Relationships between flow variability and invertebrate assemblage composition: data from four Australian dryland rivers. *River Research and Applications*.
- Siebenritt, M.A., Ganf, G.G. and Walker, K.F. (2004) Effect of an artificially enhanced flood on riparian vegetation. *River Research & Applications*, published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/rra.794.
- Smith, B.B. and Walker, K.F. (2004) Reproduction of common carp in South Australia, shown by young-of-the-year samples, gonadosomatic index and histological staging of ovaries. *Transactions of the Royal Society of South Australia* **128**, 249–257.
- Stoddard, J.L., Larsen, D.P., Hawkins, C.P., Johnson, R.K. and Norris, R.H. (in press) Setting expectations for the ecological condition of streams: the concept of reference condition. *Ecological Applications*.
- Thoms, M.C. and Olley, J.M. (2004) The stratigraphy, mode of deposition and age of inset flood plains on the Barwon-Darling River, Australia. *International Association of Hydrological Sciences* **288**, 316–325.
- Thoms, M.C., Dyer, F. and Walker, K. (2005) Proceedings of the Ninth International Symposium on Regulated Streams. *River Research and Applications* **21** (2&3).
- Thoms, M.C., Southwell, M.R. and McGinness, H.M. (in press) Floodplain-river ecosystems: Fragmentation and water resource development. *Geomorphology*.

- Thorp, J.H., Thoms, M.C. and Delong, M.D. (in press) Ecological regulation in river networks across time and space. River Research and Applications.
- Walsh, C.J., Fletcher, T.D. and Ladson, A.R. (2005) Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream. *Journal of the North American Benthological Society* **24**, 690–705.
- Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. and Morgan, R.P. (2005) The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society* **24**, 706–723.
- Westwood, K.J. and Ganf, G.G. (2004) Effect of cell flotation on growth of *Anabaena circinalis* under diurnally stratified conditions. *Journal of Plankton Research* **26**, 1183–1197.
- Young, J.E., Georges, A., Doody, J. S., West, P.B. and Alderman, R.L. (2004) Pivotal range and thermosensitive period of the pig-nosed turtle, *Carettochelys insculpta* (Testudines: Carettochelydidae), from northern Australia. *Canadian Journal of Zoology* **82**, 1251–1257.
- Non-refereed publications**
- Adams, J. (2005) Northern Basin Freshwater Forum 2004. Watershed April 2005. CRC for Freshwater Ecology.
- Adams, J. (2004) Narran Lakes Ecosystem Study News. Newsletter No.6, October. CRC for Freshwater Ecology.
- Adams, J. and Wilson, G. (2005) Northern Basin Lab winds up. Watershed August 2005. CRC for Freshwater Ecology.
- Brooks, S. (2005) Coming to grips with the science of stream restoration. Watershed April 2005. CRC for Freshwater Ecology.
- Bunn, S. and Cullen, P. (2004). Water quality and aquatic ecosystem health in the Lake Eyre Basin. In Scientific Advisory Panel Information Papers 2004. Lake Eyre Basin Ministerial Forum. Pp. 31–34. Australian Government.
- Bunn, S. and McMahon, T. (2004). Flow regimes and aquatic ecosystem health in the Lake Eyre Basin. In Scientific Advisory Panel Information Papers 2004. Lake Eyre Basin Ministerial Forum. Pp. 17–20. Australian Government.
- Capon, S. (2005) The Narran News. Newsletter No. 7, February, CRC for Freshwater Ecology.
- Capon, S. (2005) The Narran News. Newsletter No. 8, April, CRC for Freshwater Ecology.
- Crook, D. (2004) It's like reality TV underwater ... almost. Watershed October 2004. CRC for Freshwater Ecology.
- Doody, S., Osborne, W. and Bourne, D. (2004). Reconciling farming with wildlife: vertebrate biodiversity in the rice-growing Riverina. IREC Farmers Newsletter, Rice R&D Special **165**, 21–23.
- Georges, A., White, M., Guarino, E., Fitzsimmons, N. and Goodsell, T. (2005) Life in the slow lane: how a freshwater turtles comes to thrive in the outback. Watershed August 2005. CRC for Freshwater Ecology.
- Hyne, R., Pablo, F. and Aistrophe, M. (2004). Passive sampling for rice pesticides. IREC Farmers Newsletter, Rice R&D Summer Edition **165**, 29–30.
- Jones, G. (2004) The role of science and innovation in Australia's water policy reform. Watershed October 2004. CRC for Freshwater Ecology.
- Jones, G. (2005) Managing the ecological risks of water trading. Watershed April 2005. CRC for Freshwater Ecology.
- Jones, G. (2005) So long and thanks for all the fish. Watershed August 2005. CRC for Freshwater Ecology.
- McNeil, D. and Milligan, A. (2005) Billabongs: refuges or fish traps? Watershed April 2005. CRC for Freshwater Ecology.
- Milligan, A. and Cottingham, P. (2004) World experience focuses on streams suffering 'urban syndrome'. Watershed October 2004. CRC for Freshwater Ecology.
- Milligan, A. (2004) Let's cure urban syndrome. Watershed October 2004. CRC for Freshwater Ecology.
- Milligan, A., Quinn, G. and Ogden, R. (2005) Ecological effects of changing flows — clear but not simple. Watershed April 2005. CRC for Freshwater Ecology.
- Milligan, A. and Cottingham, P. (2005) A framework for monitoring and assessing the effects of environmental flows. Watershed April 2005. CRC for Freshwater Ecology.
- Milligan, A., Cottingham, P. and Dyer, F. (2005) Case study: monitoring the effects of Wimmera–Glenelg environmental flows. Watershed April 2005. CRC for Freshwater Ecology.
- Milligan, A. (2005) Progress in understanding dry rivers. Watershed April 2005. CRC for Freshwater Ecology.
- Milligan, A. (2005) Towards understanding and maintaining aquatic biodiversity. Watershed August 2005. CRC for Freshwater Ecology.
- Milligan, A. and Cottingham, P. (2005) Lessons in river rehabilitation. Watershed August 2005. CRC for Freshwater Ecology.
- Milligan, A. and George, A. (2005) Watering patterns for floodplain eucalypts. Watershed August 2005. CRC for Freshwater Ecology.
- Milligan, A. and O'Connor, R. (2005) What do we know about assessing aquatic biodiversity? Watershed August 2005. CRC for Freshwater Ecology.
- Milligan, A. and Hawking, J. (2005) 'Oils' ain't (necessarily) 'oils': the importance of knowing what you're dealing with. Watershed August 2005. CRC for Freshwater Ecology.
- Nichols, S. and Milligan, A. (2005) Watercourses Online. Brochure.
- Norris, R. and Milligan, A. (2004) Rapidly assessing thousands of kilometres of river condition across Australia. Watershed October 2004. CRC for Freshwater Ecology.
- Rennie, B., Osborne, W. and Milligan, A. (2005) New hope for the southern corroboree frog. Watershed April 2005. CRC for Freshwater Ecology.
- Schreiber, S. and Williams, D. (2005) Could targeted water management bring invading species under control? Watershed August 2005. CRC for Freshwater Ecology.
- Thiem, J. (2005) Trout cod in the Murrumbidgee River. Watershed August 2005. CRC for Freshwater Ecology.
- Walsh, C. (2005) New life for urban streams. *Australasian Science* **26(7)** 22–24
- White, H. and Milligan, A. (2005) Very young Murray and trout cod are sensitive to salinity. Watershed August 2005. CRC for Freshwater Ecology.
- Williams, D. (2004) Feature plant: Cabomba or fanwort. Watershed October 2004. CRC for Freshwater Ecology.
- Williams, D. (2005) Feature plant: Alligator weed. Watershed April 2005. CRC for Freshwater Ecology.
- Williams, D. (2005) Feature plant: Cumbungi. Watershed August 2005. CRC for Freshwater Ecology.
- Zukowski, S. (2004) Primary-schoolers hunger for facts about freshwater. Watershed October 2004. CRCFE.

Consultancy and technical reports

- Adams, J. and Rennie, B. (2005) A checklist to aid in preparing wetland management plans. Management guide/Technical report, CRC for Freshwater Ecology.
- Bardos, D.C., Grace, M.R. and Hart, B.T. (in press) Ecological risk assessment for algal bloom development in Lake Yarrunga. Technical report, CRC for Freshwater Ecology.
- Barlow, A., Norris, R., Nichols, S. and Arthur, R. (2004) Business Plan 2004 for Water Education and Training (WET) DRAFT. CRC for Freshwater Ecology, University of Canberra.
- Barlow, A., Norris, R. and Nichols, S. (2004) Training and Education for the Water Industry: Report on a Survey of CRCFE Partner Organizations and Other Water Resource Managers. CRC for Freshwater Ecology, University of Canberra.
- Barlow, A., Norris, R. and Nichols, S. (2004) Training and education for the water industry: Report on workshop proceedings, 26 February 2004, University of Canberra ACT. CRC for Freshwater Ecology, University of Canberra.
- Boys, C.A., Esslemont, G. and Thoms, M.C. (2005) Fish Habitat Assessment and Protection in the Barwon-Darling and Paroo Rivers. Final Report by the New South Wales Department of Primary Industries and the Cooperative Research Centre for Freshwater Ecology to the Australian Department of Agriculture, Fisheries and Forestry. NSW DPI, Nelson Bay, 105 pp.
- Butcher, R. and Hale, J. (2005) Wetland recovery prioritisation. Waters Edge Consulting report for CRC for Freshwater Ecology.
- Cottingham, P., Walsh, C., Rooney, G. and Fletcher, T. (Eds) (2004) Urbanization Impacts on Stream Ecology — From Syndrome to Cure? Outcomes of workshops held at the Symposium on Urbanization and Stream Ecology, Melbourne University, Melbourne, Australia 8–10 December 2003. CRC for Freshwater Ecology, Canberra.
- Cottingham, P., Barrett, J., Geddes, M. and Koehn, J. (Eds) (2005) Rivers and estuaries theme: The River Murray and Murray estuary case study. Proceedings of a workshop held at the Australian Society for Fish Biology 2004 Fisheries Ecosystem Symposium, Adelaide, September 2004. CRC Freshwater Ecology and Murray Darling Basin Commission.
- Cottingham, P., Bond, N., Lake, S., Bunn, S. and Outhet, D. (2005) Lessons on river rehabilitation in eastern Australia. Technical report, CRC Freshwater Ecology, Canberra.
- Cottingham, P., Quinn G., King A., Norris R., Chessman B. and Marshall C. (2005) Environmental Flows Monitoring and Assessment Framework. CRC Freshwater Ecology, Canberra.
- Cottingham, P., Stewardson, M. and Webb, A. (2005) Victorian Environmental Flows Monitoring and Assessment Program — Stage 1: Statewide Framework. CRC Freshwater Ecology and CRC Catchment Hydrology report to the Victorian Department of Sustainability and Environment.
- Coysh, J., Norris, R., Kottash, A. and Davies, C. (2005) Ecological and physical characteristics of the Shoalhaven River catchment: towards a conceptual understanding. CRC for Freshwater Ecology report to the Metropolitan Water Directorate — Dept of Infrastructure, Planning and Natural Resources and the Sydney Catchment Authority.
- Doody, S., Osborne, W., Bourne, D., Rennie, B. and Sims, R. (2004) Vertebrate Biodiversity on Australian Rice Farms. RIRDC Publication No 04/ RIRDC Project No RIC04-10.
- Ebner, B., Johnson, L. and Lintermans, M. (2005). Re-introduction of Trout Cod into the Cotter River Catchment. Final report to Natural Heritage Trust. Environment ACT, Canberra. 34 pp.
- Gawne, B., Baldwin, D., Beattie, G., Bowen, T., Ellis, I., Frankenberg, J., Lorenz, Z., Merrick, C., Oliver, R., Rees, G., Treadwell, S. and Williams, D. (in press) Ecological functioning of the Murray River ecosystem. CRCFE Technical report.
- Gill, A.M., Good, R., Kirkpatrick, J., Lennon, J., Mansergh, I. and Norris, R. (2004) Beyond the Bushfires 2003: Environmental issues in the Australian Alps. Report for the Australian Alps Liaison Committee, September 2004.
- Graham, R. and Harris, J. (2005) Floodplain inundation and fish dynamics in the Murray-Darling Basin. Current concepts and future research: a scoping study. Technical report, CRC for Freshwater Ecology.
- Harris, J., Bowling, L., Keller, R., Kress, J., Lake, S., McPhail, B. and Simpson, J. (in press) The Tooma River Project: interdisciplinary probes into ill-defined and capricious pollution. CRC for Freshwater Ecology technical report.
- Hart, B., Burgman, M., Webb, A., Allison, G., Chapman, M., Duivenvoorden, L., Feehan, P., Grace, M., Lund, M., Pollino, C., Carey, J., McCrea, A., (2004) Ecological Risk Management Framework for the Irrigation Industry. Water Studies Centre, Monash University, Melbourne.
- Johnson, S. (in press) The role of community data in natural resources management. CRCFE/Waterwatch Victoria.
- King, E.L., Webb, J.A., (2005) Westernport Catchment Water Quality Trend Analysis. Water Studies Centre, Monash University, Melbourne.
- Lemann, C. and Norris, R. (2004) Biological Monitoring Of Water Quality In Four Streams In Kosciusko National Park, NSW. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service for sampling period August 2004.
- Lemann, C., Tingle, F. and Norris, R. (2004) Biological monitoring of the Thredbo River June 2004. CRC for Freshwater Ecology report to Kosciusko Thredbo Pty Ltd
- Lemann, C., Tingle, F. and Norris, R. (2004) Biological monitoring of the Thredbo River August 2004. CRC for Freshwater Ecology report to Kosciusko Thredbo Pty Ltd.
- Lemann, C., Tingle, F. and Norris, R. (2004) Biological monitoring of the Thredbo River October 2004. CRCFE report to Kosciusko Thredbo Pty Ltd.
- Lemann, C., Tingle, F. and Norris, R. (2004) Determination of the Effects of Perisher Carpark on the Water Quality and Biological Integrity of Perisher Creek. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service November 2004.
- Lemann, C., Tingle, F. and Norris, R. (2004) Biological monitoring of the Thredbo River November 2004. CRCFE report to Kosciusko Thredbo Pty Ltd.
- Lemann, C., Tingle, F. and Norris, R.H. (2005) Biological monitoring of the Thredbo River January, 2005. CRC for Freshwater Ecology report to Kosciusko Thredbo Pty Ltd.
- Lintermans, M. (in press) The Re-establishment of the Endangered Fish, Macquarie Perch, *Macquaria australasica*, in the Queanbeyan River, New South Wales, with an Examination of Dietary Overlap with Alien Trout. CRC Freshwater Ecology Technical Report.

- Lintermans, M., Cottingham, P. and O'Connor, R. (eds) *Native Fish Habitat Rehabilitation and Management in the Murray-Darling Basin*. Statement, recommendations and supporting papers from a Workshop held in Albury NSW, 10–11 February 2004. Murray-Darling Basin Commission and Cooperative Research Centre for Freshwater Ecology, Canberra.
- Lutton, S. (in press) Drivers for the ecological condition of dryland rivers in northern NSW - Part A. Technical report, CRCFE. Mackay, S. and Marsh, N. (2005) The response of aquatic macrophytes to riparian shading in a stream rehabilitation site. Technical report 05/5, CRC for Catchment Hydrology and CRC for Freshwater Ecology.
- Norris, R.H., Chester, H. and Thoms, M.C. (2004) Ecological Sustainability of Modified Environmental Flows in the Cotter River During Drought Conditions January 2003–April 2004. CRC for Freshwater Ecology, Report to Environment ACT, 78 p.
- O'Connor, R. (2004) Ecological Risk Assessment of ACT Water Source Options. Report to ACTEW Corporation Ltd, from a workshop held at the University of Canberra on September 14, 2004. CRC for Freshwater Ecology.
- O'Connor, R. and Kotlash, A. Assessing and monitoring aquatic biodiversity: what have we learnt? Management guide/ Technical report, CRC for Freshwater Ecology. <http://freshwater.canberra.edu.au>.
- Ogden, R., Davies, P., Rennie, B., Mugodo, J. and Cottingham, P. (2004). Review of the 1999 ACT Environmental Flow Guidelines. CRC Freshwater Ecology report to Environment ACT.
- Peat, M. and Norris, R.H. (2004) The biological condition of the Cotter River during a drought flow regime. CRC Freshwater Ecology report to ACTEW Corporation Ltd.
- Peat, M. and Norris, R.H. (2005) The effect of low flow variation on periphyton downstream of dams on the Cotter River. CRC Freshwater Ecology report to ACTEW Corporation Ltd.
- Peat, M. and Norris, R.H. (2005) The biological condition of the Cotter River during the current drought. CRC Freshwater Ecology report to ACTEW Corporation Ltd.
- Peat, M. and Norris, R. (2005) Stream health in the ACT Forests Estate: the effects of fire and post-fire management. CRC Freshwater Ecology report to ACT Forests.
- Peat, M. and Norris, R. (2005) Potential ecological effects of releasing treated water for environmental flows into the Queanbeyan River: review and study design. CRC Freshwater Ecology report to ACTEW Corporation Ltd.
- Peat, M. and Norris, R. (2005) Investigation of nitrogen and ammonia requirements for the Perisher Valley Sewage Treatment Plant to improve aquatic ecosystem protection. CRC for Freshwater Ecology report to NSW Department of the Environment and Conservation.
- Peat, M. and Norris, R. (2004) A review of ACT Forests water monitoring 1996–2004. CRC for Freshwater Ecology report to ACT Forests.
- Peat, M., Lemann, C. and Norris, R. (2004) ACT Water quality monitoring program macroinvertebrate component. CRC for Freshwater Ecology report to Environment ACT.
- Scott, A. (in press) Historical evidence of native fish in the Murray-Darling Basin at the time of European settlement, from the diaries of the first explorers. Technical report, CRC for Freshwater Ecology.
- Scott, A. (in review) Recent advances in predicting ecology–flow relationships: outcomes of CRCFE research. CRCFE.
- Tingle, F. and Norris, R. (2005) Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW. Report for sampling period May 2005. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service.
- Tingle, F. and Norris, R. (2005) Biological monitoring of the Thredbo River. May 2005. CRC for Freshwater Ecology report to Kosciuszko Thredbo Pty Ltd.
- Tingle, F., Peat, M. and Norris, R.H. (2005) Determination of the effects of Perisher carpark on the water quality and biological integrity of Perisher Creek. Interim report for February to April 2005. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service.
- Tingle, F. and Norris, R. (2005) Biological monitoring of the Thredbo River. April 2005. CRC for Freshwater Ecology report to Kosciuszko Thredbo Pty Ltd.
- Tingle, F. and Norris, R. (2005) Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW. Report for sampling period February 2005. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service.
- Tingle, F. and Norris, R. (2005) Biological monitoring of the Thredbo River. February 2005. CRCFE report to Kosciuszko Thredbo Pty Ltd.
- Tingle, F., Lemann, C. and Norris, R.H. (2005) Determination of the effects of Perisher carpark on the water quality and biological integrity of Perisher Creek. Interim report for November 2004 to January 2005. CRC for Freshwater Ecology report to NSW National Parks and Wildlife Service.
- Walsh, C.J., Leonard, A.W., Ladson, A.R. and Fletcher, T.D. (2004) Urban Stormwater and the Ecology of Streams. CRC for Freshwater Ecology, Canberra, 44 p.
- Webb, J.A., (2004) Maribyrnong and Werribee catchments water quality trend analysis. Water Studies Centre, Monash University, Melbourne.
- Webb, J.A., Hart, B.T., (2004) Environmental Risks from Salinity Increases in the Goulburn-Broken Catchment. Water Studies Centre, Monash University, Melbourne.
- Webb, A., Bond, N., Mac Nally, R., Quinn, G., Wealands, S., Vesk, P. and Spring, D. (2005) Rivers in landscapes: heuristic models linking ecological responses and large scale drivers. CRC for Freshwater Ecology, Melbourne.
- Williams, D. and Roberts, J. (2005) Riparian vegetation diversity in the Sydney Catchment Authority's area of operation. Technical report, CRC for Freshwater Ecology. <http://freshwater.canberra.edu.au>.

Software

- Mugodo, J. (2005) Multiple lines and levels of evidence software, with MLLE Manual and Software User Guide.

Papers in conference proceedings

- Adams, J.C. and Tyson, D.R. (2005). Local knowledge of the Narran Lakes: oral history as a line of evidence in ecological understanding. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 28–33.
- Anderson, B., Reich, P., Lake, P.S., Rutherford, I., Quinn, G. and Stewardson, M. (2005) The riparian rehabilitation experiment: evolution of a practical methodology. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 40–46.
- Arthington, A.H., Lorenzen, K., Pusey, B.J., Abell, R., Halls, A., Winemiller, K.O., Arrington, D.A. and Baran, E. (2004) River fisheries: ecological basis for management and conservation. In: Welcomme, R.L. and Petr, T. (eds) Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining Livelihoods and Biodiversity in the New Millennium, Volume I. Food and Agriculture Organization of the United Nations and Mekong River Commission pp. 21–60.
- Arthington, A.H., Tharme, R., Brizga, S.O., Pusey, B.J. and Kennard, M.J. (2004) Environmental flow assessment with emphasis on holistic methodologies. In: Welcomme, R.L. and Petr, T. (eds) Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries: Sustaining Livelihoods and Biodiversity in the New Millennium, Volume II. Food and Agriculture Organization of the United Nations and Mekong River Commission, pp. 37–65.
- Balcombe, S.R. and Bunn, S.E. (2005) The trophic basis of fish assemblages in a dryland river. Proceedings of the Fisheries Ecosystem Symposium, Australian Society for Fish Biology, Adelaide, September 2004.
- Bond, N. and Lake, P.S. (2005) Disturbance regimes and stream restoration: the importance of restoring refugia. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp.90–94.
- Cornforth, R., Rees, G., Croome, R. and Baldwin, D. (2004) Bacterial abundance and extracellular enzyme activity in the surface microlayer of Normans Lagoon, near Albury, New South Wales. Environmental Engineering Research Event 2004, Environmental Change: Make It Happen. University of Wollongong Press, pp. 145–151.
- Jones, G. (2005) Integration: not seeing the forest for the trees? Keynote Address at Integration Symposium, hosted by Land and Water Australia, September 2004. On CD, from Land and Water Australia.
- King, E.L. and Webb, J.A. (2005) Temporal changes in urban stream macroinvertebrate assemblages: a Bayesian hierarchical approach to analysing sparse monitoring data. MODSIM 05, Melbourne.
- Koehn, J.D. and Nicol, S.J. (2004) A strategy to rehabilitate native fish in the Murray-Darling Basin, south-eastern Australia. In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme, R. and Petre, T. (eds.) FAO regional Office for Asia and the Pacific, Bangkok, Thailand, RAP Publication 2004/16, pp 141–149.
- Koehn, J., Stuart, I. and Crook, D. (2004) Linking the ecological importance of downstream fish movements to management of Murray-Darling Basin fish populations. In: Lintermans, M. and Phillips, B. (eds) Downstream Movement of Fish in the Murray-Darling Basin. Workshop held in Canberra, 3–4 June 2003. Murray-Darling Basin Commission, Canberra, pp. 67–78.
- Ladson, A.R., Walsh, C.J. and Fletcher, T.D. (2005) Improving stream health in urban areas by reducing runoff frequency from impervious surfaces. In: Proceedings of the 29th Hydrology and Water Resources Symposium (on CD). Engineers Australia, Canberra.
- Ladson, A.R., Walsh, C.J., Fletcher, T.D., Cornish, S. and Horton, P. (2004) Improving stream health by reducing the connection between impervious surfaces and waterways. 3rd National Conference on Water Sensitive Urban Design. Adelaide, South Australia, 21–25 November 2004 (on CD). Engineers Australia and the Australian Water Association.
- Lintermans, M. (2005) Dealing with sand in the Murrumbidgee River: Can you recreate and maintain deepwater habitats in sediment-impacted large rivers? In: Lintermans, M., Cottingham, P. and O'Connor, R. (eds) Fish Habitat Rehabilitation and Management in the Murray-Darling Basin. Statement, recommendations and supporting papers from a workshop held in Albury, 10–11 February 2004. Murray-Darling Basin Commission and CRC for Freshwater Ecology. Canberra.
- Lintermans, M. (2005) Summary of management policies and fisheries regulations for Murray cod in the Murray-Darling Basin. Pp 64–69 In: Lintermans, M. and Phillips, B. (eds) 2005. Management of Murray Cod in the Murray-Darling Basin. Statement, recommendations and supporting papers from a workshop held in Canberra, 3–4 June 2004. Murray-Darling Basin Commission, Canberra, pp. 64–69.
- Lintermans, M. and Rowland, S.J. (2005) Murray cod information sheet. In: Lintermans, M. and Phillips, B. (eds) Management of Murray Cod in the Murray-Darling Basin — Workshop Held in Canberra, 3–4 June 2004: Statement, Recommendations and Supporting Papers. Murray-Darling Basin Commission, Canberra, pp 123–125.
- Lintermans, M., Robinson, W. and Harris, J. (2005) Identifying the health of fish communities in the Murray-Darling Basin: the Sustainable Rivers Audit. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 363–368.
- Lintermans, M., Rowland, S.J., Koehn, J., Butler, G., Simpson, R. and Wooden, I. (2005) The status, threats and management of freshwater cod species in Australia. In: Lintermans, M. and Phillips, B. (eds) 2005. Management of Murray Cod in the Murray-Darling Basin-workshop held in Canberra, 3–4 June 2004: Statement, recommendations and supporting papers. Murray-Darling Basin Commission, Canberra, pp 15–29.
- Marsh, N.A., Bunn, S. and Rutherford, J.C. (2005) Restoring water temperature regimes of small streams with riparian revegetation. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 403–409.

- Marsh, N., Kennard, M., Stewardson, M. and Arthington, A. (2005) Using the River Analysis Package to quantify the effect of flow change on in-stream habitat availability. Engineers Australia. 29th Hydrology and Water Resources Symposium. 21–23 February 2005, Canberra.
- Marsh, N.A., Rutherford, I. and Bunn, S. (2005) Suspended sediment yield following riparian revegetation in a small southeast Queensland stream. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 410–414.
- Murray, O., Rayburg, S., Thoms, M.C. and Neave, M. (2005) Variations of wetland patch characteristics under different inundation levels using remotely sensed data: preliminary results from the Narran Lakes, NSW. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 439–444.
- Nichols, S., Barlow, A., Norris, R., Gray, B. and Evans, L. (2004) AUSRIVAS online: bringing education, research and the water industry together. Conference proceedings for AWA's Education: The Key to Sustainable Water Management — Going Beyond Conversation, 28–29 January 2004, Canberra, pp. 131–139.
- Norris, R., Liston, P., Mugodo, J., Nicols, S., Quinn, G., Cottingham, P., Metzeling, L., Perriss, S., Robinson, D., Tiller, D. and Wilson, G. (2004) Multiple lines and levels of evidence for detecting ecological responses to management interventions. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania.
- Pusey, B.J., Arthington, A.H. & Kennard, M.J. (2004) Hydrologic regime and its influence on broad-scale patterns of fish biodiversity in north-eastern Australian rivers. Proceedings of the 5th International Symposium on Ecohydraulics, Madrid, Spain, 12–17 September 2004.
- Pusey, B.J., Arthington, A.H. and Kennard, M.J. (2005) Threats to freshwater fishes of the wet tropics region. Proceedings of the Ozwater 2005 Watershed Symposium, Townsville, May 2005.
- Rayburg, S., Neave, M., Thoms, M.C. and Mesley, E. (2005). A preliminary investigation into the influence of changing stream network patterns on the distribution of water in the Narran Lakes ecosystem. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 509–515.
- Southwell, M.R., Thoms, M.C., Foster, J.M. and Lenon, E. (2004) Geomorphic variation and the accumulation of organic matter: the Barwon-Darling, Australia. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania.
- Thoms, M.C. and Dyer, F.D. (2004) Hydraulic diversity in a regulated river. Proceedings of the Fifth International Symposium on Ecohydraulics: Aquatic Habitats: Analysis and Restoration, Madrid, Spain, pp. 1289–1293.
- Webb, J.A., Bond, N.R., Wealands, S.R., Mac Nally, R., Grace, M.R. and Quinn, G.P. (2005) Bayesian classification of catchments using spatial data: a first step to improved modelling of catchment effects on stream ecological condition. MODSIM 05, Melbourne.
- Woods, M., Rainger, M. and Thoms, M.C. (2004) Limitations for improving flow regimes when planning at the sub-catchment scale — an example from the Barwon-Darling river system, NSW. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 704–709.
- Woods, M., Rainger, M. and Thoms, M.C. (2004) Limitations for improving flow regimes when planning at the sub-catchment scale — an example from the Barwon-Darling river system, NSW. In: Rutherford, I.D., Wiszniewski, I., Askey-Doran, M. and Glazik, R. (eds) Proceedings of the 4th Australian Stream Management Conference, 19–22 October 2004, Launceston, Tasmania, pp. 704–709.
- Bond, N. (2004) Overview of research in the Granite Creeks project. Wood in Streams Symposium, Monash University Churchill Campus, September 2004.
- Brock, M.A. and Miller, W. (2004) Persistence of seed banks in Australian temporary wetlands: a clue to wetlands resilience. 7th International INTECOL Wetlands Conference, Utrecht, Netherlands, July 2004.
- Brock, M.A. and Miller, W. (2004) Persistence of seed banks in Australian temporary wetlands: a clue to wetlands resilience. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Bunn, S.E. (2004) Distinguished Lecture Series, Department of Natural Resources & Mines, Brisbane, June 2004.
- Bunn, S.E. (2004) Food webs in floodplain river ecosystems. Queensland Department of Primary Industries and Fisheries, Deception Bay, July 2004.
- Bunn, S.E. (2004) Freshwater issues in South East Qld. Citizens Senate, South East Queensland NRM Group, Brisbane, November 2004.
- Bunn, S.E. (2004) Restoring ecological processes and ecosystem health in Australian streams and rivers. 2nd International Symposium on Riverine Landscapes, Bredsel, Sweden, 16 August 2004.
- Bunn, S.E. (2004) River ecosystem health. Environmental Engineering Society, Queensland. Brisbane, September 2004.
- Bunn, S.E., Balcombe, S., Fellows, C.S. and McKenzie-Smith, F. (2005) Influence of flow regime on the food web of a dryland river system. 53rd Annual Meeting, North American Benthological Society, New Orleans, USA, June 2005.
- Cook, B. (2004) at Second International Symposium on Riverine Landscapes, Sweden, August 2004.

Presentations by CRCFE staff

- Adams, J. and Tyson, D. (2004) Local knowledge as a line of evidence in understanding dryland aquatic ecosystems. (Poster) Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Aldridge, K., Brookes, J. and Ganf, G. (2004) Phosphorous retention in streams; influences of carbon and phosphorus stoichiometry. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Balcombe, S.R., Fawcett, J., Wright, A and Bunn, S.E. (2004) Floodplain use by the fish assemblages of an arid zone Australian river. Australian Society for Fish Biology Annual Conference, Glenelg, SA, September 2004.
- Bond, N. (2004) Granite creeks work, talk and poster at Second International Symposium on Riverine Landscapes, Sweden, August 2004.
- Bond, N. (2004) Habitat restoration in degraded rural streams: the granite creeks project. Healthy Rivers, Healthy Communities conference, the University of Melbourne at Dookie, Victoria, 9 December.

- Ebner, B., Thiem, J., Gilligan, D., Wooden, I. and Lintermans, M. (2005) Surveying a fish community in the Murrumbidgee River — the effect of effort. Australian Society for Fish Biology Conference, Darwin July 13–15, 2005.
- Fellows, C.S., Bunn, S.E., Beard, N.J., Thoms, M.C. and Mesley, E. (2005) Benthic algal production in two dryland rivers. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Fletcher, T. D. and Walsh, C. J. (2005). An overview of MUSIC v3 and its applications for modelling stormwater management to achieve ecosystem health improvement. Stormwater Industry Association of Queensland State Conference, Gold Coast 14–15 April 2005.
- Gawne, B. (2004) 'The Living Murray: A Healthy Working River?' 12th Annual Jonathan Mann Lecture, The Murray and Its People, La Trobe University, 21 October 2004.
- Glaister, A. (2004) The snag bag for sampling wood-dwelling invertebrates. Wood in Streams Symposium, Monash University, Churchill Campus, September 2004.
- Hammer, M.P. and Walker, K.F. (2004) A catalogue of South Australian freshwater fishes as a baseline for management and conservation. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Harbott, E., Grace, M. and Hart, B. (2004) Carbon bioavailability and enzyme: the effect of urbanization. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Hawking, J., Gawne, B and Gigney, H. (2004) Quantifying flow-habitat-biota relationships of macroinvertebrates using different functional patches in the Broken River, Victoria. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Hughes, J. (2004) at Second International Symposium on Riverine Landscapes, Sweden, August 2004.
- Hughes, J., Fawcett, J., Cook, B. and Ponniah, M.(2005) A translocation gives insight into the effects of hybridization between wild populations: implications for understanding the distributions of closely related species. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Humphries, P. (2004) The Campaspe flow manipulation project. Healthy Rivers, Healthy Communities conference, the University of Melbourne at Dookie, Victoria, 9 December.
- Infante, D.M., Allan, J.D., Linke, S. and Norris R.H. (2004) Environmental factors shaping fish and macroinvertebrate assemblages in streams of southeastern Michigan. Annual conference of the North American Benthological Society, Vancouver, 6-10/6/2004 British Columbia, Canada
- Kennard, M.J., Pusey, B.J. and Arthington, A.H. (2005) Ecological trait composition of freshwater fish across gradients of environmental variability in north-eastern Australia. (Invited speaker) Joint meeting of the North American Benthological Society and the American Geophysical Union, New Orleans, Louisiana, USA May 2005.
- Kennard, M.J., Pusey, B.J., Arthington, A.H. and Harch, B.D. (2004) Overview of a program for quantitative assessment of the status of aquatic ecosystems in eastern Australia using fish. 4th International Ecohydraulics Symposium, Madrid Spain, September 2004.
- Kennard, M.J., Pusey, B.J., Marsh, N. and Arthington, A.H. (2004). Modelling relationships between environmental variability and assemblage responses: stability, persistence and resilience of freshwater fish in eastern Australian rivers of contrasting flow and habitat variability (Poster). 4th International Ecohydraulics Symposium, Madrid Spain, September 2004.
- Lake, P.S. (2004) at Second International Symposium on Riverine Landscapes, Sweden, August 2004.
- Lake, P.S., Bond, N., Glaister, A. and Downes, B. (2005) Restoration in sand-slugged streams and drought. Joint meeting of the North American Benthological Society and the American Geophysical Union, New Orleans, Louisiana, USA May 2005.
- Lake, S. (2004) Restoration ecology and looking forward. Healthy Rivers, Healthy Communities conference, the University of Melbourne at Dookie, Victoria, 9 December.
- Lake, S. (2004) The ecology of stream restoration. Keynote Address at the Northern Rivers Conference on Ecological Restoration and Monitoring, Southern Cross University, Lismore, NSW, October 2004.
- Linke, S., Hawkins, C.P. and Norris, R.H. (2004) Rapid assessment of conservation value: the influence of taxonomic resolution. Annual conference of the North American Benthological Society, Vancouver, 6-10/6/2004 British Columbia, Canada
- Linke, S., Bailey, R., Norris, R., Bailey, J. and Bailey, B. (2005) Muddy waters: introducing systematic conservation planning to riverine landscapes. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Marchant, R., Barlow, A. and Norris, R. (2004) The effect of dams on macroinvertebrate recolonisation in the Cotter River. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- McQuire, L., Neave, M. and Rayburg, S. (2004) Assessing agrochemical trends in the Namoi River catchment using an index model. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Mugodo, J., Norris, R., Metzeling, M., Yuan, L., Liston, P., Wilkinson, S., Perriss, S., Robinson, D. and Nichols, S. (2005) Using taxon–environment relationships for defining macroinvertebrate reference communities in disturbed areas. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Nichols, S., Barlow, A., Norris, R. and Gray, B. (2004) AUSRIVAS online: learn to assess river condition. (Poster) Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Nichols, S., Barlow, A., Norris, R. and Rennie, B. (2004) Training to support water resource managers. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Nielsen, D.L. and Brock, M.A. (2004) Impacts of increasing salinity on Australian wetland seed and egg banks. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 Nov – 4 Dec.
- Nielsen, D.L. and Brock, M.A. (2004) Impacts of increasing salinity on Australian wetland seed banks. 7th International INTECOL Wetlands Conference, Utrecht, Netherlands, July 2004.
- Nielsen, D.L. and Brock, M.A. (2004) Predicting the ecological consequences of aquatic salinity. Northern Basin Forum, Murray-Darling Freshwater Research Centre Laboratory, Goondiwindi, November 2004.

- Nielsen, D.L., Brock, M.A., Sim, L., Davis, J. and Chambers, J. (2004) Wetland diversity: the role of climate change and salinity in creating a homogeneous landscape. Limpacs Climate Change Conference, Mildura, September 2004.
- Norris, R. (2004) River health and water quality – where does it come from and where does it matter? Invited Address at the Australian Fertilizer Industry Conference, August 2004, South-east Queensland. See www.fifa.asn.au.
- Norris, R. (2005) Lessons learned from developing Australia's National River Health Program. Invited Address to the USEPA (Washington DC, USA). 20 May.
- Norris, R.H., Liston, P., Linke, S., Mugodo, J., Metzeling, M., Newall, P., Nichols, S., and Wilson, G. (2004) Bioassessment methods minefield: choosing a method. Annual conference of the North American Benthological Society, Vancouver, 6-10/6/2004 British Columbia, Canada
- Norris, R., Liston, P., Mugodo, J. and Nichols, S. (2005) Multiple lines and levels of evidence for detecting ecological responses to management intervention. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Padgham, M. and Walsh, C. J. (2005) A method for adapting ecological distance matrices to asymmetrical autocorrelation within dendritic stream networks. Joint meeting of the North American Benthological Society and American Geophysical Union, New Orleans 23–27 May 2005.
- Page, T. and Hughes, J. (2005) Biological and earth history as revealed by Australian subtropical sand islands. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Page, T., Choy, S. and Hughes, J. (2004) Indistinct freshwater shrimp: genetics and morphology of cryptic species within *Caridina indistincta* and *Caridina mccullochi* (Decapoda: Atyidae) in eastern Australia. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Peat, M. and Norris, R. (2005) Environmental flows: implementing adaptive management with a water utility, government agency and researchers. Riversymposium, Brisbane 6-9 August 2005.
- Perryman, S., Walsh, C. and Rees, G. (2004) Denitrifiers along an urban gradient: they're not that cosmopolitan. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Petrie, R., Nielsen, D.L., Vogel, M. and Brock, M.A. (2005) How long does it take to deplete the egg bank in wetland sediments? Australian Society of Limnology Conference, Adelaide, December 2004.
- Reich, P. (2004) at Second International Symposium on Riverine Landscapes, Sweden, August 2004.
- Reid, M., Thoms, M., Munro, F. and Schmidt, S. (2004) The importance of connectivity between patches in riverine landscapes: an example from the Lower Macintyre River, Murray-Darling Basin. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Rennie, B., Ogden, R., Nichols, S., Barlow, A. and Norris, R. (2004) Courses in Freshwater Ecology for Catchment Management (poster). 4th Australian Stream Management Conference, Launceston, September.
- Ryan, K., Ebner, B. and Norris, N. (2004) Ecological characteristics of the freshwater crayfish *Euastacus crassus* (Decapoda: parastacidae), with observations of reproductive biology and the implications of changes in flow. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Sheldon, F. and Costelloe, J. (2004) Variability and river health in ephemeral streams. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Stewardson, M. and Metzeling, L. (2005) relations between flow regime and invertebrate communities in upland rivers of the Latrobe Basin, Victoria, Australia. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Stoddard, J.L., Larsen, D.P., Hawkins, C.P., Johnson, R.K. and Norris, R.H. (2005) Setting Expectations for the Ecological Condition of Streams: The Concept of Reference Condition. Annual conference of the North American Benthological Society, 22-27/5/2005, New Orleans, Louisiana, USA.
- Tewman, M., Walsh, C. and Tsyrlin, E. Impacts of stormwater treatment wetlands on stream macroinvertebrates: could we be degrading streams to reduce pollutant loads? Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Tewman, M., Walsh, C. and Tsyrlin, E. (2004) Impacts of stormwater treatment wetlands on stream macroinvertebrates: could we be degrading streams to reduce pollutant loads? Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Thiem, J., Ebner, E., Johnston, L. and Broadhurst, B. (2005) Home-range of a large endangered Percichthyid: the effect of temporal resolution Australian Society for Fish Biology Conference, Darwin July 13–15, 2005.
- Thoms, M. (2005) A continua or a series of patches — the downstream morphology of a large dryland river system. 53rd Annual meeting, North American Benthological Society, New Orleans, USA, May 2005.
- Vanderkruk, K., Hart, B. and Grace, M. (2004) Hyporheic nutrient dynamics in Creightons-Branjee Creek, Victoria. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Vogel, M., Nielsen, D.L., Petrie, R. and Brock, M.A. (2004) The impact of saline water on wetland seed germination and aquatic plant growth. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December.
- Wallace, T., Ganf, G. and Brookes, J. (2004) Kinetics and bioavailability of dissolved organic carbon leached from autumn leaf litter and garden waste. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Walsh, C. (2004) Setting objectives for stormwater management to protect stream ecosystems. Stormwater Workshop, Auckland Regional Council, 21–22 October 2004, Auckland, NZ.
- Walsh, C.J. (2004) The costs of not changing the way we manage stormwater. Water the precious drop. Stormwater Industry Association of Victoria Seminar, 3 November 2004.

- Walsh, C.J. and Padgham, M. (2005) An inter-city comparison of macroinvertebrate assemblage response to urban land use in south-eastern Australia. Joint meeting of the North American Benthological Society and American Geophysical Union, New Orleans 23–27 May 2005.
- Webb, J.A. (2004) Incorporation of uncertainty into the outputs of probabilistic risk assessment: what do we know about what we don't know? Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- William, J., Baldwin, D., Rees, G. and Watson, G. (2004) Microbial diversity in a stream impacted by sand slug — effects of 'rehabilitation'. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Wilson, G., White, M., Khan, T. and Khan, M. (2004) Fish community structure across a floodplain terminal wetland system: the Narran Lakes, north-west NSW. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.
- Wright, A., Balcombe, S., Fawcett, J. and Bunn, S. (2004) Floodplain use by the fish assemblages of Cooper Creek, Lake Eyre Basin, Australia. Australian Society for Limnology, 43rd Annual Congress, Adelaide 29 November – 4 December 2004.