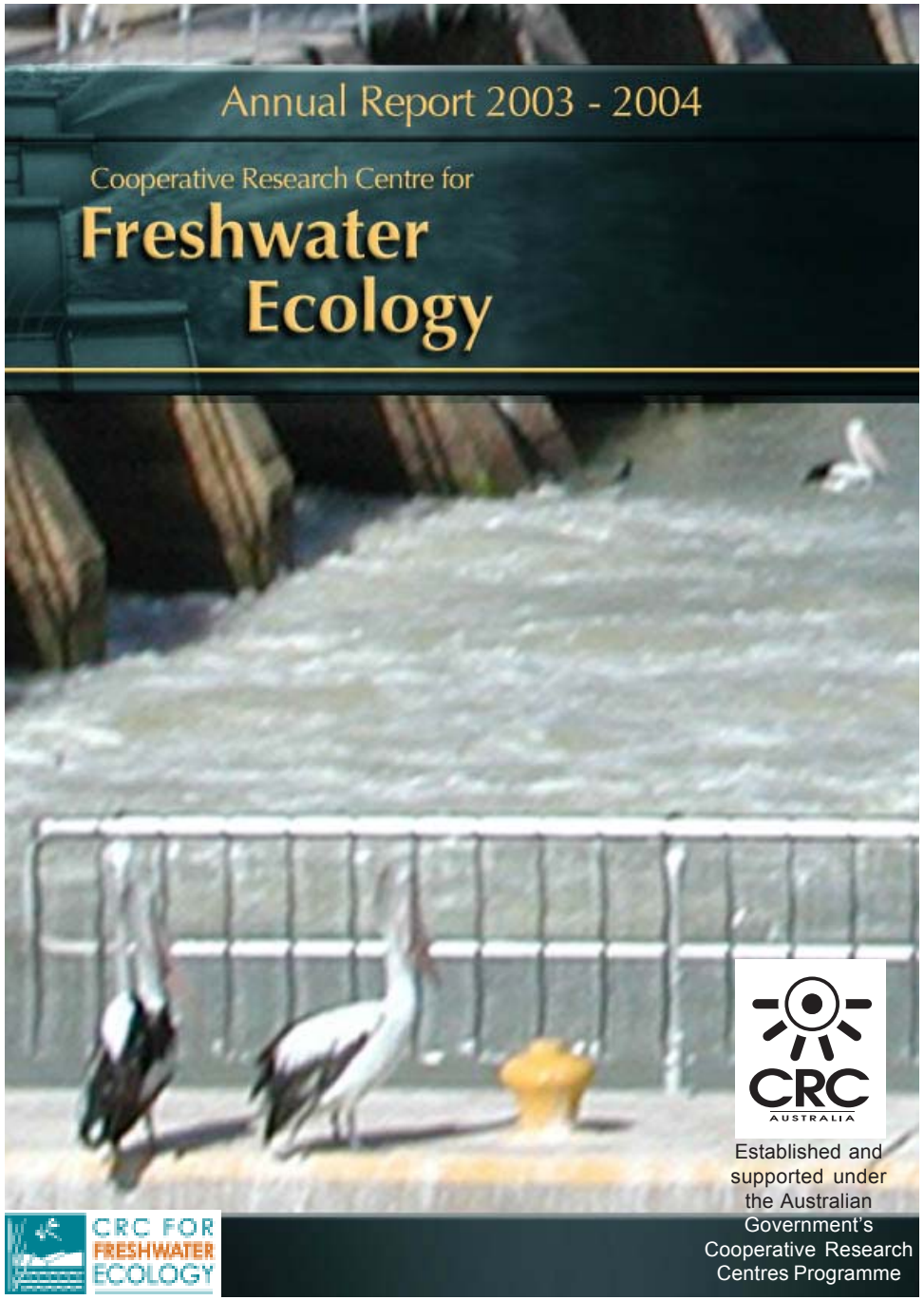


Contents

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, Mines and Energy, Queensland

Department of Sustainability and Environment, Victoria

Department of Water, Land and Biodiversity Conservation, South Australia

Environment ACT

Environment Protection Authority, NSW

Environment Protection Authority, Victoria

Goulburn-Murray Rural Water Authority

Griffith University

La Trobe University

Lower Murray Water

Melbourne Water

Monash University

Murray-Darling Basin Commission

Sunraysia Rural Water Authority

Sydney Catchment Authority

University of Adelaide

University of Canberra

Foreword

In the Australian water industry, the twelve months July 2003–June 2004 will be largely remembered for the government decisions on national water reform that they contained.

First, the Council of Australian Governments (CoAG) agreed in principle to a national water initiative (NWI), and announced that agreement on 29 August 2003. One of the five key tenets of the NWI is the integrated management of environmental water, including environmental flows that should allow more water to remain in regulated river systems. Then the Murray-Darling Basin Ministerial Council met in October and announced a historic first-step decision to progressively reclaim environmental water for the River Murray, until it averaged an extra 500 gigalitres per year by around 2009. Finally, at the end of June 2004, CoAG met again and set out its formal agreement to a program of national water reform. The agreement endorsed the two previous announcements — the NWI and the first step decision for the River Murray — but also reassured water-dependent landholders that they would have permanent water access rights and not have to bear the full cost of recovering water for the environment.

If it were not for scientific information provided by a number of research groups but particularly the CRC for Freshwater Ecology (CRCFE) continuously since 1993, it is conceivable that these three announcements would have had different forms and emphases, or might not have existed at all.

The CRCFE led the Scientific Reference Panel which assessed all available data and concluded, this financial year, that habitats in the eastern Australian Murray river-system would be likely to benefit if designated reference volumes of environmental water were to be made available to the rivers. This huge undertaking by the CRCFE has been preceded by years of scientific guidance, initially from the Murray-Darling Freshwater Research Centre (MDFRC) before CRCFE was created, and more recently by joint studies with other institutions. For example, there was the CRCFE-based expert reference panel on environmental flows and water quality requirements for the River Murray in 2002; and the Assessment of River Condition made for the National Land and Water Resources Audit by CRCFE and CSIRO, for agricultural areas in all states of Australia in 2000–2001. Before those, there have been numerous expert panels and other studies assessing flow requirements for rivers in Queensland, NSW, Victoria and South Australia, as well as a relatively recent assessment for the Daly River in Northern Territory.

Partners and staff of the CRCFE can feel proud to be part of an effective and respected team that has continued working together across state and institutional boundaries for eleven years, to help solve national water issues.

Water issues have been under scrutiny also in the states during 2003–2004, with the state governments in Victoria and NSW both recently releasing plans and policies for securing a sustainable water future. Again, aspects of the CRCFE's work have contributed to these announcements, not least because the state agencies most involved sit on the CRCFE Board.

This year, the CRCFE and CRC for Catchment Hydrology have been simultaneously preparing for a rebid, to obtain funding after June 2006. The two CRCs have increasingly collaborated over the years, to assist managers of large river systems who have needed both hydrologic and ecological knowledge. The two Boards, which have many partners in common, discussed the possibility of creating one new CRC in place of the two. This idea became a firm proposal once the guidelines for Funding Round 9 of the Australian Government CRC Programme were released, requiring public-good CRCs to develop a more-commercial focus. Selection of the proposed eWater CRC to submit a full business plan, in a tough funding environment, has vindicated the Boards' move.

The rebid process has turned CRCFE's thoughts firmly to the completion of this CRC's research efforts on behalf of water managers. It was interesting for the Board to attend the Annual General Meeting in November 2003 with many of the CRC staff. All the research groups described 'what we know now that we did not know five years ago', and the progress is pleasing. The findings have come largely from the first phase core projects that wound up in July–September 2003. They have yet to be augmented by the out-

comes of the final three years' research projects, which began in July 2003. While some teams are moving to new research themes, such as aquatic aliens, others are tying-up research threads left hanging from the completed projects.

2003–2004 has produced major changes for the MDFRC laboratories. The Northern Basin Laboratory at Goondiwindi moved into larger premises on 27 August, allowing the staff there to more than double in number. The Lower Basin Laboratory at Mildura moved into new purpose-built premises on 21 November. The lab is now on the La Trobe University campus and nearer to the Sunraysia Institute of TAFE, which can only benefit the interaction between tertiary students and freshwater research in that area. The headquarters of the MDFRC at Albury-Wodonga, is also to move, in February 2005, onto the local La Trobe University campus in Wodonga, after several years on the Charles Sturt University campus in Albury.

At the start of January 2004, we welcomed a new core participant to the CRCFE — the Department of Water, Land and Biodiversity Conservation, South Australia. The Department is contributing a new knowledge broker to be based in Adelaide, rounding out an already well-placed knowledge exchange team working to ensure adoption of the CRCFE's research findings.

The CRCFE is working hard to complete its research programs, delivering on its vision and maintaining its reputation as a highly successful CRC. Outcomes of all areas of work in CRCFE are exciting and proving useful for managers at regional, state and national scales, and software, advice and guidelines are being readily adopted. My thanks go to Gary Jones, his program leaders, the members of the Program Advisory Committees, and my fellow members of the Board for their strong leadership through a year that has been extremely busy and diverse.

We wish the eWater CRC all the best in the coming selection process, and a bright future thereafter.

Dr John Langford

Chairman of the Board
CRC for Freshwater Ecology

Chief Executive's overview

This has certainly been a very full year for the CRC for Freshwater Ecology, both operationally and strategically.

In November, our long period of hard work on the Living Murray Initiative culminated in an agreement by the Murray-Darling Basin Ministerial Council to make a 'first-step' allocation of environmental flows to the River Murray of 500 GL. This was a major outcome from CRCFE research and knowledge exchange activities on environmental flows going back over almost a decade. It should remind us how research organisations need to be 'in for the long haul' if they really want to see the best science incorporated into public policy decision-making. Shouting loudly from the wings from time to time may bring a warm feeling for some, but public trust and confidence in science and scientists is best built on long-term relationships, a commitment by all to the highest quality possible in scientific investigation, and adoption of uncompromising professional standards.

Nevertheless, we were at times in the firing line of one or two strong vested interests and their lobbyists. I am proud to say our team of scientists and knowledge brokers maintained the highest scientific and ethical standards throughout. I have no doubt that the independent international reviewers of the interim CRCFE (Scientific Reference Panel) report got it right when they said:

> [the report] ...represents a major first achievement in the integration of science within large-scale water resource management in Australia, [is] …providing sound scientific advice to the MDBC and Ministerial Council, and [provides a] …high degree of scientific honesty and integrity.

In October, we commenced our Phase 2 research projects that will run through until the end of the CRCFE. Planning for the new projects has involved extensive consultation with our industry partners to ensure that we remain well aligned with the ecological knowledge requirements of eastern Australia's urban and inland water managers. The National Water Initiative has provided an even greater imperative for the work we are doing on environmental flows allocations and monitoring, river restoration, managing the impacts of salinity on river and wetland biodiversity, conservation of biodiversity in arid zone rivers, management of urban streams, and new evidence-based methods for river health assessment.

In September 2003, the Board approved several new research and knowledge exchange initiatives: (i) scoping studies in river–landscape interactions and potential long-term impacts of the drought–fire–flood cycle; (ii) development of collaborative linkages with the cotton and rice industries; (iii) seed funding for a community-focused project in the northern Murray-Darling to be based at MDFRC's Goondiwindi laboratory; (iv) project supplementation to address areas of research identified in the National Water Initiative; (v) new collaborative writing-up scholarships for students, and (vi) the development of a business outline for modular training courses in river management. Also included was funding for an evaluation of the education program, and a teams-effectiveness analysis across the CRCFE.

Prior to the new research projects commencing, the Board took what I believe was an outstanding decision to fund a three-month writing-up period for our research scientists. While some might say that writing up scientific papers should be included as part of the normal project completion process, the reality is that the need to start planning for the next round of projects inevitably takes priority over writing papers. With the level of scrutiny that our science is being increasingly subjected to, the quality assurance that publication in international peer-reviewed journals brings to our work cannot be understated. The writing-up period was a great success with almost 60 research papers being completed for publication.

This year, re-bidding CRCs were set the responsibility of organising their own independent Year-5 review process. The CRCFE review panel was established consisting of two members from the second year review — Professor Ian Rae and Assoc. Professor Jenny Davis — plus Mr David Dole. The review was carried out over two-and-a-half days in June. The reviewers' report was very positive, highlighting the high quality of research, education and knowledge exchange activities. The reviewers noted:

> The CRC has performed well against the milestones set out in the program for achievement at year 3 and has made substantial progress against those for the longer term, 5–7 years. ... The management team and the Board are to be complimented on th[eir] holistic approach which makes the best use of the skills of the researchers in providing useful data for the industry partners.... It is our judgment that the CRC, through its research and investigation and consequent ability to provide advice to the industry partners, has made significant improvements to improving the condition of Australia's inland waters…. The CRC has adapted to the needs of the community and their partner organizations so that their overall approach reflects social, economic and ecological values…. They have achieved this holistic position without relinquishing their great strengths in research. … The CRC's postgraduate program is extremely well managed with students guided to set targets for their research and to report on them regularly. … The Knowledge Exchange program, first developed by CRCFE MkI, has gone from strength to strength and development of such a program has been emulated by a number of other organizations.

Even with the very best research, CRCs cannot be successful without effective transfer of knowledge to their industry partners. In the past year we have boosted communications with partners to provide them with greater influence over knowledge exchange outputs. Processes for partner communication have been embedded within each of our knowledge exchange projects to ensure that they fulfil our partners' present business needs. Project scoping is performed through forums (Flows & Restoration, Biodiversity), focus groups and steering committees (comprising members of the Program Advisory Committees and other useful contributors identified by brokers), questionnaires and one-on-one conversations between partners and brokers. Knowledge exchange is also informed by more informal processes for obtaining partner input through regular meetings between partner staff and the CRCFE executive or knowledge brokers. These activities have been ramped up over the past year, and have led to even better connections with a number of partners. Our knowledge brokers have also been active in the last year in the facilitation of workshops for partners (such as the Fish Rehabilitation workshop for the MDBC, and Drought Flows Advisory workshops for ACTEW and Environment ACT), which give them useful insights into the latest business drivers.

Three new 'Research Highlights' have been circulated to partners during 2003–2004, outlining significant findings in our research-in-progress. Feedback from the Board on this initiative has been very positive.

The CRCFE organised two successful international conferences this year — the Ninth International Conference on River Research & Applications in Albury, and the Symposium on Urbanization and Stream Ecology in Melbourne. These were good opportunities for our university and industry partners to be informed of the latest international research findings in the management of urban and inland rivers. I thank the respective conference organisers, Martin Thoms (University of Canberra) and Chris Walsh (Monash University), for their outstanding efforts in showcasing CRCFE research to the national and international audiences.

On the 'people' front, Professor Stuart Bunn (Griffith University) was appointed as the CRCFE's Director of Research, a position that I had been managing in the 15 months or so since Barry Hart 'retired' from the position. I am very pleased to have Stuart join us in this role, building on his excellent work over the past 5 years as program leader. With Stuart's move came the appointment of Dr Nick Bond (Monash University) as Stuart's replacement as Program B Leader. Professor Jane Hughes (Griffith University) has been acting Education Program Leader during the year while Dr Debbie Heck was on study leave.

Again this year our staff and associates have received a number of awards and honours. Anthony Scott, Bronwyn Rennie and Sarah Cartwright (MDBC) received the 2003 CRCFE Chairman's Award for Excellence for their outstanding work in coordinating the application of MFAT and the Scientific Reference Panel on environmental flows for the Living Murray process. Bill Maher received a very rare honour — a second medal from the Royal Australian Chemical Institute, this time in recognition of his outstanding work in promoting environmental chemistry. Ben Gawne (MDFRC) received the 2003 Australian Society for Limnology Early Career Excellence Award. Daryl Nielsen and Gavin Rees (both of MDFRC Albury) were the inaugural winners of the CSIRO Land & Water Chief's Award, for their work in lifting the profile of salinity research within Australia. CSIRO Achievement Awards also went to Helen Missen and Anthony Conallin, for their outstanding contributions at the MDFRC Mildura lab. In June, we congratulated Professor Peter Cullen, our former Director, who was awarded an Order of Australia in the Queen's Birthday Honours listings, for service to freshwater ecology. Jane Doolan, our Board member from DSE Victoria, won the inaugural Victorian DSE International Women's Day Award for Innovation.

The CRCFE's students have also excelled: Michael Hammer (University of Adelaide), received the River Murray Catchment Water Management Board's Open Literary Award, Trish Bowen (University of Canberra, based at MDFRC Albury) won the Sydney Catchment Authority Best Student Presentation at the Ninth International Conference on River Research & Applications, and Heath Chester and Claire Sellens, respectively, won the 'Best Honours Paper' and the 'Best Poster' at the December ASL/NZLS congress at Warrnambool. And visiting PhD student, Anne Baums, won the Young Women in Science Excellence Award for her presentation at MODSIM 2003, the biennial congress of the Modelling and Simulation Society of Australia and New Zealand. Congratulations to all for your outstanding achievements!

As noted by CRCFE Chairman, John Langford, much work and thinking has been directed at our bid for a new CRC. The scope of the original rebid task envisaged 12 months ago was expanded by our partners' decision in mid-December 2003 to replace the existing CRCs for Freshwater Ecology and Catchment Hydrology (CRCCH) by a single new eWater CRC bid. This is seen as desirable to provide a fully integrated 'whole of water cycle' approach to our R&D, and support implementation of the CoAG National Water Initiative. Showing their long-term commitment to our shared objectives and performance, all existing partners from both CRCs have signed on as participants for eWater. As well, several new partners have joined with us to provide a powerful alliance of scientific and management expertise. We have worked hard to provide a vision and process for the eWater business case that meets the needs of our water-industry partners, while addressing the key requirement from Minister McGauran that CRCs must provide significant commercial outcomes for Australian businesses.

As you can see, it has been a year both of consolidation and of new initiatives and planning for the future for the CRC for Freshwater Ecology. I thank all our researchers, knowledge brokers, industry personnel and support staff for the great job they have done through the year. I am looking forward to an exciting future, and will be doing everything I can to get a successful outcome for the eWater CRC bid.

Gary Jones
Chief Executive

Winners of the Chairman's Award for 2003: Anthony Scott, Bronwyn Rennie and Sarah Cartwright, with Professor Gary Jones

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, and has just completed its fifth year.

In January 2004 a new partner, the Department of Water, Land and Biodiversity Conservation, South Australia, joined the CRCFE, so the Centre is now an unincorporated joint venture between 20 partners:

- ACT Government
- ACTEW Corporation
- CSIRO Land and Water
- Department of Environment and Conservation (DEC)
- Department of Infrastructure, Planning and Natural Resources, New South Wales (DIPNR)
- Department of Natural Resources, Mines and Energy, Queensland (QNRME)
- Department of Sustainability and Environment, Victoria (DSE)
- Department of Water, Land and Biodiversity Conservation, South Australia (DWLBC)
- Environment Protection Authority, Victoria (EPAV)
- Goulburn-Murray Rural Water Authority
- Griffith University
- La Trobe University
- Lower Murray Water
- Melbourne Water
- Monash University
- Murray-Darling Basin Commission (MDBC)
- Sydney Catchment Authority (SCA)
- Sunraysia Rural Water Authority
- University of Adelaide
- University of Canberra.

CRCFE Board and committees

The CRCFE is governed by a Board comprising the following members at 30 June 2004:

Chair: Dr John Langford (University of Melbourne)

Dr Jane Doolan (DSE, VIC)

Dr Kath Bowmer (CSIRO Land & Water)

Dr Maxine Cooper (Environment ACT)

Dr Ruth Foxwell (University of Canberra)

Mr Barrie Turner (SCA)

Mr Bruce Cooper (DIPNR, NSW)

Mr Don Blackmore (MDBC)

Mr Grant Wilson (Melbourne Water)

Mr Lamond Graham (DNRME, QLD)

Prof. Nancy Millis (Independent)

Prof. Rob Norris (Monash University)

Prof. Roger Braddock (Griffith University).

The Board meets quarterly.

The Finance Committee and the Research Committee continued to operate during 2003–2004. The Finance Committee oversees the CRCFE's finances and makes recommendations to the Board. It meets once a quarter. The Research Committee oversees the research undertaken and provides input into the new research program development.

Finance Committee

Chair: Dr 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 (QNRME)

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), carries executive responsibility for managing the CRCFE within the policy framework established by the Board. He is supported by the **Senior Management Team**, which consists 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.

The research staff of the CRCFE are almost all provided by the five university partners (Adelaide, Canberra, Griffith, La Trobe, Monash) at labs in Adelaide, Canberra, Brisbane, Albury and Melbourne. Other research staff are provided by 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 may work 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 — is led by Assoc. Professor Gerry Quinn (Monash University, Melbourne).

Research Program B — ecology of river (and wetland) restoration — is now led by Dr Nick Bond (Monash University), in place of Professor Stuart Bunn.

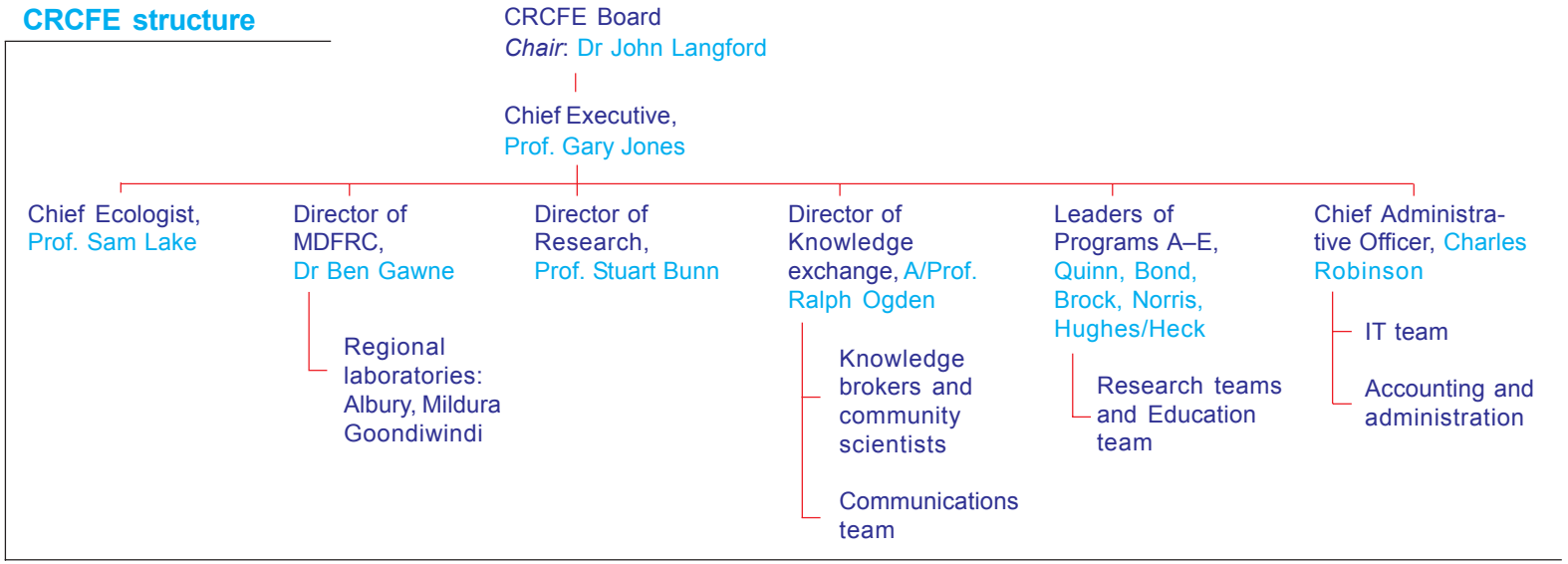
Research Program C — conservation ecology and aquatic biodiversity — is led by Dr Margaret Brock (DIPNR, Armidale).

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

The education and training program (*Program E*) is led by Professor Jane Hughes (Dr Debbie Heck being on study leave), assisted by Ms Linda Brennan (all at Griffith University).

Knowledge exchange (Director: Assoc. Professor Ralph Ogden) involves researchers as well as a team of knowledge brokers and community scientists.

CRCFE structure



Program Advisory Committees

Program Advisory Committees (PACs), one for each research program, allow representatives of public industry partners to oversee the CRCFE's research programs, strengthening the links between industry needs and CRCFE research. The PACs met in November 2003 to review the just completed research portfolio from CRCFE II phase 1, and discuss the new projects just beginning for phase 2.

Program A Advisory Committee

Jane Doolan (DSE)
Tony Paull (SCA)
Gerry Quinn (Program Leader)
Tom Vanderbyl (QNRME)
Paul Wettin (DIPNR)

Program B Advisory Committee

John Amprimo (QNRME)
Nick Bond (Program Leader)
Peter Donnelly (Environment ACT)
Kate Lenertz (SCA)
Graham Rooney (Melbourne Water)
Tony Roper (DIPNR)
Scott Seymour (Melbourne Water)
Wayne Tennant (Goulburn-Broken CMA)

Program C Advisory Committee

Margaret Brock (Program Leader)
Martin Krogh (SCA)
Neal Foster (DIPNR)
Julia Reed (DSE)
David Shorthouse (Environment ACT)

Program D Advisory Committee

Gary Bickford (MDBC)
Brian Bycroft (QNRME)
Bruce Cooper (DIPNR)
Amir Deen (SCA)
Lisa Dixon (EPAV)
Peter Donnelly (Environment ACT)
Richard Norris (Program Leader)
Graham Rooney (Melbourne Water)

2. Research

Research in the CRCFE's portfolio addresses 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 integrates expertise from several of the CRCFE's research and management partners in several states. They tackle problems at a range of geographic and time scales, and combine 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 research projects are examining immediate management problems and related scientific knowledge-gaps. They are listed at the end of this chapter. Student research projects (not included here) are listed in Chapter 3.

Program A — Flow-related ecosystem processes

Leader: Assoc. Prof. Gerry Quinn
Deputy leader: Assoc. Prof. Martin Thoms

This program is investigating how flow affects ecological processes in rivers and their floodplains. It is examining fundamental ecological issues (Theme A1) and management needs (Theme A2).

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 are examining selected ecological processes in river channels and their floodplains and wetlands, and the transfer of materials between these parts of the landscape. We want to understand how key components of flow (including flood and drought) interact with representative biota and ecological processes in rivers and their floodplains. Our aim is 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 are studying 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. There is considerable scope to interact with the environmental flow allocation processes occurring in Victoria, NSW and Queensland. We are measuring the effects of different water-release regimes on various species, communities and processes, chosen to represent ecologically important 'response' groups. Fish, invertebrates and riparian- and floodplain-vegetation are being 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. A literature review (published early in 2004) demonstrates that flow modification almost always induces an ecological response, although the nature of the flow–response relationship is rarely simple. Variability is a key component of unregulated Australian aquatic systems, and so for regulated rivers it may be more appropriate to restore a fluctuating flow around a recommended level than to set a single flow level. Program A research has demonstrated that low flows and flood flows are both important in providing a heterogeneous set of habitats.

Besides reducing flow and habitat diversity, regulation can exacerbate the effects of other impacts. For example, after bushfires in early 2003, sediment washed from the catchment into the Cotter River (ACT). Instead of flushing through, the sediment was trapped by the dams that store the main drinking water supply for Canberra, causing their closure (it is an untreated system). However, collaborative discussions between CRCFE staff and the river managers have led to adaptively-managed environmental flow releases being used to flush sediment from the main water supply reservoir with minimal environmental impact.

In southern Australian lowland rivers, CRCFE work is identifying the sources of the carbon that drives the food-webs of rivers. Rather than coming mainly from the catchment and floodplain, as was previously thought, carbon appears to be largely derived from internal sources such as phytoplankton (floating single-celled algae) and possibly bacteria. Bacterial production increases substantially after flow pulses, and could potentially dominate production.

In subtropical dryland streams as well, autochthonous (within-stream) phytoplankton and benthic algae (attached to the banks) are the key drivers of food webs in dry periods, when rivers contract to a series of turbid waterholes. Again, this finding is contrary to the predictions of all the overseas conceptual models of riverine productivity. The relatively infrequent floods appear to represent boom times, with productivity orders-of-magnitude greater than in non-flood periods. CRCFE is investigating the importance of these to food webs and biodiversity in the long term.

Program A projects are showing that slackwater areas (such as backwaters and macrophyte beds) are important hot spots of invertebrate biodiversity, production and fish recruitment. These slackwaters are destroyed by the artificially high summer flows during the irrigation season in regulated rivers. Other CRCFE research on the lower Murray is suggesting that by manipulating the timing and locations of flow pulses and floodplain inundation we may be able to manage the spawning and recruitment of local native fish.

In total, these results give us considerable confidence in recommending environmental flow regimes for rivers and floodplain wetlands and designing monitoring programs to detect ecological responses to environmental water allocations.

PROGRAM HIGHLIGHTS

New projects (October 2003–)

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

Based on the completed CRCFE core projects in upland and lowland rivers (Campaspe River, Broken River, Cotter River, Lower Murray River), we hypothesise 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 these zones, which we term Functional Patches (FP), have been identified in three river settings:

- surface flow type, in the Cotter (a high-energy, upland river);
- slackwaters, 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).

A240 is describing how flow (hydrology and hydraulics) affects these three FPs, and how flow regime interacts with in-stream habitats and stream biota (such as zooplankton, fish and fish larvae, and macrophytes) and ecological processes (including metabolism). The intention is to develop guidelines so that river managers can predict the likely ecological response to any given flow regime.

Sampling of FPs and ecological character (including biota and water quality) began in all three rivers in late 2003, using protocols developed specifically for the project, and is now complete. Samples have been or are being analysed. Habitats have been mapped in the Cotter River, and we are halfway through mapping habitats on the River Murray. Habitat mapping of the Broken River has required modifications to the method, and is now in progress.

We are examining the productivity of these three rivers by installing artificial substrate ('BioPinBalls') for eight (or 10) weeks at selected parts of each site, and measuring the growth and chlorophyll-a (μg/L) content of the biofilm that develops on it. So far, biofilm in the Cotter and Murray sites has yielded double or treble the weight of chlorophyll found in biofilm at the Broken River sites. In general, the chlorophyll-a content of the biofilm appears to increase with increasing flow. (The project is comparing pools, riffles, runs, created flow or slackwater vs natural flow or slackwater, and sites on various parts of bends.)

A250: Development of flow–ecological-response models

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

Since the project started in July 2003, we have developed conceptual models relating flow–biota and flow–ecological processes, and reviewed the literature on fish responses to flow regime or flow events, extracting suitable hypotheses. A large database now holds all available information on biological response to flow change. Similar work is in progress for macroinvertebrates. The team has begun to explore new statistical techniques for analysing and modelling the associations between flow and stream ecology, for rivers in Victoria, NSW and Queensland. The methods resemble those being applied by QNRME for similar purposes in Queensland rivers.

As the project proceeds, gaps in the available data are becoming evident, highlighting research needs, but the team still expects to deliver a five-level rules-based predictive model of flow–fish, flow–invertebrate and flow–ecological process relationships by the end of the project.

A718: Monitoring ecological effectiveness of environmental flows in the Wimmera and Glenelg rivers

A monitoring design was needed for assessing ecological responses to environmental flows in the Wimmera and Glenelg Rivers, western Victoria. This short project entailed field assessment and a (now published) literature review of monitoring for environmental flows. There is no clear starting time for implementation of environmental flows and the nature of those flows may vary greatly from year to year and from reach to reach, meaning that a classical BACI (before–after control–impact) design is difficult to use for these rivers.

The final report has been submitted to the Victorian Department of Sustainability and Environment. The recommended design is based on detecting trends through time at key sites in each reach. It calls for monitoring of variables that are predicted to respond to changed flow regimes, especially salinity, dissolved oxygen, and fish abundance.

2000–2003 core projects completed

A100: Campaspe flow manipulation project

The macroinvertebrate assessment components of A100 were favourably reviewed by Dr Leon Metzeling (EPA Victoria) in August 2003. Shrimp distribution was surveyed in northern-flowing rivers in Victoria and some interesting patterns were evident. Production was estimated for key macroinvertebrate taxa. Also, techniques for using macroinvertebrates to assess responses to environmental flows were developed. Macro-invertebrates were sampled in two ways — using snag-bags, and AUSRIVAS protocols — to compare not only the methods but also the habitats (snags and free-flowing water). There were differences between the reaches within the Campaspe River and between the lower Campaspe reaches and the Broken River, most likely due to the different flow regimes. Key findings from the Campaspe Project have been summarised and forwarded to the Victorian Department of Sustainability and Environment, together with a package of publications from the project.

A210: Environmental flows and ecosystem response in gravel-bed streams

Environmental flow rules applied by the managers of the Cotter River in the ACT during 2003–2004 have continued to be influenced by the findings of project A210. Initial advice to Environment ACT was in the form of total volumes needed to sustain target habitat and maximise the environmental and water quality benefit during drought. Since the January 2003 bushfires a technical working group has been involved in the adaptive management of flows and release patterns in the Cotter River. An continuing 'Low Flows Project' (led by Richard Norris) is monitoring the river post-fires and during the ongoing drought. The team has sampled fine sediment movement and changing benthic production associated with targeted flushing flows.

Program B — Restoration ecology

Leader: Professor Stuart Bunn (till November 2003); *Dr Nick Bond (from June 2004)*

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

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, is providing the ecological knowledge that is essential to support and guide practical restoration measures.

Experimental projects in Program B have shown that manipulation of in-stream habitat (say, by installing wood — projects B200, B704) can bring about some restoration provided the catchment is not too severely degraded. However, restoring 'residential' habitat may not be enough to ensure the long-term persistence of populations. Recent work (projects B240, B706) has shown that 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.

Simply returning a range of physical habitats to a stream does not guarantee improved ecological conditions in that stream. For example, when artificial riffles were built in previously channelised streams in the Yarra catchment (Victoria), there was no improvement in the structure and diversity of macroinvertebrate communities (project B705). Work in Program D has found that during urbanisation the streams' hydrology and hydraulics have been altered and they have been contaminated by stormwater runoff, very efficiently delivered in pipes and drains. These catchment-scale factors override improvements to in-stream habitats and make it difficult for the stream biota to recover community structure.

Once catchment factors have been taken care of and in-stream habitats have been restored, organisms still have to be able to reach restored areas to colonise them. The dispersal of a range of stream and river animals is being measured in several projects (such as B230, B250, B703, C200) with molecular-scale genetic tools. The research has found that if aquatic invertebrates have a mobile adult stage (say, as flying insects) their populations can disperse widely, at least across areas of continuous forested habitat. In contrast, many fully aquatic invertebrates, such as snails, mussels, shrimp, crayfish and even some species of fish, have markedly different genetic structures between sub-catchments, suggesting that these populations do not disperse and will not reach and recolonise disturbed areas that have been restored. Dispersal ability and the presence of natural barriers (e.g. waterfalls) can pose a major constraint to the recovery of disturbed stream and river ecosystems. These genetic studies are also showing that populations of aquatic species may naturally be highly fragmented in distribution, and therefore that the barrier effect of small dams and weirs may be less significant than previously thought. The work has also discovered some cryptic species, raising interesting biodiversity issues (see Program C).

Program B research has led to management guidelines for rehabilitating streams and river systems in both rural and urban settings (e.g. guidelines for managing wood in streams, produced as a technical update by Land and Water Australia; and recommendations for rehabilitation of urban streams through the manipulation of 'effective imperviousness'). The CRC has also developed a suite of tools for monitoring the success of restoration (e.g. the SEQ Freshwater Ecosystem Health Monitoring Program — project D721). Where possible, demonstration sites have been set up to showcase ecologically sound rehabilitation methods (e.g. B200, B708, B710). In some of these activities we are collaborating with the CRC for Catchment Hydrology.

PROGRAM HIGHLIGHTS

New projects (October 2003–)

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

After rehabilitation work on streams, are there factors that limit the effectiveness of the work, as shown by, for example, the diversity of microorganisms present, and the functioning of ecological processes? This project expands the findings of B200, the 'Granite Creeks Project', in which large woody structures were installed to partly rehabilitate stream reaches that had been degraded by sedimentation. During 2003–2004, the project has been affected by drought, but good progress has been made on the study of invertebrate and fish samples and stream metabolism (food webs and benthic primary production). Ultimately, the project team will be measuring microbial diversity as well as selected biochemical processes in the stream, to see if they are limiting the recolonisation of the habitat by macroinvertebrates, and the team may revegetate the stream banks to boost in-stream carbon concentrations.

B250: Managing fragmentation and connectivity in river systems

How are species and populations of river organisms distributed among reaches, tributaries and streams, under natural conditions? This project team intends first to answer that question and then to predict the groups of susceptible freshwater species — that is, the species most likely to be disadvantaged when waterbodies become separated from each other by

human activities. The ultimate aim is to recommend management strategies for lessening the potential effects of fragmentation in susceptible species.

Sampling has been completed in the Sydney catchment area, the upper Darling, Warrego and Cooper rivers, and the Goulburn, Ovens and Campaspe rivers. Genetic analysis is currently underway, as is otolith analysis of fish, to find out when populations of biota might have become separated. Microsatellite markers have been developed for one of the new fish species from the Goulburn River, and are currently being screened.

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

B260, which began late in the financial year, is taking a step back from the channel to examine streams and rivers in a landscape context, building on the premise that 'the valley rules the stream'. It contributes to a long-term objective: namely, to build a framework for examining the combined effects of multiple disturbances acting on aquatic ecosystems at the local (site), reach, and catchment-scales.

As a first step, B260 will use analytical techniques being developed by landscape ecologists to characterise landscapes in catchments and sub-catchments of the southern Murray-Darling Basin, particularly focusing on the nature and extent of land use change in these areas. The characterisation should provide a detailed description of land use patterns (areal extent, distribution across the catchment, proximity to streams, etc.). Based on the classification, the project team will employ heuristic and conceptual models of stream ecosystems to ask how drivers and stressors might differ under different landscape configurations. It is expected that by first identifying key stressors operating under different land-use scenarios we will be better able to target future research questions, as well as management actions aimed at addressing stream-catchment linkages.

B710: Effectiveness of riparian zone restoration in the streams of the Murray-Darling Basin (MDB)

Riparian revegetation is probably the most common stream restoration technique employed in Australia. However, despite the cost and effort that goes into this form of rehabilitation, there is little evidence that ecological benefits result, particularly in-stream. In collaboration with stream management agencies across the southern MDB, B710 is establishing a long-term experiment to determine the physical and biological outcomes of riparian revegetation, and the time scales over which these occur. In setting up the experiment, the project team aims to develop a comprehensive monitoring protocol targeted directly towards measuring links between riparian and in-stream condition, and to gather information on the factors that are likely to influence the success or otherwise of this form of stream management.

Continuing projects

B704: River rehabilitation through re-snagging

New work in this ongoing project includes monitoring of effects of resnagging in the River Murray, and further rehabilitation in-stream and in riparian zones.

The work has two parts. The first is continuing to evaluate the resnagging trial conducted below Yarrawonga on the Murray. This experiment placed constructed habitat — large woody debris — in the river, in 2000, and has monitored its occupancy by native fish every year since then. Results to date show that Murray cod, trout cod and golden perch use both these sites and reference sites, which consist of naturally-occuring woody debris acculumations, in similar ways.

The second part of this project is examining the restoration of instream and riparian habitats in the Murray River between Lake Hume and Lake Mulwala. This is a joint program between the CRCFE, DSE, NSW DPI, NSW DIPNR, NECMA and MDBC. To date a restoration plan and monitoring strategy have been prepared in anticipation of works commencing in the 05/06 finacial year. The project is being implemented under an adaptive management framework and is now entering the second review cycle within this framework, during which the stakeholders are reassessing their learning and restoration goals.

B708: National Riparian Lands Program (Phase 2): in-stream ecological issues

This project (jointly with CRCCH project 6.4 and National Institute of Water & Atmospheric Research, New Zealand) has identified the relationship between shading and stream temperature, and can predict how the extent of cover and the length of river bank revegetated reduces impacts of temperature and light on stream fish and the production and composition of aquatic vegetation. Long-term monitoring of a riparian restoration experiment in south-east Queensland is determining how quickly the stream temperature regime approaches that observed in natural forested systems. Guidelines for riparian management of temperature extremes are in preparation for Land & Water Australia.

What is the direct influence of riparian vegetation on the ecosystem processes (and overall 'health') of large rivers? In the Mary River, coastal south-east Queensland, the team is measuring production of carbon in vegetated and unvegetated reaches, and sampling fish and invertebrates to determine the degree to which aquatic food webs are supported by aquatic or riparian sources of carbon.

B709: A synthetic analysis of the scientific basis of ecological restoration of stream ecosystems

In collaboration with the National Centre for Ecological Analysis and Synthesis, funded by the US National Science Foundation, B709 is building a database of ~40,000 restoration projects in the USA. The next step is to interview waterway managers about approximately 45 specific restoration projects, to gather more information about the motivation, methods, perceived outcomes, and any monitoring associated with these particular projects. The surveys will be followed by detailed analysis and synthesis of all projects already in the database, to identify the strengths and weaknesses of existing stream-restoration activities.

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 is researching threats to biodiversity as a step towards conserving freshwater biota and ecosystems. The research underway will guide decisions for restoring habitats and abating threats, and will help maintain or restore biodiversity values 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.

Theme C1 — Biodiversity assessment and regulation

What do we have left? What of our natural freshwater biodiversity remains relatively intact; how do we measure it; and how is it distributed across the landscape? How does the system work? What are the factors that regulate biodiversity in natural and modified ecosystems?

Theme C2 — Conserving biodiversity

What can we do? How can we identify key threatening processes, manage their impacts, protect biodiversity values in natural and partially degraded systems, and conserve threatened species and communities?

PROGRAM SUMMARY

The Conservation Ecology program is addressing 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 are:

(a) working towards the establishment of a national heritage rivers system,
(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 (see Program A) and habitat (Program B).

Specific work in the Conservation Ecology program is addressing the major threats of invasive species and salinity. These were identified in 2003 as being of high priority for partners. An innovative project, 'Predicting the spread of invasive aquatic biota' (C260), started in late 2003. Key results from the initial salinity project (C713) are showing how salinity can be managed with hydrology. The finding, that the effects of salinity on aquatic plant recruitment are more marked at the edges of wetlands than in the flooded zones, may lead to management indicators of salinity stress. The initial finding, that salinity constantly above 1000 mg/L reduces species richness and abundance of recruiting organisms, while pulses of salinity (up to 5000 mg/L) can be ameliorated by the return to freshwater within a week, could lead on to the development of guidelines for release of saline water into freshwater systems. The new core project (C240), examining how increasing salinity influences structure, function and diversity, has developed from this project.

PROGRAM HIGHLIGHTS

The program has made major advances in our understanding of episodic systems in arid Australia, via the two projects examining the role of refugia in maintaining biodiversity in dryland rivers (C200 and C250) (addressing the first program-objective). This research has provided insights into the way waterholes are related to each other and their role as refugia for aquatic organisms in dryland river catchments. It has also identified processes that are sustaining biodiversity in these waterholes.

For example, the research shows that although satellite waterholes can be distinguished from main waterholes on the

basis of their morphology there is no clear distinction between these types for most taxonomic groups, with the exception of turtles which only depend on permanent large (main) waterholes. Waterholes in the two major catchments, the Cooper and Warrego, have similar geomorphology, but species in the Cooper are very endemic and diverse compared with those in the Warrego for most groups (again except for the turtles). Cryptic species (which can only be identified genetically and not morphologically, e.g. mussels) further challenge traditional interpretations of biodiversity, with morphologically different species being similar genetically and morphologically similar species showing high genetic diversity. There is connectivity betweeen drainage systems and through time for many genetic groups (taxa).

Waterholes seem to be relatively permanent features of the landscape compared to the life histories of biota. Most taxa of biota show little dispersal between drainage systems, but populations of some taxa (e.g. fish) are connected within drainage systems. This was not the case for snails, mussels, or *Macrobrachium* (freshwater prawn), which showed that floods did not results in broadscale mixing between populations throughout the catchments. Waterholes appear to be largely sustained by surface flow, though some are more persistent than might have been predicted from evaporation measurements.

Biodiversity and Assessment forum

The Biodiversity and Assessment forum has met twice since July 2003, to identify achievements, gaps and ideas for further research, and decide on processes for disseminating current knowledge.

New core projects (October 2003–)

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

This project is examining 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, macroinvertebrates and freshwater plants? Sediments from sites in the Macquarie Marshes, NSW, have been used in mesocosm tanks in the first six months of experimentation, after being tested for biological suitability. The mesocosms have been sampled each month since February 2004, and some early analyses have been completed.

C250: Role of refugia in maintaining biodiversity in dryland rivers

C250 has relied on studying dryland rivers in the dry phase, but in 2004 the wet phase has been examined because the Cooper Creek flooded in January. The inundated floodplain was sampled to estimate diversity and abundance of fish, and the presence and identities of larval fish. Samples of water were collected for chemical analysis, and invertebrate fauna and fish tissue were collected for food web analysis. This opportunistic research will subsequently provide information to help explain patterns of fish recruitment, such as the source of the larvae, and whether the fish are cued to spawn in response to floods.

Field trips examined turtle productivity and pelagic productivity in selected waterholes of the Cooper Creek, and fish recruitment and size structures in the Border Rivers, as the January 2004 flood receded into the waterholes. Dataloggers have been installed in Cooper Creek waterholes to track changes in water depth through time. The results will be compared with estimates of evaporation rates based on sodium concentration in a subset of previously sampled Cooper Creek waterholes. Further investigation of fish recruitment patterns is underway, and a major review of existing data has already been made.

C 260: Predicting the spread of invasive aquatic biota

Trying a new approach to the problem of invasive fauna and flora in freshwaters, this project is integrating and synthesising existing knowledge and data as inputs to a yet-to-be-developed predictive model. The model will make comparative forecasts of the outcomes of invasions under various environmental scenarios. The first stage of the project is now complete with a large database of references and a conceptual model.

Continuing projects

C220: Conservation ecology and systematics of mountain galaxias

Studies of allozymes, morphology and mitochondrial DNA have been the main focus this year. Genetic tissue samples and whole samples have been collected from data-gap areas in central–north NSW, and the forests of East Gippsland/southern Victoria and southern NSW. A total of 160 sites were visited, of which approximately 40 were found to be dry. The morphologies of 126 populations consisting of 1100 individual fish have been measured, including reference populations of other galaxiid species.

C 702: Systematics of Australian mayflies

There has been a need to revise the Australian Baetidae and Caenidae and publish descriptions of new species recognised recently. State collections are being examined to identify the Baetidae and Caenidae to species. The mayfly data are being compared with distributional and environmental data to provide ecological profiles for each species. During 2003–2004 the team has completed the SA and WA material.

C713: Predicting ecological consequences of increasing salinity on wetland sustainability

The project team is using a combination of salinity and flooding regimes in experimental trials, to learn how varying salinity and hydrology individually and in combination stimulate plant and invertebrate communities from the 'seed-bank' of spores and eggs in wetland sediment. The aim is to predict how changes in salinity influence wetland sustainability and learn if modification to hydrological management can ameliorate those effects.

The experimental facility, which includes mesocosms (tanks) is at the Wonga Wetlands education site (Albury City Council), www.wongawetlands.nsw.gov.au/. Experiments on constant salinities and

pulses of salinity have been conducted already, and during 2003–2004 experiments are examining gradients of salinity. Results have been published in international journals and presented to national management and scientific audiences and to international conferences.

Phase I core projects C200 and C210 have been completed.

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 are addressing 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. We are determining the responses to nutrient cycles, particularly of nitrogen and phosphorus, and to pesticides and herbicides, land-use, habitat degradation and flow regulation, in a range of winter- and summer-rainfall river systems.

Theme D2 — Innovative bioassessment methods

We are making a comparative assessment of the effectiveness and relative costs of various bioasssessment methods. Are they robust to geographic changes in environmental variables, and are some methods better than others for particular situations? Can we identify relationships between ecological patterns and processes that may influence the regional distributions and abundances of organisms and habitats?

Theme D3 — Ecological risk assessment

We are developing and testing ecological risk assessment procedures for use particularly where several human-induced disturbances are operating in combination. The focus is on defining damaging agents in the Australian context and combining them in ERA models.

PROGRAM SUMMARY

Comparison of rapid biological assessment methods (project D200, Assessment and delivery of methods for determining river health) has shown that these methods can be divided into those more suitable for assessing short-term, episodic impacts, e.g. diatom methods, and those better suited for longer term assessment of river health and land management impact, e.g. macroinvertebrate methods.

At present, metabolism and nitrogen-15 methods are still developing.

Only AUSRIVAS Observed/Expected ratio showed clear significant relationships with gradients from high to low salinity and from complex to simple habitats. Other macroinvertebrate methods (EPT and SIGNAL) respond to salinity gradients, and some diatom and macrophyte methods can relate to a habitat gradient. Comparison of assessment methods and their application along disturbance gradients highlights the need to develop more diagnostic bioassessment indices.

Seven papers have been prepared and they are being joined by others, invited, to fill a special issue of *Hydrobiologia*, on bioassessment methods.

In projects D210 & D729 in urban streams, 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). This suggests that streams in urban areas can be conserved if drainage systems maximise dispersed retention and infiltration.

The previous, prevailing model was that stream condition is driven by total imperviousness, according to which the only way to conserve streams is to limit urban density to very low levels. The new finding raises the hypothesis that streams draining existing urban areas might be restored by altering existing stormwater drainage systems.

D220 (Ecological Risk Assessment (ERA) for aquatic resource management) has been used to assess the STREAMS decision support system developed by Melbourne Water as a tool for prioritising waterway management actions. Building complex ecosystem models is not useful for ERA. Models should be kept as simple as possible. There are many crucial steps to ERA, including formulation, defining issues, values, spatial and temporal scales, creating conceptual model(s). Incorporation of uncertainty is also vital but rarely done. The early phases of ERA are the most crucial.

PROGRAM HIGHLIGHTS

New projects (October 2003–)

D240: Assessment methods: environmental flows and biological diversity

The application of Multiple Lines and Levels of Evidence (MLLE) to an ecological question is new to all of us.

Lines of evidence = evidence coming from different groups of animals or process measures (diatoms, birds, fish, benthic metabolism)

Levels of evidence = evidence within a particular line (diatoms) that applies to the different criteria (presence of a biological response, specificity of association, consistency of response, etc.).

The D240 team has conducted a pilot application of MLLE to clarify our application of the technique in project D240. First, it distinguished between MLLE and WOE (weight of evidence):

WOE involves accumulation of evidence that supports the hypothesis until it can be concluded that the hypothesis has been proved.

MLLE also accumulates evidence, but also requires evidence to be sought which would support alternative hypotheses.

MLLE has been used for two quite different purposes:

1) assessment of condition at a site, and
2) evaluating causality between a potential stressor and a biological response.

In project D240 we are trialling MLLE to assess causality. We are refining the technique at two levels:

1) ensuring that the different levels of evidence are meaningful and practical when we apply them, and:
2) developing a series of decision points about the application of MLLE data that will form a framework for its application.

Fundamental to this second point and new to the application is the need to weight the quality of studies by their experimental design and relevance. The pilot application has identified uncertainties, decision points and data needs.

Extensive documentation has been prepared on the application of Multiple Levels and Lines of Evidence to environmental assessment. Software has been developed to aid recording study characteristics from the literature.

D250 Predicting ecological condition of streams in response to stormwater management

D250's primary objective is to produce new validated models of macroinvertebrate community composition in relation to catchment stormwater treatment infrastructure for three cities (Melbourne, Canberra and Brisbane) integrated as modules for the MUSIC software. The project is still in a data acquisition phase,

and has successfully collated relevant macroinvertebrate data for the three cities in centralised databases. A new method for the assessment of catchment imperviousness has been developed and is being trialled.

2) 2000–2003 projects completed

D210: Urbanisation and the ecological function of streams

From D210, we see that to plan a sustainable sub-division/suburb/town requires knowledge of catchment imperviousness and drainage connection. Gathering and maintaining this sort of information is a vital investment for effective planning. Melbourne Water, Environment ACT, Brisbane City Council and NSW EPA (now Dept of Environment and Conservation) have all begun to collect this information as a result of D210. Based on the findings for the east of Melbourne, truly sustainable urban developments will require a cap on effective imperviousness of <5%. This will almost certainly require a limit to total imperviousness of <50% and the pervious areas of the development will need to be used for stormwater retention or infiltration.

D220: Catchment based ecological risk assessment framework

A major outcome of this project is that a risk-based approach will be incorporated into development of guidelines for suspended sediments for the Victorian EPA. After ERA assessment by D220, uncertainty ranges and a critique or discussion of appropriate methods will be included in two of Victoria's decision support systems (RiVERS, and STREAMS).

D721 South-east Queensland Water Quality Management Strategy

Direct measures of benthic metabolism, GPP (gross primary production) and R_{24}, and several indirect measures, are found to be good indicators of stream ecosystem health and are recommended in assessing process-related responses to catchment land-use change and the success of ecosystem rehabilitation actions.

D722 Nutrient cycling, primary production & aquatic food webs in coastal river systems: implications for eutrophication management

Measures of key nutrient processes, such as algal bioassay results and the nitrogen-15 content of aquatic algae, were correlated with measures of increasing disturbance, indicating the processes could be used to monitor ecosystem health. Denitrification had a non-linear response to the disturbance gradient suggesting it would be less useful in monitoring programs.

D725 Robust procedures for measuring metal speciation & bioavailability

D725 is enabling regulatory agencies to measure the contaminants they regulate, and industry to monitor the composition of their effluents. The team has tested the 'Chelex column method' and finds it can be recommended for measuring metal compounds and complexes, within the decision framework recommended in the ANZECC/ARMCANZ guidelines. This method is readily applicable, unlike previous methods which were complicated and could only be performed by specialised laboratories.

D726 Ecological risk assessment of irrigation schemes

Statistical (Bayesian) network models have been used to choose the best ways managing fish at a range of sites. The Bayesian network model is composed of four sub-models describing water quality, hydraulic habitat, structural habitat and biological potential.

A blue-green algal model has been developed for use in the Goulburn River catchment, where factors increasing the likelihood of algal blooms varied from site to site. The model shows managers the factors they need to actively manage to reduce the risk of algal blooms, e.g. nutrient inputs and water temperature.

D727 Development of ecosystem guidelines for sedimentation and suspended particulate matter for rivers and streams

D727 has improved our understanding of the fate, behaviour and effects of sediment in rivers and streams. There is strong evidence that sediment layers as thin as 1–4 mm kill fish eggs. Effects upon aquatic diatoms, algae, and macroinvertebrates were not detected at the tested sediment levels.

TABLE of RESEARCH PROGRAMS and OUTCOMES

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

Major outcomes from the four research programs during the five years July 1999–June 2004 are shown in the table on the final seven pages of this chapter. 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 5.

RESEARCH PROJECTS active or being written-up during 2003–2004

Project	Project Name
Core	
Phase 1	
A100	Environmental flows in regulated rivers
A200	The effects of flow on lowland river productivity
A210	Environmental flows & ecosystem response in gravel-bed streams
B200	Restoration ecology of degraded rural streams
B220	Processes and patterns
B230	Connectivity and dispersal
C200	Dryland river refugia
C210	Adaptive fish management
C220	Conservation ecology and systematics of the mountain galaxias
D200	Assessment and delivery of methods for determining river health
D210	Urbanisation and ecological functioning of streams
D220	Development of an ecological risk assessment framework
Phase 2	
A240	Quantifying flow–habitat–biota relationships in riverine ecosystems
A250	Development of flow–ecological-response models
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
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
C300	Narran integrated project
D240	Assessment methods: environmental flows and biological diversity
D250	Predicting ecological condition of streams in response to stormwater management
Non-core projects	
A713	Floodplain indundation and fish dynamics
A716	Fish habitat protection in the Darling and Paroo Rivers
A717	The character and flow criteria for wetlands along the Barwon-Darling River
A718	Monitoring ecological effectiveness of environmental flows in the Wimmera and Glenelg 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 MDB
C702	Illustrated key to the nymphs of the Australian Ephemeropteran Baetidae & Caenidae
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 between Queanbeyan and Captains Flat
C713	Predicting ecological consequences of increasing salinity on wetland sustainability
C714	An ecological approach to restablishing trout cod
D724	Tooma River study
D725	Robust procedures for measuring metal speciation and bioavailability
D726	Ecological risk assessment of irrigation schemes
D727	Suspended particulate matter
D728	Delivering sustainability through risk management
D729	The development of guidance for environmental management objectives for managing urban stormwater for the NSW Stormwater Trust
D730	Development of risk-based approaches for managing contaminants in catchments
D731	Development of long term ecological monitoring and research program for waterway management

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
PROGRAM A Better understanding of the links between flows, ecological processes and biodiversity in a range of river types	**PROGRAM A** 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. 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.	**PROGRAM A** • 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 Freshwater Biology (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) has commenced, examining 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 on the Cooper Creek and Warrego River in arid Australia. (See Program C).
New tools that will lead to improved recommendations for, and evaluations of, environmental water allocations.	3-year Ecological characterisation of flow regimes in rivers in Eastern Australia including both winter and summer rainfall systems.	• 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 current CRCFE project A250, working with hydrologists from CRCCH, is analysing 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.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
Program A continued 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.	3-year Assessment and development of designs for: • 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. 5–7 year Implementation and analysis of (i) monitoring designs for assessing the effects of environmental water allocations to rivers, floodplains and wetlands, and (ii) multi-scale experiments testing the causal links between attributes of flow regimes and specific ecological processes.	• 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 Conference on River Research and Applications 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) is experimentally testing 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.
Develop and promote the adoption of flow restoration recommendations that could lead to measurable ecological benefits in degraded rivers.	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. 5–7 year Quantifying the benefits of environmental flows on key biota and ecological processes in winter- and summer-rainfall regulated rivers.	• 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. Three key examples: – 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 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.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
PROGRAM B An improved understanding of the constraints to recovery of disturbed aquatic ecosystems and the processes that can facilitate rehabilitation.	**PROGRAM B** 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. 5-7 year Identify important factors that constrain ecological recovery of degraded aquatic ecosystems and guide rehabilitation strategies to overcome such constraints.	**PROGRAM B** • 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. – 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) – 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. – some fully aquatic taxa (including some species of fish) show highly fragmented populations and limited dispersal capability – 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)

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
Program B continued To ensure that public funds invested in restoration of degraded ecosystems result in the maximum environmental benefit possible. This will be achieved by: • 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.	3-year Initiate demonstration sites aimed at showcasing practical, cost-effective and ecologically sound methods for the rehabilitation of rivers and wetlands. Contribute to the development of best management practice for the cost-effective and ecologically sound rehabilitation of rivers and wetlands. 5-7 year Promote and assist with (i) adoption of monitoring tools and protocols into restoration programs undertaken by stakeholders. (ii) adoption of best practice methods for rehabilitation of rivers and wetlands by stakeholders.	• 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) has been 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 to examine the effectiveness of riparian rehabilitation on the River Murray has also commenced as 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 the to QNRME. 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 are 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) are being planned in 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 NRM publications and brochures (see list of publications). • Riparian rehabilitation projects have been undertaken with stakeholders as adaptive management experiments. Ongoing projects include Echidna Creek riparian restoration project (with CRCCH and the Healthy Waterways partnership) and a large-scale project on the Murray River (B710) • In addition to physical habitat restoration projects, flow manipulation experiments have been undertaken under Program A.

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
PROGRAM C New knowledge on the distribution, life history and conservation ecology of threatened freshwater biota	**PROGRAM C** 3-year Organisation of a national forum on conservation of biodiversity in freshwater ecosystems, bringing together the range of perspectives from science and management 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. Decision-making tools for biodiversity conservation, provided in a form that can be readily used by managers.	**PROGRAM C** • 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 Aquatic Ecosystem Health and Management, called Freshwater Biodiversity in Australia (Volume 6 (1) 2003), Arthur Georges, Angela Arthington and Pierre Horwitz as guest editors, publishes 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 have agreed to develop a framework for assessing biodiversity in consultation with managers.
Principles and recommendations for assessing the biodiversity values of freshwater systems	3-year Design of experimental protocols for testing hypotheses on the processes that regulate biodiversity in natural and modified freshwater ecosystems 5-7 year Principles and recommendations for assessing the biodiversity values of freshwater systems and recommendations for management options.	• The Biodiversity Knowledge Project and the Biodiversity Forum are facilitating the generalisation of principles and recommendations in a form that is of real use to managers. • Biodiversity values are emerging 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 year 5
Program C continued 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	3-year Development of principles for the assessment of biodiversity in freshwater ecosystems 5-7 year Direct involvement in policy and decision-making through established government processes for implementing policy on biodiversity and threatened species conservation	• Advice on salinity, invasives and threatened species is being provided. See highlights. • 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. • CRCFE scientists are members of state Threatened Species Scientific Committees (Prof Jane Hughes (QLD), Dr Margaret Brock (NSW)) 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 derived from the Fenner Conference and from other CRCFE publications such as Conserving Natural Rivers: A Guide for Catchment Managers (Cullen 2002) and Biodiversity in Inland Waters — Priorities for its protection and management (Georges and Cottingham 2002). Our research on adaptive management in restoration ecology (C210) and in fish recovery (C220, C715) also feeds into policy implementation.
Advice on the possible ecological effects of invasive species on native flora and fauna.	3-year Identification of primary threatening processes for aquatic biodiversity.	• Our ability to influence the management of aquatic invasive species increases as our understanding of the process of invasion increases. Much of the relevant knowledge has been developed through student projects. • A new project has just begun to predict the spread of invasive biota (C260).

Outcomes (from Schedule)	Milestones (from Schedule)	Situation at year 5
PROGRAM D Improved scientific knowledge on the ecological effects of damaging agents (including nutrients and pesticides) in Australian freshwater systems.	**PROGRAM D** 3-year Development of priority areas for research in ecological response to agents that damage freshwater ecosystems 5-7 year Understanding of cause and effect links between ecological features and processes and methods of assessment	**PROGRAM D** • 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. • Furthered our understanding of sediment dynamics during storm events and base flow, (1) measuring the relationship between storm hydrograph, sediment concentration and particle size in transportation; (2) explored the relationship between sedimentation and aquatic diatom, algae and macroinvertebrate communities; (3) established levels at which sedimentation induces mortality of Australian native fish eggs. • Nitrogen found to be the primary limiting nutrient in SE QLD 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 steam productivity. (D722)
Improved and robust bioassessment methods that provide information on ecosystem health and assist in identifying the degrading processes (including habitat modification).	3-year Integration of AUSRIVAS with other techniques for assessment of river condition. 5-7 year • 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	• 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, QLD 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.
New ecological risk assessment procedures and associated tools for use by water industries.	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).	• Development of Bayesian approaches in risk assessment. • STREAMS DSS refined for Melbourne Water, algal models for Lake Yarrunga being developed for SCA. • Models for impact of sediment on biota.

3. Education and training

Leader: Professor Jane Hughes
(standing in for Dr Debbie Heck, on leave)

The overarching focus of the Education Program is to broaden the CRCFE's students' education and training experience, particularly in graduate programs. This is 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 is 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 is 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 has 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 are handled largely by researchers and knowledge exchange staff.

By meeting these five objectives, CRCFE aims 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 attracts 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 are offered through the CRCFE. This encourages students to take up PhD projects that are relevant to the water industry. Most of the recent recipients of top-up scholarships also have a mentor from the water industry, with whom they meet regularly.

At 26 May 2004, the CRCFE had seven postgraduate students on full scholarships, 24 on top-up scholarships and six working on associated (non-scholarship) projects: 36 in total plus 1 expired scholarship with submission pending.

A scheme of collaborative write-up scholarships is planned to start in September 2004 for students who have recently submitted their PhDs. The CRCFE and the collaborative industry partner will each contribute 50% of the scholarship. Under the terms of the scholarship the student works half time for the industry partner and spends the rest of the time completing the PhD thesis.

Training workshops and professional development courses have been offered to CRCFE postgraduate students during the past year. Topics have included presentation and media skills, PhD project management, and writing successful grant applications. The workshops have been well attended by students. A media skills workshop was also held prior to the annual general meeting in November 2003, for both staff and students.

Specialist scientific short-courses have also been run this year, on the use of geographic information systems in freshwater ecology, and on advanced statistics.

Postgraduate student statistics

During 2003–2004, the CRCFE has had 48 full-time and part-time PhD students, including those who have submitted, and

one MSc student (currently deferred). At the end of June, 39 PhD students were active and had not yet submitted their theses (see table at end of this chapter).

The following students' PhD theses were submitted or accepted between July 2003 and June 2004:

- Andrea Ballinger, 'Invertebrate biodiversity of coarse woody debris on floodplains' (Monash University)
- Rhonda Butcher, 'Conservation assessment of Victorian wetlands using invertebrates' (Monash University)
- Sam Capon, 'Flow related response of vegetation in arid inland floodplains' (Griffith University)
- Giovanella Carini, 'The role of flooding in the maintenance of genetic diversity in four floodplain invertebrates' (Griffith University)
- Piyapong Chotipuntu, 'Aspects of sublethal salinity on the early life stages of an Australian native freshwater fish, Murray cod (*Maccullochella peelii* Mitchell 1838)' (Monash University)
- Patrick Driver, 'Interactions between the age-structure of common carp (*Cyprinus carpio*, L.) populations and their habitat at catchment and experimental scales' (University of Canberra)
- Brendan Ebner, 'Introphic interactions between zooplankton and fish' (La Trobe University)
- Lisa Evans, 'The influence of fluvial geomorphology on riparian vegetation in upland river valleys: south eastern Australia' (University of Canberra)
- Julia Howitt, ' Photochemical degradation of aquatic dissolved organic matter: the role of suspended iron oxides' (Monash University)
- Dale McNeil, 'Fish, zooplankton and algae dynamics in Murray River billabongs' (La Trobe University)
- Kylie Peterson, 'Age, growth and survival of larval fish in the Murray-Darling Basin' (University of Canberra)
- Mark Siebentritt, 'The influence of water regime on the floristic composition of Lower River Murray wetlands' (University of Adelaide)
- Simon Treadwell, 'Role of snags in carbon dynamics in lowland rivers' (Monash University)
- Kelly Vanderkruk, 'Biogeochemistry of nutrients in a sand slug stream, Creightons Creek, Victoria' (Monash University).

The following students graduated at ceremonies during 2003–2004:

- Rhonda Butcher
- Sam Capon
- Patrick Driver
- Lisa Evans
- Julia Howitt
- Fiona McKenzie-Smith
- Jon Marshall
- Kylie Peterson
- Simon Treadwell
- Marcus Wishart.

Three new students began PhDs during the year. *Collette Thomas* is researching 'Ecological risk assessment of land-derived contaminants to coastal ecosystems', with Professor Barry Hart at Monash University. *Karen Cooper* is researching 'How do aquatic ecosystems respond to different configurations of landscape drivers?', with Associate Professor Gerry Quinn at Monash University. *Nadine Kelly* is researching 'Quantifying flow–habitat–biota relationships in riverine ecosystems' with Keith Walker at University of Adelaide, and Trevor Daniell and Martin Lambert of the School of Civil and Environmental Engineering (U. Adelaide) and Shaun Meredith of MDFRC Mildura.

Conference/workshop attendance and travel

The CRCFE supported postgraduate students to travel to and present papers and posters at the following national and international conferences and workshops this financial year:

- 42nd Annual ASL Congress (seven students)
- Enzymes in the Environment: Activity, Ecology & Applications, Prague (two students)
- Ninth International Conference on River Research and Applications (five students)
- Interact 2004 Royal Australian Chemical Institute Conference, Gold Coast (one student)
- Australian Society For Fish Biology Conference, Wellington, New Zealand (one student)
- Symposium on Urbanization and Stream Ecology (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, Vancouver (two students)
- Society of Wetland Scientists Conference (one student)
- Third European Phycological Congress (one student).

Students may 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 session 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 are funded to attend the CRCFE Annual General Meeting and the associated workshops. This encourages interaction between students from the different university campuses, as well as introducing them to other researchers and managers in the water industry. They learn about research being conducted at other campuses and attend specialised workshops prior to the AGM.

Forward thinking

After recommendations from staff and students at the 2003 annual general meeting, the education program has developed a number of plans to improve both undergraduate and postgraduate education courses. These plans include the development of a web forum which students, supervisors and industry can use; encouraging postgraduate participation in workshops and industry meetings and the development of training sessions which could be delivered online; creating a greater number of industry mentors for postgraduate students; and the completion of a business plan for online and face to face delivery of undergraduate and postgraduate teaching courses across partner universities.

Destination surveys

Graduates from the CRCFE PhD program are currently being surveyed to follow the progress of past students. We are asking them where they are currently working, how long they have been employed, their approximate salary level, and how they see the strengths and weaknesses of the CRCFE education program.

Young Water Scientist of the Year

The CRCFE is managing the 2004 and 2005 CRCs' Water Forum Young Water Scientist of the Year Award program. For 2004, the awards are part of the River*festival* River*symposium* in Brisbane from 31 August to 3 September. The symposium theme for 2004 is 'Threats to Sustainable River Systems — beating the odds'. This year, the students will present their talks during the conference sessions most related to their subject matter, rather than in a separate session. It is hoped that will give them large interested audiences and good exposure to the industry and other scientists in their fields.

The CRCs' 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 five finalist postgraduates, one per CRC. Selection criteria, which are applied to both a written and a spoken paper from each candidate, are: (i) the industrial relevance of their research topic, (ii) the quality of their scientific research approach, and (iii) their skill in communicating their subject matter. The award is intended to showcase the best students from each of the Water Forum CRCs.

Dale McNeil (now working for DIPNR at Forbes, NSW) has been selected as the CRCFE's finalist for the 2004 Young Water Scientist of the Year Award. His topic is 'The importance of seasonal drying in structuring floodplain fish communities under natural flow conditions'. Dale completed his PhD this year at La Trobe University.

TRAINING FOR WATER INDUSTRY PROFESSIONALS

CRCFE researchers and knowledge exchange staff ran and/or supported twelve courses for water industry professionals during 2003–2004.

The AUSRIVAS Online training course was polished and began being delivered during 2003–2004, particularly to water industry personnel. The course is now run once each semester — that is, twice per year. It consists of four modules that are self-paced and accessed via the Internet and also a four-day face-to-face practical workshop. The modules teach participants about assessing river health using the methods and predictive models of AUSRIVAS (Australian River Assessment System).

The 'Stream habitats and hydraulics' course was held on the Mary River, near Brisbane, in April 2004, attended by 21 participants from several partner agencies (e.g. QNRME, DIPNR, MDBC), city councils and other natural resources management agencies.

The 15th MDFRC & CRCFE Taxonomy and Ecology Workshop was held at the Lake Hume Resort, Albury, 10–11 February 2004, for around 50 participants. These workshops, run by John Hawking and held annually so far, train biologists in the identification and ecology of freshwater invertebrates. The groups covered in this years's workshop included Mussels (Bivalvia), Fairy Shrimps (Anostraca), Caddis Flies (Trichoptera), Lacewings & Spongeflies (Neuroptera), Dragonflies & Damselflies — adults & larvae (Odonata) — and Fish larvae. Corresponding to these groups, six new identification guides were published for the workshop, bringing the total number of guides published to 51.

John Hawking has run 'Train the trainer' sessions for Waterwatch staff in Victoria (2), South Australia (2) and ACT (1). They 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.

The Water Studies Centre, Monash University, ran a training course in PRIMER v.5 for Windows during November–December. The course was presented by Dr Bob Clarke, Plymouth Marine Laboratories, who was the originator of many of the statistical techniques included in the software.

CRCFE supported a Wetland Ecology and Management Training Course, run by Greening Australia at the end of November at Gippsland Lakes, Victoria.

To research the needs of stakeholder partners and educators for water education and training, a seminar/workshop was held in February 2004 at the University of Canberra. It was attended by and industry professionals. This was backed up by a more formal market survey of training needs.

UNDERGRADUATE EDUCATION

Undergraduate teaching takes place at Monash University, University of Canberra, La Trobe University, Griffith University, Adelaide University 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.

- Griffith University: BSc Ecology and Conservation Biology; BSc Environmental Science; Aquatic Ecology unit; Field Ecology
- La Trobe University: BSc in Environmental Management and Ecology; also an honours degree; Graduate Diploma in Environmental Management.
- Monash University: units offered in the BSc degree, Freshwater Ecology unit; Aquatic Chemistry
- University of Adelaide: B Sci and B Environmental Science
- University of Canberra: BSc Resource and Environmental Science.

Summer scholarships and work experience

Summer scholarships were undertaken for a period of 8–10 weeks from November 2003 through to February 2004. Short projects were completed under the supervision of CRCFE staff at the various institutions. The scholarships were provided to:

Monash University (3),
University of Canberra (3),
Griffith University (3), and
La Trobe (1),
Mildura Lab (1),
Albury Lab (1).

COMMUNITY EDUCATION

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

We work with Waterwatch and Greening Australia, in particular, but also interact with the broader community via presentations, forums, field events and working groups.

- A member of CRCFE staff is currently 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.
- Particular groups ask CRCFE staff to set up research/instruction that will show them what *they* can do to improve river condition (e.g. cotton growers) and biodiversity in their areas (e.g. rice growers).
- Occasionally, targeted fact sheets are 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.
- During 2003–2004, 2 pairs of public lectures have been run at University of Canberra, with very high-profile speakers, addressing current issues in freshwater ecology and water science.
- Presentations are invited by a wide range of community groups, including bird observers, field naturalists, Rotary and Lions Clubs, eco-tourism groups, wetland community groups, Landcare. Topics include the findings of the CRCFE, local aquatic ecological issues and the importance of careful water resource development and management.

SCHOOL-BASED EDUCATION & ASSISTANCE TO THE GENERAL PUBLIC

Australia's top Year 11 students had the opportunity to participate in the National Youth Science Forum (NYSF) in January of 2004 at the University of Canberra. Associate Profesors Ralph Ogden and Martin Thoms, Professor Richard Norris and Dr Fiona Dyer introduced students to the work of the CRCFE, and led a sampling activity on the Murrumbidgee River. The CRCFE component of the Forum is an opportunity to educate students about our work and encourage them to have careers in freshwater ecology. The CRCFE has run similar outings for the NYSF students in previous years.

In April 2004, approximately 85 students from years 9 to 11 attended the two very popular annual freshwater schools run by the Murray-Darling Freshwater Research Centre, and Rotary.

First, the 6th 'Health of the River System' youth forum in Mildura attracted 37 students in years 9–10 from NSW, South Australia and Victoria. Each year, students investigate the biology of fish, water bugs and plants, as well as some of the social and economic aspects of water management. They also work with catchment managers and scientists; this year

the scientists included Jason Nicol and Sue Gehrig, both CRCFE PhD students at Adelaide University. Student presentations at the end of the 2004 forum were excellent, and demonstrated good understanding of the issues of river ecology.

Also in April 2004, the 9th Rotary Murray-Darling School of Freshwater Research brought together around 50 year 11 students. They worked in teams with leading scientists from La Trobe University, the Murray-Darling Freshwater Research Centre (MDFRC) and Charles Sturt University. Students experienced both work in the MDFRC laboratories and fieldwork at Wonga Wetlands, and gave excellent presentations at the end of the week to a group of scientists and Rotarians.

CRCFE staff (particularly knowledge brokers and scientists based at the regional laboratories) visited schools and colleges (pre-primary–tertiary) or led excursions of school-students on at least 22 occasions. Presentations are tailored to the particular groups but usually focus on salinity, aquatic food webs, ecological sampling, work of the regional labs, stormwater education, flow alteration, flooding, native fish and introduced fish.

Other education and communication activities during 2003–2004 related to schools included:

- displays and hands-on activities at school-focused events, which also reach the adult community (Science Week in Canberra in August 2003; National Water Week (Mildura), World wetlands day in Mildura and Albury, February 2004),
- supply of materials to teachers (including putting them in touch with local Waterwatch contacts). Materials include brochures, books, posters, waterbug identification slides, AUSRIVAS videos.
- a strong work experience program for senior secondary and early tertiary students, run by MDFRC at Mildura, Albury and Goondiwindi. Outcomes range from an increased interest to actual tertiary study in freshwater ecology. During 2003–2004, the MDFRC labs hosted four work experience students.
- mentoring for students (a) at the MDBC International River Health Conference at Mildura (two groups for the October 2003 conference); (b) with OzGreen 2003 (Goondiwindi, for the Darling River) and 2004 (Albury and Mildura, for the Murray). Outcomes in all situations include heightened awareness of: (i) the kinds of trade-offs required for healthy working rivers, and (ii) the need for balance among the interests of river users.

For the general public, CRCFE staff also answer questions, identify biota, supply general CRCFE written material, newsletters (e.g. *Watershed*, *Dryland River Refugia*) and run stands at displays and field days (e.g. La Trobe University Open Day, regional laboratory open days, Goondiwindi agricultural field day). Issues of interest range from blue-green algae in small dams to parasites found on fish.

CRCFE postgraduate students active at June 2004

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 2004

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, 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
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
Conway, Carol PhD	Reactivity of organic carbon under anaerobic conditions and its role in sediment nutrient dynamic	Bill Maher, University of Canberra	APA + CRCFE Top-up scholarship
Cook, Ben PhD	Recovery and recruitment of aquatic fauna to rehabilitate 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 + APA
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 cycle 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
George, Amy PhD	Population dynamics and recruitment of eucalypts on the Lower Murray Floodplain	Keith Walker, University of Adelaide	Adelaide and CRCFE Associated Project

Hammer, Michael PhD	Setting a framework for conservation: molecular systematics and conservation biology of small dishes of the Murray Darling Basin	Keith Walker, University of Adelaide	APA + CRCFE Top-up scholarship
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	APA + CRCFE Top-up scholarship
Hunter, David PhD	Life history of declining and non declining frogs in the Southern Highlands of NSW	Will Osborne, University of Canberra	APA + CRCFE Top-up 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), University of Adelaide + Shaun Meredith, MDFRC	Associated project + CRCFE top up scholarship
Kennard, Mark PhD, part-time	A quantitative basis for the use of fish as indicators of river condition	Angela Arthington, Brad Pusey, Griffith University	Associated Project
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
McKenny, Claire PhD	The relationship between ecosystem processes and community structure in south east Queensland rivers	Stuart Bunn and Heather Proctor, Griffith University	Self funded after 30 June 2003
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 Maher	APA + CRCFE Top-up (expired)
Page, Timothy PhD	Historical biogeography of the sand barrier islands of Moreton Bay as revealed by molecular phylogeography of obligate freshwater species	Jane Hughes, Stuart Bunn, Griffith University	APA + CRCFE Top-up scholarship
Perryman, Shane PhD	Nitrogen cycling and bacterial bio-diversity in urban Australian stream	Barry Hart, Mike Grace, Monash University	CRCFE full scholarship
Price, Amina PhD	Influence of hydrology on the recruitment of native fishes to the Narran Lakes, north-western New South	Martin Thoms, University of Canberra	CRCFE full scholarship

	Wales		
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
Sellens, Claire PhD	Defining the reference condition: implications for biological assessment	Richard Norris,	CRCFE full scholarship
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
Smith, Ben PhD	Carp spawning dynamics and early growth in the River Murray, South Australia	Keith Walker, University of Adelaide	APA + CRCFE Top-up scholarship
Sonneman, Jason PhD	The development of rapid bioassessment protocol for the use of diatoms as water quality indicators	Peter Kershaw, Monash University	APA + CRCFE Top-Up
Stojkovic-Tadic, Slobodanka PhD	Interactions between nutrient status and UVB in microalgae	John Beardall, Monash University	Monash Graduate Scholarship + CRCFE Top-up scholarship
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 (industry)	CRCFE top-up scholarship

4. Providing for end-users via 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 rely on *collaborative linkages* within and beyond the CRCFE, and particularly on a process we call '*knowledge exchange*'.

Collaborative linkages between CRCFE partners

The CRCFE is a cooperative assemblage of 20 research and management institutions, as listed above. 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 operate to build mutual trust between the groups, across sites and disciplines.

- The strongest mechanism is the cross-institutional collaboration that exists among our research provider partners and between them and our water industry partners. The CRCFE's research teams work across disciplines and organisations. Program and project meetings, field-work and joint supervision of PhD students all offer opportunities for face-to-face interaction among team members from different institutions and states, reinforcing email and phone contact.
- The cross-institutional collaboration is led by the senior management team structure, which brings together representatives from five of the research sites, four to five times per year.
- Important collaborative linkages are 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 Program Advisory Committees (PACs) — largely comprising representatives of CRCFE's industry partners — stimulate cooperation among our industry agencies and authorities and the research programs. Their interaction ensures that the CRCFE's research is relevant to the water industry. The PACs meet face-to-face at least once per year and report their progress to the Board. Their members are listed in Chapter 1.
- The CRCFE's knowledge exchange (KE) team also aims to help the development of trust between groups. In part of their work, the KE team members assemble forums and steering committees consisting of industry and research staff, and they are also an important contact point for the CRCFE's other stakeholders.
- All CRCFE staff are invited to contribute news items to the fortnightly internal e-newsletter. Staff are also emailed *Research Highlights*, which notes progress in current research projects. All members of staff are sent copies of *Watershed*, the CRCFE's public newsletter/magazine.
- The Annual General Meeting, a busy two-and-a-half day meeting at a country venue, brings together staff and students from all sites and programs. The postgraduate students from all sites also meet for discussions, at least once per year, usually during the AGM.

External collaborative linkages

Beyond the CRCFE partners, collaborative links have been established or are being developed with:

- policy-makers, natural resource managers, government officials from non-partner organisations
- community groups; some parliamentarians
- non-partner members of the water industry, including small-to-medium size enterprises
- the four other water-related CRCs in the Water Forum: the CRC for Catchment Hydrology; the CRC for Water Quality and Treatment; the CRC for

Waste Management and Pollution Control; and the CRC for Coastal Zone, Estuary and Waterway Management; this collaboration operates 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) establish international linkages and reputations partly by:

- attending international conferences and working with relevant research groups overseas,
- running international conferences here,
- publishing work that is relevant to water management issues everywhere.

In 2003–2004, staff of the CRCFE were again invited or elected members of committees and working groups and editorial boards overseas; including:

- Australian–Japanese 'Predictions in Ungauged Basins' Working Group (Baldwin, CSIRO)
- Scientific Committee for the 4th International Workshop on Phosphorus in Sediments, Spain 2003 (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.)
- *Hydrobiologia* Editorial Board, based in Belgium (R. Norris, U. Canberra)
- *River Research and Applications* Editorial Board, based in the United Kingdom (K. Walker, U. Adelaide)
- *Freshwater Biology* Editorial Board, based in UK (Sam Lake, Monash U.)
- a workshop being held in early July 2004 by the Royal Society, London, entitled 'Beyond extinction rates: Monitoring wild nature for the 2010 target' (R. Norris, U. Canberra)
- N. American Benthological Society Executive Committee (R. Norris, U. Canberra) elected Chair, to take effect later in 2004.

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

- Sam Capon (PhD student, Griffth U.) worked for three months with Professor Christer Nilsson of Umea, from August to October 2003 after completing her thesis
- Glenn Wilson (Goondiwindi) is liaising with Bruce Paxton, U. Cape Town Zoology Department, on threatened freshwater fishes
- Bill Maher and Ian Lawrence (Canberra) hosted 12 visitors from Lombardy, Italy, at a discussion day–seminar, with a view to possible collaborative work
- four of five keynote speakers at the Symposium on Urbanization and Stream Ecology were important researchers of urban streams from USA
- five of the keynote speakers at the Ninth International Conference on River Research and Applications were from USA, UK and South Africa
- 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 (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 — scientists and a specialist team of 'knowledge brokers' and 'community scientists'. Members of the KE team are all science graduates with communication skills and postgraduate degrees or experience — at levels reflected in the two job titles.

Our aim is 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 interact 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 synthesise tacit and explicit knowledge from the CRCFE research providers. They make knowledge products available in the form of decision tools, guidelines, summary booklets, web pages, and so on.

The knowledge exchange team at June 2004 is led by its director, Associate Professor Ralph Ogden. He is 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, newly appointed in July 2003), Albury-Wodonga (John Hawking), and in Canberra (Ruth O'Connor, newly appointed in July 2003, & Bronwyn Rennie) backed up by the communications group (Ann Milligan & Bronwyn Rennie), all three based at University of Canberra. As at June 2004, a new knowledge broker is being sought to work with the CRCFE partners in Adelaide, SA, to be funded by and based at the SA Dept of Water, Land and Biodiversity Conservation.

Scientific and public communication

Apart their knowledge exchange activities, CRCFE research staff also engage in the standard activities for disseminating scientific information: seminars, conferences, journal papers, technical reports.

CRCFE findings are also publicised by newsletters, fact sheets, brochures, web sites and media articles. Publications have been handed out this year at Science Week (Canberra), at the University of Canberra open-day, at the CRC Programme's Innovation networking evening, and at the CRC Association conference in Adelaide, as well as at World Wetlands Day and other public events and agricultural shows near the regional laboratories. CRCFE receives numerous requests for publications.

This year, apart from three issues of our newsletter *Watershed*, which maintains a circulation of around 2500 copies per issue, four issues of the *Narran Lakes Ecosystem Newsletter* have been sent to 200 stakeholders and landholders in the Narran Lakes area, two issues of a newsletter from the Health of Ephemeral Rivers project have been sent to stakeholders (mainly catchment water management board staff) in South Australia, and the second issue of the *Dryland River Refugia* newsletter has been sent to landholders who live around the Cooper, Warrego and Border Rivers, in south-west Queensland.

All new publications are made available on the CRCFE web site. This year two new interactive web sites have been built — one for the Narran Lakes project (http://mooki.canberra.edu.au/narran), and one for the CRCs' Water Forum (see p.35) (http://mooki.canberra.edu.au/waterforum). Both are available via the CRCFE home page, http://freshwater.canberra.edu.au.

Media representatives contact the CRCFE for comment from Professor Gary Jones and other senior staff. Twenty-six staff have been interviewed or mentioned in the media this year. Our media releases generally focus on events and outcomes, rather than resarch findings. Some *Watershed* articles about research findings were reprinted in other general circulation magazines this year, such as *Australian Landcare*, and *Irrigation and Water Resources,* the *Bendigo Advertiser* and a *Canberra Times* supplement on water. We featured in two *Canberra Times* supplements: the October 2003 supplement on water contained six articles about aspects of CRCFE work, and we contributed an article about our Cotter River work to the *Canberra Times* supplement in August, on recovery from the bushfires. CRCFE staff have published two 'op-eds' in the press this year, one in response to articles about the Scientific Reference Panel assessment of flows for the River Murray, and one to do with ACT's future water supplies.

In press, TV and radio, CRCFE staff and CRCFE work have been mentioned or featured in over 200 media items during 2003–2004.

	TV	Radio	Print
Rural	15	34	100
Capital city	6	14	34

Technical publications, public presentations and communication publications are 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 in Chapter 3.

Summarised below are significant outcomes of knowledge exchange activities and ongoing interations between the KE staff and industry end-users and policy-makers at all levels of government, during 2003–2004.

Highlights of the knowledge exchange program

Living Murray

At the start of the financial year, the CRCFE was pivotal in finding and packaging management knowledge required by the Murray-Darling Basin Commission for the Living Murray initiative. Using the Murray Flows Assessment Tool (MFAT), the Regional Evaluation Groups (REGs) and Scientific Reference Panel (SRP) used all available data, backed up by expert knowledge, to predict potential benefits to riverine habitats if any of three reference volumes of environmental water were to be returned to the River Murray. The SRP's Interim Report, 'Ecological assessment of environmental flow reference points for the River Murray System' was completed in October, and the REGs and SRP also reported on the MFAT itself as a tool. The SRP was chaired by Professor Gary Jones; many of its members (scientists) were from CRCFE; and CRCFE knowledge brokers coordinated the reference panel process and report. Some scientists on the REGs were from CRCFE regional labs.

The Goulburn River Scientific Panel for the Living Murray, led by Peter Cottingham of CRCFE, completed environmental flow recommendations for the Goulburn River below Lake Eildon, Victoria, in November, for DSE. The Goulburn River was included within the Living Murray initiative, both for its environmental values and because its water might contribute to the volumes being considered for return to the Murray.

These outputs, developed with a large amount of scientific input from CRCFE researchers and the support of knowledge exchange staff, have contributed to 'triple bottom line analyses' for the Living Murray.

At least eight public talks, by Gary Jones, CEO of CRCFE, and Ben Gawne, Director of the MDFRC, contributed to community understanding of the Living Murray initiative during July –September 2003. One talk attracted several thousand people.

Also, during March 2004, Gary Jones was invited to meet with Parliamentary Standing Committee on Agriculture, Forestry and Fisheries at Parliament House to discuss the science underpinning water allocations for the River Murray and more widely.

Highlights among our other activities

- CRCFE scientists worked regularly with ACTEW and Environment ACT, the ACT water managers, to devise the best ways of managing environmental flows during this drought and the after-effects of bushfire in Canberra's main water supply catchments.
- During 2003–2004, for DSE, CRCFE devised a monitoring design specifically for assessing ecological responses to future environmental flows in the Wimmera and Glenelg Rivers, western Victoria. This project highlighted the challenges in designing monitoring programs for environmental flows in lowland rivers with naturally variable flow regimes. The CRCFE has now established a multi-state working group to further develop a generic framework for monitoring environmental flows (see next point).
- The Flows and Restoration Forum in December held an environmental flow-monitoring workshop at Monash University to begin the process of establishing consistent recommendations for monitoring ecological responses to environmental flows to be applied across eastern Australia (see KE project list below). Nine of our industry partners are involved in this process, together with DPIWE (Tasmania) and four of our partner research-providers, and more will be included later. The project is consistent with DSE's environmental flow-monitoring program being finalised for the Thomson-Macalister Rivers.
- City water managers in Melbourne, Canberra, Brisbane and Sydney have accepted CRCFE's recommendations on stormwater drainage connection with urban streams, and have begun to collect the information on infrastructure that they need to be able to apply the recommendations. CRCFE has shown that the sustainability of urban streams depends on the effective imperviousness of their catchments.
- A risk-based approach formulated by CRCFE is to be incorporated into guidelines for suspended sediments, by EPA Victoria.
- The Biodiversity Forum has brought managers and scientists together twice this year to identify the types of knowledge products needed to communicate biodiversity management information.
- The MDBC and CRCFE ran workshops to exchange knowledge about ephemeral wetlands and deflation basins, during August 2003. The workshops presented and verified a conceptual model developed for ephemeral wetlands, and collected insights and learnings from the wetland managers attending. The outcomes from these workshops have been incorporated into management guidelines for ephemeral deflation basin lakes for the MDBC.
- The Ninth International Conference on River Research and Applications in early July at Albury, NSW, was run by CRCFE. Our staff also presented three keynote papers, 30 contributed papers and three posters, and ran several of the mid-conference field trips. A pre-conference forum, on flow ecology and environmental flows, allowed targeted exchange of information between river managers and national and international researchers.
- CRCFE jointly (with Melbourne Water and CRC for Catchment Hydrology) ran a successful international Symposium on Urbanization and Stream Ecology, in December, attended by over 100 delegates from both developed and developing countries. Our staff contributed at least eight papers or posters.
- Ways of improving transfer of current scientific knowledge to managers of Canberra's urban lakes were discussed at a meeting of stakeholders, including representatives from ACTEW, University of Canberra, Environment ACT and ACT Urban Services.
- CRCFE has released Technical Report 2/2003: Lloyd, N., Quinn, G., Thoms, M., Arthington, A., Gawne, B., Humphries, P. and Walker, K. (2003) *Does flow modification cause geomorphological and ecological response in rivers? A literature review from an Australian perspective*. From an extensive literature review it establishes that there is strong evidence for impacts from flow modification in rivers, but a poor relationship between the intensity of modification and response, due to a number of factors. This report should make a valuable contribution to managers facing questions about the evidence-base underpinning environmental flow initiatives.
- With the River Murray Catchment Water Management Board and DWLBC, the MDFRC/CRCFE at Mildura launched the SA Wetlands Baseline Monitoring project, 31 January 2004, with SA Minister Hon John Hill officiating. CRCFE-run community-field-days are being held periodically, demonstrating techniques for monitoring fish, macroinvertebrates, birds and vegetation
- As outlined in Chapter 3, Waterwatch staff, water industry personnel and others have attended MDFRC/CRCFE training workshops on identification and ecology of freshwater invertebrates and larval fish.
- CRCFE staff facilitated a workshop on 'Fish Habitat Rehabilitation and Management in the Murray-Darling Basin' for MDBC in February 2004. Eighty scientists and aquatic managers met to discuss the current status of knowledge on habitat rehabilitation and management issues. The workshop papers are to be a benchmark.

Mark Lintermans of Environment ACT and CRCFE was part-organiser of the workshop.

- For the Narran Project (joint CRCFE-MDBC), CRCFE has created an interactive website (http://freshwater.mooki.canberra.edu.au/narran), produced and distributed four newsletters to residents and stakeholders, and met with community members, from both the Lower Balonne Community Reference Group and the Narran Community Reference Panel. The project has been reviewed in Walgett by a three-person International Scientific Review Panel. The recommendations of the review report have been accepted and are being acted on by the project team. Also (see below) preparations have been made for collecting oral history of the Narran River and Lakes area.
- As outlined described in Chapter 3, CRCFE staff have interacted with considerable numbers of secondary-school and primary-school students during 2003–2004, via school visits and particularly via the annual April freshwater schools at Lake Cullulleraine (near Mildura) and Albury. The aim is to increase young people's understanding of the multiple uses needed from sustainable rivers.

Six important knowledge exchange activities have begun during 2003–2004, formulated as specific CRCFE 'Knowledge exchange' projects.

- *1. Freshwater Findings* is bringing together the major advances in scientific knowledge made by the second phase of CRCFE research.
- *2. Biodiversity project* has investigated the needs and capabilities in biodiversity management among our management partners. This is providing a foundation for outputs to help in setting benchmarks and targets for biodiversity assessment and management.
- *3. Oral History of the Narran River and Lakes* will interview long-time residents of the Narran Lakes region, to provide a 'line of evidence' for the ecosystem study of the Narran Lakes. During the first six months of 2004, ethical and legal constraints have been worked through, in preparation for interviews to take place later in 2004.
- *4. Generic framework for environmental flow monitoring programs* is adapting the National Water Quality Management Stategy's Monitoring & Reporting Guidelines to suit monitoring to assess ecological responses to environmental flows in rivers.
- *5. Guides for selecting appropriate Rapid Biological Assessment (RBA) techniques* is summarising our current state of knowledge about RBA techniques so they can be output as guidelines or a decision support tool.
- *6. Development of training modules in the ecological management of catchments* aims to develop a series of training modules that will disseminate practical ecological knowledge useful for catchment management personnel.

Table of knowledge exchanges with end-users during 2003–2004

The table that follows (pp. 40–43) summarises exchanges of knowledge and information between CRCFE staff and end-users.

In the table, information exchanges about a topic can take these forms:

- input to planning committees or other responsible groups;
- services (assessment and reporting, project management);
- workshops;
- publications and/or presentations;
- training;
- advice;
- discussions and briefings.

They are expected to result in *outputs* in the form of:

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

and *outcomes* such as:

(i) end-users having more comprehensive knowledge,

(ii) support for evidence-based decision-making,

(iii) action (or policy for action), and, ultimately

(iv) solutions to the underlying issues.

End-users for the CRCFE's research findings are 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.

The CRCFE has established cooperative interaction with the Cotton RDC, Cotton Australia, the Rice Growers Association, and several community-based management groups, particularly the Mallee CMA and 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 freshwater ecology and floodplain land-use. It is important to the CRCFE that we cooperate together to achieve common goals.

Knowledge exchanges with end-users in the water industry and community during 2003–2004

Topics information has been exchanged about	Activities involved	Locations and/or species involved	End-user involvement: core participants (P) and others, via consultancy (C), grant (G), taking training course (T) or other interaction	CRCFE staff involved (from KE team and research providers)
acid producing sediments	discussions, input to responsible groups	NSW waterways	Murray Wetlands Working Group, Environmental Trust (DEC)	Baldwin, Rees
algal management: blue-green algae	advice, workshop, publications	R. Murray at Mildura ACT lakes;	Lower Murray Water (P), Sunraysia Regional Algal Coordinating Committee, DIPNR (P), Mallee CMA (C), SRWA (P); Environment ACT (P)	Bald, Whiterod; Scholtz; Jones
biodiversity: threatened species listing, recovery plans, survey of aquatic species	input to responsible groups, assessment, publications	Threatened spp. in general; Murray crayfish, Victorian mallee; amphibians; rice growing area	Threatened spp. committees of NSW and Queensland, Mallee CMA (C), MDBC (P); ACT Government	Brock, Hughes; Mildura lab; Osborne, Rennie
biodiversity: research findings on connectivity & dispersal of taxa	briefing, workshop	NSW, Queensland, Victoria	SCA (P), DIPNR (P), NSW Fisheries; DNRME (P)	Kotlash
biodiversity: management of	discussions, workshops	eastern Australia	DIPNR (P), EPAV (P), QNRME (P), SCA (P), Environment ACT (P), DSE (P)	Kotlash, O'Connor, Rennie, Brock, Hughes, Arthington, Lake, Norris and postgraduate students
catchment and/or river condition:	assessment and reporting, advice, discussions and briefings, workshops	southern Queensland; northern NSW; Australia-wide; Lake Eyre Basin; Port Phillip Bay; Yarra R	Condamine Alliance (C), Maranoa-Balonne CMA, Border Rivers CMA, SW Natural Resource Management Group Charleville, Queensland Murray-Darling Committee (QMDC); Western CMA, Border Rivers/Gwydir CMA; National Land & Water Resources Audit 2 (C), CRC for Catchment Hydrology; CRC LEME; Coastal CRC; Water for a Healthy Country; Lake Eyre Basin Ministerial Council Scientific Advisory Panel; Port Phillip and Westernport CMA; Yarra Forum	Wilson, Adams and Goondiwindi lab staff; Ogden; Bunn; Cottingham, Hart, Walsh
collaborative partnerships: development of	discussions	Condamine R area; northern NSW (from Armidale); rice growing area; north east Victoria;	Condamine Alliance; Cotton CRC, Cotton RDC, Border Rivers Food & Fibre, major cotton growers; DIPNR (P), DEC (P), QNRME (P); Rice Growers Association; Greening Australia; North-East CMA	Wilson, Adams, Jones, Ogden, Cottingham, O'Connor; Gawne
ecological monitoring, long-term	input to responsible groups, discussions	Melbourne area	Melbourne Water (P)	Walsh, Cottingham, Lake, Quinn, Hart, Grace, Webb, Butcher

Topics	Activities involved	Locations, species	End-user involvement	CRCFE staff involved
ecological risk assessment: risk management for sustainability	assessment briefing, discussions	Goulburn-Broken, Ord, Fitzroy (Q) river irrigation areas; suspended sediments from catchments; Sydney; South Australia	EPAV (PG), Melbourne Water (P), DSE (P), Goulburn-Murray Water (P), NPIRD; Land & Water Australia (G), MDBC (P) SCA (P), SA Water	Grace, Webb, Pollino, Hart Kotlash
environmental flows (e-flows): setting	assessment and reporting, advice, briefings, workshops	R. Murray, Goulburn R, Cotter R	DSE (PC), MDBC (PC), Goulburn-Murray Water, federal politicians, Goulburn-Broken CMA, ACTEW (P), Environment ACT (P)	Scientific Reference Panel: (Jones, Scott, Rennie and research staff); Cottingham, Norris, Liston, Dyer
e-flows: monitoring of effects	publications, assessment workshops, advice, briefings, discussions	world, Australia, Wimmera and Glenelg Rivers; Thomson-Macalister R; Lindsay Wallpolla Is.	DSE (PG), DSE (P), DIPNR (P), QNRME (P), Environment ACT (P), DWLBC (P), Melbourne Water (P), SCA (P), MDBC (P), EPAV (P), DPIWE Tasmania; Mallee CMA (C)	Lloyd, Quinn, Arthington, King, et al.; Cottingham, partner staff; Sharpe
e-flows: management	discussions, input to responsible groups, workshops, presentations	eastern Australia; R. Murray (Lindsay Wallpolla); River Murray; Vic. mallee rivers; Pindari Dam	Land & Water Australia, CRCCH; CSIRO; ABC Radio (Bush Telegraph Water Challenge) and the community; Mallee CMA (C); DIPNR	Ogden; Gawne; Zukowski; Wilson
fish and turtle management; habitats management	workshops, input to responsible groups, discussions, presentations, publications	Murray-Darling Basin, Mildura, Goondiwindi; Lindsay Is.; Charleville; Bourke (Darling R); trout cod, Murrumbidgee R; Cardross Lakes	Environment ACT (P), MDBC (P); NSW Fisheries; Goondiwindi town council; Charleville and Warwick District fishers; QNRME (P); DIPNR (P); DLWBC; FRDC (G), Environment ACT (PG), NSW Fisheries (G), MDBC (PG); Mallee CMA (C); Goulburn-Broken CMA;	Cottingham, O'Connor, Lintermans; Bald, Wilson; Rennie; Meredith, Bald; Humphries; Baldwin; Rees; Lintermans, Ebner; Conallin
habitats in streams/rivers	training, input to responsible groups	Mary River Qld Murray-Darling Basin	QNRME (T), DIPNR (T), MDBC (T), city councils (T), NRM agencies (T); Environment ACT (P), MDBC (P)	Bunn and staff; Cottingham, O'Connor, Lintermans
identification of biota	training, input to responsible groups, advice	Australia, SA, Victoria, ACT	Sunraysia Rural Water Authority (P); CRC Viticulture; DPIWE; Torrens/Patawalonga CMB; Murray-Darling Association; RMIT; water agencies and research groups across Australia (T); Waterwatch SA, Vic and ACT (T)	R. Walsh; Hawking, Serafini, Humphries, Walker and colleagues.
knowledge exchange within other organisations (not CRCFE)	advice		DSE (P), DWLBC (P); ACTEW (P), Environment ACT (P), National Capital Authority; Canadian Health Services Research Foundation; Aboriginal Health CRC; Weeds CRC; Biosecurity CRC;	Cottingham; Ogden

Topics	Activities involved	Locations, species	End-user involvement	CRCFE staff involved
Narran Lakes area	discussions, input to responsible groups,	Lower Balonne floodplain	MDBC (P), DIPNR (P), QNRME (P)	Ogden, Adams, Quinn, Thoms, Rayburg, Brandis
river condition assessment, development and delivery of training in	discussions, training	Australia-wide	DSE (P), Environment ACT (P), QNRME (P), EPAV (P); DEH (G); Consultants across Australia, DPIV, RMIT, U Queensland, SA Water, catchment management groups, DPIWE (all T)	Norris, Nichols, Ogden
river management via anabranches	input to responsible group, publication	Macintyre R; Darling R (Great Anabranch)	DIPNR (PC); Macintyre R landholders	Bald, Thoms, Southwell; Scholtz
river management via riparian zone (vegetation) restoration	briefing, advice, publications, input to responsible or planning groups,	Sydney area, R. Murray, eastern Australia, Goondiwindi area	SCA; MDBC (PG); Greening Australia, Cotton CRC	Kotlash, O'Connor, Adams
river management via flows	discussions, advice, briefings, input to responsible groups, workshops, presentations, publications	Campaspe R, Broken R; R. Murray; Darling R; Cotter R; Ovens R.; Victorian mallee	DSE (P), GMW (P), Waterways Authority of NSW (C); ACTEW (P), Environment ACT (P); North-East CMA; Mallee CMA (C)	Campaspe project staff; Quinn, Cottinghams, Thoms, Southwell; Norris, Liston, Dyer, Jones, Ogden; Gawne; Zukowski;
river management via renagging	publications	NSW coast	Central South Coast CMB; Member for Lake Macquarie;	communications group
river management via fauna	assessment and reporting	Darling R. (Great Anabranch)	DIPNR (PC)	Scholtz
river management for multiple uses	briefing, training, input to responsible groups, presentation	eastern Australia; Goulburn River; Potterwalkagee Ck	school students, Rotary; Goulburn-Broken CMA; Mallee CMA	Bald, Hawking; Cottingham; Zukowski
salinity effects on ecology (wetlands)	assessment and reporting, workshop,	Albury; Australia	DIPNR (PG); Ecological Society of Australia	Brock, Nielsen
SE Queensland freshwater areas of high ecological value	input to responsible groups	SE Queensland, Moreton Bay	QNRME (P), QEPA Moreton Bay and Catchments Healthy Waterways Partnership	Bunn, Nielsen
stream metabolism: measurement of	workshop, presentation, publication	eastern Australia	DEC (P), QNRME (P), DIPNR (P)	Grace, Bunn
urban waters: management and rehabilitation, rural–urban gradient	assessment, reporting, workshops, input to responsible groups, advice, briefing, presentations	Melbourne, Sydney, Brisbane, ACT; Adelaide; Mildura	Melbourne Water (P), SCA (P), DEC (P), Environment ACT (P); NSW Stormwater Trust (G), Brisbane City Council; Victorian water resources green paper; River Basin Management Society (G); Mildura Rural City Council, Mallee CMA;	Walsh, Grace, Cottingham, O'Connor; Kotlash; Lawrence, Jones; Aldridge; Bald, Zukowski;
water management for whole-of-water-cycle	discussions and briefings	eastern Australia	all CRCFE partners + 10 other organisations	Jones and Senior Management Team

Topics	Activities involved	Locations, species	End-user involvement	CRCFE staff involved
water quality: management	assessment, reporting, input to responsible groups, discussions, advice	Snowy Mountains; ACT; R. Torrens (Adelaide); Lake Mulwala; Border Rivers; Mildura region; Darling R; R Murray	Thredbo and Perisher companies (C), Environment ACT (PC), Ecological Associates SA (C), Mallee CMA (C); Goulburn-Murray Water (PC); Border Rivers Landcare CMB; Mildura Rural City Council; DIPNR (P); OzGreen; National Audit Office	UC lab staff, Norris; Albury lab; Scholtz; Adams; Zukowski; Bald, Jones, Cottingham, Meredith, Nielsen, Brock, Hart
water recycling: environmental risks	input to responsible group	Australia-wide	Dept Environment and Heritage;	Gawne; Cottingham
water resources management	assessment, reporting, advice, input to responsible groups	ACT	Environment ACT (P); ACTEW (P)	O'Connor, Jones
waterbody management: lakes, storages, waterholes, weir pools	assessment, reporting, workshops, input to responsible groups, briefings, advice	Keepit Dam; ephemeral lakes; Border and Warrego river; Lindsay Island; Menindee Lakes	DIPNR (PC), QNRME (P), ACTEW (P), Environment ACT (P), SRWA (P), State Water (C), Mallee CMA, MDBC (PC), QDPI; Murray Irrigation Ltd	Kotlash, Barlow, Norris, Thoms; Scholtz, Gawne; Wilson; Scott; Bald; Bunn;
wetlands: monitoring, management, salinity issues; rehabilitation; community education	workshops, assessment, input to responsible groups, reporting, training	along River Murray; 1000 wetlands in Victorian mallee; Albury; Wingecarribee Swamp; Barren Box Swamp; Kings Billabong; Thegoa Lagoon;	MDBC (PC), SCA (P), DWLBC (PC); SKM; Mallee CMA; NSW Murray Wetlands Working Group (C); general community in SA (T); DIPNR (PG); Greening Australia Victoria;	Bald; Nielsen, Brock; Mitchell; Sinclair, Mildura staff

5. Operations and Staff matters

Buildings

The MDFRC laboratory at Goondiwindi moved into new premises during the year. Also, the MDFRC laboratory at Mildura moved into new, purpose-built premises on the La Trobe University campus. Neither building is owned by CRCFE.

Equipment purchases

Major purchases during the year were related to the research effort of the CRCFE. Major purchases were:

Base locating system	$29,725
Incubator	$ 4,874
Server (Goondiwindi)	$ 8,703
Server (AUSRIVAS)	$ 5,317

Specified personnel

During 2003–2004 there were two changes to the Specified Personnel. Professor Stuart Bunn became Research Director, and leadership of Program B passed from him to Dr Nick Bond. Specified personnel at the end of June 2004 are shown in the table (above right).

Specified personnel at 30 June 2004

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. Gerry Quinn Monash U.	Program leader	75%
Dr Margaret Brock DIPNR	Program leader	75%
Dr Nick Bond Monash U.	Program leader	100%

Staff comings and goings

In the knowledge exchange team, Ruth O'Connor has replaced Dr Anthony Scott in Canberra, and Janey Adams (Senior Community Scientist) has replaced Mark Southwell (Community Scientist) at Goondiwindi.

Sara Johnson has been appointed to Waterwatch Victoria as Science Coordinator, as part of the CRCFE knowledge exchange team.

Changes to the staff contributed by partners during the year are detailed in the Financial and Staffing Report (separate document).

Awards and honours to staff during 2003–2004

Dr *Ben Gawne* (Director of the MDFRC) received the 2003 Australian Society for Limnology Early Career Excellence Award at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society (ASL/NZSL) at Warrnambool, Victoria, in December 2003. Ben was recognised for his substantial and tangible contributions to international limnology, both theoretical and applied.

Professor *Bill Maher* received his second Royal Australian Chemical Institute Medal, in recognition of his outstanding work in promoting environmental chemistry and for his contributions to the Institute. His previous medal, in 2002, was for analytical chemistry.

Bill Maher was also elected to the board of FASTS (Federation of Australian Scientific and Technological Societies) which represents the views of the workers in Australian science.

Dr *Anthony Scott* and *Bronwyn Rennie* (CRCFE) and *Sarah Cartwright* (MDBC) won the CRCFE Chairman's Award for 2003. They are the team that coordinated the Scientific Reference Panel and our report on the Living Murray for the MDBC this year.

Professor *Peter Cullen* was awarded an Order of Australia in the Queen's Birthday Honours, for services to freshwater ecology, particularly in policy development, implementation and sustainability in relation to water and natural resource management, and education.

Michael Hammer (U. Adelaide) received the River Murray Catchment Water Managment Board 'Open Literary Award' presented at the Australian Water Association Awards, in recognition of his 'Recovery Outline for the Southern Pygmy Perch in the Mount Lofty Ranges'.

Dr *Daryl Nielsen* and Dr *Gavin Rees* (MDFRC Albury) were inaugural winners of the CSIRO Land & Water 'Chief's Awards', for consistent effort in lifting the profile of salinity research within Australia. *Helen Missen* and *Anthony Conallin* (MDFRC Mildura) were also inaugural winners of Chief's Awards, for outstanding contributions to the laboratory's work.

Dr *Jane Doolan* won the inaugural Victorian Department of Sustainability and Environment's International Women's Day Award for Innovation.

Professor *Angela Arthington* has been appointed to membership of the Scientific Committee of the DIVERSITAS crosscutting network on freshwater biodiversity, for a period of three years. DIVERSITAS is an international scientific program dedicated to the science of biodiversity, under the backing of ICSU, IUBS, SCOPE, IUMS and UNESCO.

Professor *Richard Norris* was invited to be part of a Royal Society, London, workshop entitled 'Beyond extinction rates: Monitoring wild nature for the 2010 target', which is scrutinising and developing scientifically robust measures of progress towards the 2010 biodiversity target, in the 2004–2005 financial year.

Richard Norris was (again) a finalist in the Australian Museum's Eureka Awards, 2003.

Richard Norris also has been elected the next Chair of the North American Benthological Society's Executive Committee, to take effect next financial year.

Trish Bowen (MDFRC Albury, PhD student of U Canberra) was awarded the Sydney Catchment Authority's Best Student Presentation award at the Ninth International Conference on River Research and Applications in Albury in July.

Heath Chester and *Claire Sellens* (both of U. Canberra) won the Best Honours Paper and Best Poster awards at the ASL/NZSL congress at Warrnambool in December.

Anne Baums (studying at U. Canberra as part of PhD studies with the Technical University Dresden, Germany) won the Young Women in Science Excellence Award for her presentation at MODSIM 2003, the biennial congress of the Modelling and Simulation Society of Australia and New Zealand.

Dr Ben Gawne, winner of the ASL Early Career Excellence Award for 2003

6. Performance indicators

Cooperative arrangements

Activities of the centre seen by stakeholders as making a difference to water management, July 1999 – June 2004

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 eventually 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 intiative 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 (Environment ACT and ACTEW) 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.
- 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 jointly (with Melbourne Water and CRC for Catchment Hydrology) ran a successful international Symposium on Urbanization and Stream Ecology, in December, attended by over 100 urban water managers and researchers from developed and developing countries.
- 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 Lakes Project (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 Anabranch 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. The guides have been in strong demand.

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, 1999–2004

Large multi-disciplinary projects form 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 is 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 invest in leadership training to help staff work in these integrated projects, and each project has input from industry via the Program Advisory Committees and other collaborations.

Of 33 active core- and associated-research projects in 2003–2004, 18 involve staff from several partner institutions. All 11 core projects are cross-institutional, and also seven 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, 1999–2004

Having gained one new partner this year, at June 2004 the CRCFE comprises 20 partners consisting of six research providers and 14 public and private water-industry agencies. The South Australian Department of Water, Land and Biodiversity Conservation joined the CRCFE in January 2004. It is contributing a new knowledge broker to be based at that office in Adelaide. The broker will service all the South Australian knowledge exchange needs — for DWLBC and for the University of Adelaide which joined the CRCFE in 2000–2001.

The Senior Management Team and the Knowledge Exchange team are in regular contact with members of the CRCFE's partner organisations, discussing their requirements and supplying advice and information. The members of the Senior Management Team come from four partner research providers.

The Program Advisory Committees consist of representatives of partner organisations, particularly the water agencies and the water industry (see Chapter 1). The committees contribute to the design and running of core research projects.

Also, knowledge-exchange-run forums bring together our industry and research provider partners to ensure strong industry input to core CRCFE research, particularly in biodiversity, and environmental flows and river restoration.

CRCFE highlights the role of its partners in media reports and publicity.

During 2003–2004, CRCFE has attracted around ten prospective new partners for the CRC's rebid (with CRC for Catchment Hydrology) for Round 9 of the CRC Programme. The new partners comprise representatives from private industry, including 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 targets 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. Additional targeted funding is 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. The Program Advisory Committees (PACs), established for each research program, formalise the involvement of industry staff in research planning and activities. The PACs meet at least once per year and report their progress to the Board.

Industry personnel are also involved directly with many of the latest postgraduate students, as mentors (see below), ensuring that the students' research topics are relevant to water industry issues.

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

All research projects undertaken within the CRCFE undergo a rigorous review process to ensure excellent quality science which is relevant and of benefit to our partners.

To reinforce this, we have a quality assurance review process that all research projects must undergo. It has three levels:

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

All research projects must be approved by the CRCFE's Board.

The list of articles accepted by, or published in, refereed journals varies from year to year. In total the CRCFE has published approximately 350 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:

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

One of the ways in which the CRCFE ensures its research is world-class is through international collaborations with selected institutions and researchers. These linkages enrich the research generated by both parties and benefit the broader water science community in Australia as CRCFE researchers share their knowledge. Several key researchers in CRCFE are on international committees (e.g. DIVERSITAS, and editorial boards) by invitation.

Effective project management with regular reporting to Board

The CRCFE Project Management System tracks the achievement of milestones for individual projects. All staff access the Project Management System through the secure CRCFE intranet web site. Reasons for missed milestones are provided by the Project Leader and these form part of the Exceptions Report to the Board.

Education and training

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

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

Eight of the non-university co-supervisors are from industry. Our industry mentoring scheme for postgraduate students, introduced in 2003, has continued this financial year, 2003–2004. Recipients of CRCFE top-up and APA scholarships have industry mentors, as well as university-based supervisors, to ensure that the students' training will produce new scientists with a sound understanding of the water industry.

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

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

na = information not available

Short courses and workshops developed and presented

During 2003–2004, CRCFE personnel have run, or jointly run:

- two international conferences
- one national conference,
- 28 short courses and interactive workshops for industry- and other end-users.

Thirteen 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, 1999–2004

- River health assessment methods (Sydney Catchment Authority (SCA), MDBC, QNRME, DSE, DIPNR, EPA NSW, EPAV, Environment ACT)
- Waterway condition assessment (National Land & Water Resources Audit, ACTEW, Environment ACT)
- Integrated urban land and water management (ACT Government, Melbourne Water)
- Urban stream rehabilitation (ACT Government, Melbourne Water, NSW EPA, SCA, QNRME)
- Biodiversity assessment methods and management (SCA, EPAV)
- Environmental flows assessment and setting (MDBC, DSE, SCA, QNRME, ACT Government, ACTEW, Melbourne Water, Goulburn-Murray Water)
- Environmental flow effects — monitoring (DSE, EPAV, Melbourne Water, MDBC, DIPNR, QNRME, Environment ACT)
- Taxonomic guides (DSE, QNRME, DIPNR, EPAs)
- Fish management (MDBC, DWLBC, DIPNR, DNRME)
- Lake, reservoir, wetland management (Lower Murray Water, DIPNR, Environment ACT, MDBC, SCA, DWLBC, ACTEW Corporation)
- Stream rehabilitation (DSE, QNRME, SCA, MDBC)

- Ecological risk assessment (Melbourne Water, EPAV, Goulburn-Murray Water)
- CRCFE research staff work as consultants for partner agencies (e.g. DWLBC, DIPNR, MDBC, Goulburn-Murray Water, EPA NSW)

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 more than 20 consultancies generating income of $715,000 during 2003–2004, and provided advice, continuing input, training or assistance to all 14 of our industry partners as well as our six research providers, plus at least 112 non-partner groups.

In 2002–2003, 19 consultancies raised $576,000 in income. During 2001–2002, 2000–2001, 1999–2000, there were 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.

Technical publications produced, 1999–2004

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

The CRC uses a variety of communication strategies to reach end users, including seminars, workshops, conferences, consultative and business meetings, international visits, committees and training sessions.

Centre staff involvement in government and other advisory bodies

CRCFE staff have been members of at least 38 committees and advisory bodies to government agencies and natural resources management groups during 2003–2004, and chair or deputy chair of seven of those bodies. They include:

- NSW Scientific Committee for the Threatened Species Conservation Act
- Queensland threatened species scientific committee
- ACT Flora and Fauna Committee (Deputy Chair)
- ACT Environment Advisory Committee
- Australian State of the Environment Committee
- Independent expert task force advising the Victorian Government on the White Paper
- DSE Technical Advisory Panel on environmental flows (Chair)
- CSIRO Water for a Healthy Country Advisory Council
- Gippsland Lakes Task Force
- Gippsland Integrated Natural Resource Forum (Chair)
- Victorian Catchment Management Council
- Gippsland Water Technical Review Committee (Chair)
- EPA Victoria Scientific Advisory Panel
- Board of EPA Victoria
- Board of Wetland Care Australia
- Scientific Reference Panel for the Living Murray (Chair)
- 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 Expert Panel for the Moreton Bay and Catchments Healthy Waterways Partnership (Chair)
- Lake Eyre Basin Ministerial Council Scientific Advisory Panel.

During the first four years of this CRCFE, staff were members of 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 2003–2004, staff and students of the CRCFE generated over 200 media hits that we know of, partly due to a media focus on possible effects of the Scientific Reference Panel report for the Living Murray Initiative. CRCFE led and provided a large part of the expertise for that project. Comparable numbers in 2002–2003, 2001–2002, 2000–2001, 1999–2000 were 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 current research portfolio and with setting other policies for the CRCFE. The Board's Research Committee enables 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 receives financial information on a quarterly basis and research-progress reports at each Board meeting.

The Australian Government is 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 tracks the completion of milestones for the research component. The other performance indicators are 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

The postgraduate student manual outlines the CRCFE's administrative procedures, and explains the organisation, and funding opportunities.

Provide appropriate staff development opportunities within the centre

Staff are 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 for this purpose ($50,000 for staff training plus a further $30,000 to support conference attendance, during 2003–2004).

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

The CRCFE was paid $715,000 during 2003–2004 for contract research and consultancy work. Income from consultancies in earlier years is reported above.

7. Publications and presentations

Books and chapters in books

Bailey, R.C., Norris, R.H. and Reynoldson, T.B. 2004. *Bioassessment of Freshwater Ecosystems Using the Reference Condition Approach*. Kluwer Academic Publishers, USA.

Baldwin, D.S., Howitt, J. and Beattie, J. 2004. Abiotic degradation of organic phosphorus in the environment. In: B. Turner, E. Frossard and D.S. Baldwin (eds). *Organic P in the Environment*. CAB International press, Wallingford, UK.

Fien, J. and Heck, D. 2003. Environmental education and education for sustainable development. In: J. Keeves and R Watanabe (eds). *International Handbook of Educational Research in the Asia-Pacific Region, Part One*. Kluwer Academic Publishers, Dordecht, the Netherlands.

Georges, A. and Legler, J.M. (In press) *Emydura* sp. (Fraser Island Short-neck). In: Pritchard, P.C.H. and Rhodin. A. (eds). *The Conservation Biology of Freshwater Turtles.* IUCN Publications, Gland, Switzerland.

Georges, A., Doody, J.S., Beggs, K. and Young, J.E. (In press) Thermal models of TSD under laboratory and field conditions. In: Valenzuela, N. and Lance, V. (eds). *Temperature dependent sex determination in reptiles*. Smithsonian Institute, Washington.

Georges, A., Rose, M. and Doody, J.S. (In press) *Carettochelys insculpta*, Pig-nosed Turtle. In: Pritchard. P.C.H. and Rhodin, A. (eds). *The Conservation Biology of Freshwater Turtles*. IUCN Publications, Gland, Switzerland.

Georges A. and Thomson, S. (In press) Evolution and zoogeography of the Australian freshwater turtles. In: Merrick, J.R., Archer, M., Hickey, G. and Lee, M. (eds). *Evolution and Zoogeography of Australasian Vertebrates*. Australian Scientific Publishing Pty Ltd, Sydney.

Jones, G.J. and Cottingham, P. 2004. Chapter 4. Environmental Flows. In: *Water and the Australian Economy*. CEDA Publication, Melbourne, pp. 31-37.

Jones, G.J. and Orr, P. 2003. Bloom-forming Blue-Green Algae (Cyanobacteria). In: G. Sainty and S. Jacobs (eds). *Waterplants in Australia*. Sainty and Associates, NSW, pp. 314-336.

Marchant, R. 2003. Aquatic values. In: L. Cairnes (ed.) *An Assessment of the Values of Kosciuszko National Park*. NSW National Parks and Wildlife Service, pp. 47–54.

Mitchell, A. and Baldwin, D.S. 2003. Organic phosphorus in the aquatic environment: speciation, transformations and interactions with nutrient cycles. In: Turner, B., Frossard, E. and Baldwin, D.S. (eds). *Organic P in the Environment*. CAB International press, Wallingford, UK.

Pusey, B. J., Kennard, M. J. and Arthington, A. H. 2004. *Freshwater Fishes of Northeastern Australia*. CSIRO Publishing, 400 pp.

Turner, B., Frossard, E. and Baldwin, D.S. (eds). 2003. *Organic P in the Environment*. CAB International press, Wallingford.UK.

Identification guides

Dean, J.C., St Clair, R.M. and Cartwright, D.I. 2004. *Identification keys to Australian Families and Genera of Caddis-Fly Larvae (Trichoptera)*. CRCFE/MDFRC Identification Guide Series No.50, CRCFE, Albury.

New, T.R. 2004. *Introduction to the systematics and biography of Australia aquatic Neuroptera*. CRCFE/MDFRC Identification Guide Series No.49, CRCFE, Albury.

Serafini, L.G. and P, Humphries. 2004. *Preliminary guide to the identification of larvae of fish, with a bibliography of their studies, from the Murray Darling Basin*. CRCFE/MDFRC Identification Guide Series No.48, CRCFE, Albury.

Theischinger, G. and Hawking, J.H. 2003. *Dragonflies of Victoria. An identification guide to adult and larval dragonflies (Odonata)*. CRCFE/MDFRC Identification and Ecology Guide Series, No.46, CRCFE, Albury.

Timms, B. V. 2004. *An identification guide to the fairy shrimps (Crustacea: Anostrace) of Australia*. CRCFE/MDFRC Identification Guide Series No.47, CRCFE, Albury.

Walker, K.F. 2004. *A guide to the provisional identification of the freshwater mussels (Unionoida) of Australasia*. CRCFE/MDFRC Identification Guide Series No.51, CRCFE, Albury.

Refereed journal articles

Adam, K., Baldwin, D.S., Lindoy, L.F., Meehan, G., Vasilescu, I. and Wei, G. 2003. Metal-Ion-Recognition. Modelling the stability constants of some mixed-donor macrocyclic metal ion complexes - a simple Model. *Inorganica Chimica Acta* **352**, 46-50.

Arthington, A.H. and Pusey, B.J. 2003. Flow restoration and protection in Australian rivers. *River Research and Applications* **19**, 377-395.

Arthington, A.H., Rall, J.L. Kennard, M.J. and Pusey, B.J. 2003. Environmental flow requirements of fish in Lesotho Rivers using the DRIFT methodology. *River Research and Applications* **19**, 641-666.

Baker, A.M., Bartlett, C., Bunn, S.E., Goudkamp, K., Sheldon, F. and Hughes, J.M. 2003. Cryptic species and morphological plasticity in long-lived bivalves (Unionoida : Hyriidae) from inland Australia. *Molecular Ecology* **12**, 2707-2717.

Baker, A.M., Hurwood, D.A., Krogh, M., and Hughes, J.M. (In press) Mitochondrial DNA signatures of restricted gene flow within divergent lineages of an atyid shrimp (*Paratya australiensis*). *Heredity*.

Baker, A.M., Williams, S.A. and Hughes, J.M. 2003. Patterns of spatial genetic structuring in a hydropsychid caddisfly (*Cheumatopsyche* sp. AVI) from south-eastern Australia. *Molecular Ecology* **12**, 3313-3324.

Baldwin, D.S., Rees, G.N., Edwards, M., and Robertson, A.I. 2003. A simple, reproducible substrate for studying biofilms in aquatic environments. *Environmental Technology* **24**, 711-717.

Baldwin, D.S., Whittington, J., and Oliver, R. 2003. Temporal variability of dissolved P speciation in a eutrophic reservoir - implications for predicating algal growth. *Water Research* **37**, 4595-4598.

Baldwin, D.S., Rees, G.N., Mitchell, A.M., Watson, G.O. and Williams, J.L. (In press) The effects of acute salinisation on anaerobic nutrient cycling and microbial community structure in sediment from a freshwater wetland. *Biogeochemistry*.

Ballinger, A., Mac Nally, R. and Lake, P.S. 2003. The effects of coarse woody debris and flooding on terrestrial invertebrate assemblages in river red gum *Eucalyptus camaldulensis* (Dehnh.) floodplain forest. *Records of the South Australian Museum Monograph Series* **7**, 145-151.

Barton, J.L. and Metzeling, L. 2004. The development of biological objectives for streams in a single catchment: A case study on the catchment of Western Port Bay, Victoria, Australia. *Environmental Monitoring and Assessment* **95**, 239-256.

Bearlin, A.R., Schreiber, E.S.G., Nicol, S.J., Strafield, A.M. and Todd, C. R. 2002. Identifying the weakest link: simulating adaptive management of reintroduction of a threatened fish. *Canadian Journal of Fisheries and aquatic Sciences* **59**, 1709-1716.

Bond, N. and Lake, P.S. 2003. Local habitat restoration in streams: Constraints on the effectiveness of restoration for stream biota. *Ecological Management and Restoration* **4**, 193-198.

Bond, N. and Lake, P.S. 2003. Characterising fish-habitat associations in streams as the first step in ecological restoration. *Austral Ecology* **28**, 611-621.

Bowles, K., Apte S., Maher, W.A., and Bluhdorn, D. 2003. Mercury cycling in Lake Gordon and Lake Pedder, Tasmania, Australia. 1: In-lake processes. *Water, Air and Soil Pollution* **147**, 3-23.

Bowles, K., Apte S., Maher, W.A., and Bluhdorn, D. 2003. Mercury cycling in Lake Gordon and Lake Pedder, Tasmania, Australia. 2:Catchment processes. *Water, Air and Soil Pollution* **147**, 25-38.

Brock, M.A., Nielsen, D.L., Shiel, R.J., Green, J.D. and Langley, J.D. 2003. Drought and aquatic community resilience: the role of eggs and seeds in sediments of temporary wetlands. *Freshwater Biology* **48**, 1207-1218.

Bunn, S.E., Davies, P.M. and Winning, M. 2003. Sources of organic carbon supporting the food web of an arid zone floodplain river. *Freshwater Biology* **48**, 619-635.

Capon, S.J. 2003. Plant community responses to wetting and drying in a large arid floodplain. *River Research and Applications* **19**, 509-520.

Carini, G. and Hughes, J.M. (In press). Past and present patterns of connectivity among populations of the freshwater prawn *Macrobrachium australiense* in inland rivers in Queensland Australia. *Heredity*.

Chenoweth, S.F. and Hughes, J.M. 2003. Speciation and phylogeography in *Caridina indistincta*, a complex of freshwater shrimps from Australian heathland streams. *Marine and Freshwater Research* **54**, 807-812.

Choquenot, D., Nicol, S. and Koehn, J. (In press) Bioeconomic modelling in the development of invasive species policy. *New Zealand Journal of Marine and Freshwater Research* **38**.

Clapcott, J.E. and Bunn, S.E. 2003. Can C4 plants contribute to the aquatic food webs of subtropical streams? *Freshwater Biology* **48**, 1105-1116.

Cook, R., Humphries, P. and Richardson, A. (In press) Persistence of macroinvertebrate communities in lowland rivers. *Freshwater Biology*.

Cranston, P.S., Hillman, T.J. and Cook, R. (In press) The use of chironomid pupal exuviae in environmental assessment. *Proceedings of the Australian Entomological Society*, Hobart.

Crook, D.A. 2004. A method for externally attaching radio transmitters to minimize dermal irritation. *Journal of Fish Biology*, **64**, 258-261.

Crook, D.A. 2004. Is the home range concept compatible with the movements of two species of fish in an Australian lowland river? *Journal of Animal Ecology* **73**, 353-366.

Doody, J.S., Sims, R. and Georges, A. 2003. Gregarious behaviour does not dilute predation risk in pig-nosed turtles. *Copeia* **2003**, 894-898.

Doody, J.S., West, P. and Georges, A. 2003. Beach selection in nesting pig-nosed turtles, *Carettochelys insculpta*. *Journal of Herpetology* **37**, 178-182.

Doody, J.S., Georges, A. and Young, J.E. 2003. Twice every second year: reproduction in the pig-nosed turtle, *Carettochelys insculpta*, in the wet-dry tropics of Australia. *Journal of Zoology* **259**, 179-188.

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* **81**, 1-16.

Douglas, G.B., Ford, P.W., Jones, G.J. and Palmer, M.J. 2003. Identification of sources of sediment to Lake Samsonvale (North Pine Dam), south-east Queensland, Australia. *Intl. Assoc. Hydrol. Sci. Sp. Publ. Red Book* **279**, 33-42.

Doyle, C.J., Pablo, Lim, R.P., and Hyne, R.V. 2003. Assessment of metal toxicity in sediment pore-water from Lake Macquarie, Australia. *Archives of Environment Contamination and Toxicology* **44**, 343-350.

Ebner, B., Raadik, T. and Ivantsoff, W. 2003. Threatened fishes of the world: *Craterocephalus fluviatilis* McCulloch, 1913 (Atherinidae). *Environmental Biology of Fishes* **68**, 390.

Georges, A., Arthington, A.H. and Horwitz, P. 2003. Preface. Freshwater Biodiversity in Australia. Special issue of *Aquatic Ecosystem Health & Management* **6**, 3-4.

Georges, A., Beggs, K., Young, J.E. and Doody, J.S. (In press) Modelling reptilian development under fluctuating temperature regimes. *Physiological and Biochemical Zoology.*

Gribben, D.L., Rees, G.N. and Croome, R.L. 2003. Anoxygenic phototrophic bacteria and aerobic phototrophs in Normans Lagoon, a “billabong” adjacent to the Murray River, south-eastern Australia. *Lakes and Rivers Research and Management* **8**, 95-104

Hart, B.T., Lake, P.S., Webb, J.A., and Grace, M.R. 2003. Ecological risk to aquatic systems from salinity increases. *Australian Journal of Botany* **51**, 689-702.

Hatt, B.E., Fletcher, T.D., Walsh, C.J. and Taylor, S.L. (In press) The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management*.

Hawking, J.H. and Theischinger, G. 2004. Critical species of Odonata in Australia. *In:* Guardians of the watershed. Global status of Odonata: critical species, threats and conservation. Clausnitzer, V. and Joedicke R (Eds). *International Journal of Odonatology* **7**, 113-132.

Hawking, J., Suhling, F., Wilson, K., Theischinger, G. and Reels, G. 2004. Underwater and epilithic oviposition by Australian Aeshnidae (Odonata). *International Journal of Odonatology* **7**, 33-36.

Hazell, D., Osborne, W. and Lindenmayer, D. 2003. Impact of post-European stream change on frog habitat; south-eastern Australia. *Biodiversity and Conservation* **12**, 301-320.

Heck, D. 2003. The state of environmental education in the Australian school curriculum. *Australian Journal of Environmental Education* **19**, 115-124.

Hudson, P. Sheldon, F. and J. Costelloe. 2003. Aquatic macroinvertebrate biodiversity in the western Lake Eyre Basin: the role of naturally fluctuating salinity. *Records of the South Australian Museum Monograph Series* **7**, 135-144.

Hughes, J.M., Goudkamp, K., Hurwood, D.A., Hancock, M. and Bunn, S.E. 2003. Translocation causes extinction of a local population of the Glass Shrimp, *Paratya australiensis*. *Conservation Biology* **17**,1007-1012.

Hughes, D.A., Hughes, J.M., Bunn, S.E. and Cleary, C. 2003. Population structure in the freshwater shrimp (*Paratya australiensis*) inferred from allozymes and mitochondrial DNA. *Heredity* **90**, 64-70.

Hughes, J.M. and Hillyer, M.J. 2003. Patterns of connectivity among populations of *Cherax destructor* (Decapoda : Parastacidae) in western Queensland, Australia. *Marine and Freshwater Research* **54**, 587-596.

Hughes, J.M., Hillyer, M. and Bunn, S.E. 2003. Small-scale patterns of genetic variation in the mayfly *Bungona narilla* (Ephemeroptera: Baetidae) in rainforest streams, south-east Queensland. *Freshwater Biology* **48**, 709-717.

Hughes, J.M., Mather, P.B., Hillyer, M.J., Cleary, C. and Peckarsky, B. 2003. Genetic structure in a montane mayfly *Baetis bicaudatus* (Ephemeroptera : Baetidae), from the Rocky Mountains, Colorado. *Freshwater Biology* **48,** 2149-2162.

Humphries, P. (In press). Spawning time and early life history of Murray cod. *Environmental Biology of Fishes*.

Humphries, P. and Baldwin, D.S. (eds). 2003. Drought in Aquatic Environments. Special edition of *Freshwater Biology* **48**, 1141-1283.

Humphries, P. and Baldwin, D.S. 2003. Drought and aquatic ecosystems: an introduction. *Freshwater Biology* **48**, 1141-1146.

Hunt, R.J., Vlad, M., Jones, G.J. and Warburton, K. 2003. Structuring of the cyanobacterial community by pelagic fish in subtropical reservoirs: experimental evidence from Australia. *Freshwater Biology* **48**, 1-14

Hyne, R.V., Leonard, A., Pablo, F. and Ahmad, N. (In press) Comparison of time-integrated pesticide concentrations determined from field deployed passive samplers with daily river water extractions. *Environmental Toxicology and Chemistry*.

Jackson, J.E., Raadik, T.A., Lintermans, M. and Hammer, M. (In press) Alien salmonids in Australia: impediments to effective impact management, and future directions. *New Zealand Journal of Marine and Freshwater Research*.

Kennard, M.J., Arthington, A.H., Pusey, B.J. and Harch, B.D. (In press) Are alien fish a reliable indicator of river health? *Freshwater Biology*.

Kennedy, S.A., Ganf, G.G. and Walker, K.F. 2003. Does salinity influence the distribution of exotic willows (*Salix* spp.) along the Lower River Murray? *Marine and Freshwater Research* **54**, 825-831.

King, A.J., Humphries, P. and Lake, P.S. 2003. Use of floodplain environments during high and low flow conditions by larval and juvenile fish. *Canadian Journal of Fisheries and Aquatic Sciences* **69**, 773-786.

Koehn, J.D. 2004. Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology* **49,** 1-13.

Koehn, J.D. and Mackenzie, R.F. (In press) Priority management actions for alien freshwater fish species in Australia. *New Zealand Journal of Marine and Freshwater Research* **38**.

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* **13**, 89-96.

Lake, P.S. 2003. Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology* **48**, 1161-1172.

Lake, P.S. and O'Dowd, D.J. 2003. Guest editors of Special Section: Invasive species in Freshwaters: Impacts and Distributions. *Freshwater Biology* **48**(6).

Linke, S. and Norris, R. 2003. Biodiversity: bridging the gap between condition and conservation. *Hydrobiologia* **500**, 203-211.

Mackay, S.J., Arthington, A.H., Kennard, M.J. and Pusey, B.J. 2003. Spatial variaiton in the distribution and abundance of submersed macrophytes in an Australian subtropical river. *Aquatic Botany* **77**, 169-186.

MacNally, R. and Walsh, C.J. 2004. Hierarchical partitioning public-domain software. *Biodiversity and Conservation* **13**, 659-660.

Maddock, I., Thoms, M.C., Jonson, K., Dyer, F. and Lintermans, M. 2004. Identifying the influence of channel morphology on physical habitat availability for native fish: application to the two-spined blackfish (*Gadopsis bispinosus*) in the Cotter River, Australia. *Marine and Freshwater Research* **55,** 173-184.

Maher, W.A. and Batley G.E. 2003. Smart environmental sampling: obtaining information not just data. *Chemistry in Australia* **70**, 15-18.

Manuel, J. de and Shiel, R.J. (In press) Billabong biodiversity: the rotifers of floating *Azolla* and *Ricciocarpus* mats. *Arch. Hydrobiol.*

Marshall, J., Hoang, H., Choy, S. and Recknagel, F. 2003. Relationships between habitat properties and the occurrence of macroinvertebrates in Queensland streams (Australia) discovered by a sensitivity analysis with artificial neural networks. *Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie* **28**, 1415-1419.

Meredith, S.N., Matveev, V.F and Mayes, P. 2003. Spatial and temporal variability in the distribution and diet of gudgeon (Eleotridae: *Hypseleotris* spp.) in a subtropical Australian reservoir. *Marine and Freshwater Research* **54**, 1009-1017.

Metzeling, L., Chessman, B., Hardwick, R. and Wong, V. 2003. Rapid assessment of rivers using macroinvertebrates: the role of experience, and comparisons with quantitative methods. *Hydrobiologia* **510**, 39-52.

Muschal, M. and Warne, M.St.J. 2003. Risk posed by pesticides to aquatic organisms in rivers of northern inland New South Wales, Australia. *Human and Ecological Risk Assessment* **9**, 1765 - 1787.

Newall, P. and Walsh, C.J. (In press) Response of epilithic diatom assemblages to urbanization influences. *Hydrobiologia*.

Nicol, J.M., Ganf, G.G. and Pelton, G.A. 2003. Seed banks of a southern Australian wetland: the influence of water regime on final species composition. *Plant Ecology* **168**, 191-205.

Nielsen, D.L., Brock, M., Rees, G.N. and Baldwin, D.S. 2003. The effect of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany* **51**, 655-665

Nielsen, D.L., Brock, M.A., Crosslé, K., Harris, K., Healey, M. and Jarosinski, I. 2003. The effects of salinity on aquatic plant germination and zooplankton hatching from two wetlands sediments. *Freshwater Biology* **48**, 2214-2223.

Nielsen, D.L., Shiel, R.J. and Green, J.D. (In press) Are successional patterns in billabongs the same? *Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie* **28**.

Oliver, R.L. and Whittington, J. (In press). Abstract. Probing the inner cell: changes in variable chlorophyll-a fluorescence identify phytoplankton responses to fluctuating irradiance at micro- and macro-scales. *Verh. Int. Ver. Limnol.* **27**.

Oliver, R.L., Whittington, J., Lorenz, Z. and Webster, I.T. 2003. The influence of vertical mixing on the photoinhibition of variable chlorophyll-a fluorescence and its inclusion in a model of phytoplankton photosynthesis. *Journal of Plankton Research* **25**, 1107-1129.

Orr, P.T., Jones, G.J., Hunter, R.A. and Berger, K. 2003. Exposure of beef cattle to subclinical doses of *Microcystis aeruginosa*: toxin bioaccumulation, physiological effects and human health risk assessment. *Toxicon* **41**, 613-620.

Orr, P.T., Jones G.J. and Douglas, G.B. 2004. Response of cultured *Microcystis aeruginosa* from the Swan River, Australia, to elevated salt concentration and consequences for bloom and toxin management in estuaries. *Marine and Freshwater Research* **55**, 277-283.

Parsons, M.E., Thoms, M.C and Norris, R.H. 2003. Scales of macroinvertebrate distribution in relation to the hierarchical organization of river systems. *Journal of the North American Benthological Society* **22**, 105-122.

Poff, L.N., Allan, J.D., Palmer, M.A., Hart, D.D., Richter, B.D., Arthington, A.H., Rogers, K.H., Meyer, J.L., and Stanford, J.A. 2003. River flows and water wars: emerging science for environmental decision-making. *Front. Ecol. Environ. 2003* **1**, 298–306.

Regel, R.H., Brookes, J.D. and Ganf, G.G. 2004. Vertical migration, entrainment and photosynthesis of the freshwater dinoflagellate, *Peridinium cinctum* in a shallow urban lake. *Journal of Plankton Research* **26**, 143-157.

Regel, R.H., Brookes, J.D., Ganf, G.G. and Griffiths, R.W. 2004. The influence of experimentally generated turbulence on the MashO1 unicellular *Microcystis aeruginosa* strain. *Hydrobiologia* **517**, 107-120.

Reid, M.A. and Quinn, G.P. (In press) Hydrological regime and macrophyte assemblages in temporary floodplain wetlands: implications for detecting responses to environmental water allocations. *Wetlands* **24**.

Ricci, C., Shiel, R., Fontaneto, D. and Melone, G. 2003. Bdelloid rotifers recorded from Australia with description of *Philodinavus aussiensis* n.sp. *Zoologischer Anzeiger* **242**, 241-248.

Richardson, A.J., Growns, J.E. and Cook, R.A. 2004. Distribution and life history of caridean shrimps in regulated lowland rivers in southern Australia. *Marine and Freshwater Research* **55**, 295-308.

Schreiber, E.S.G., Bearlin, A.R., Nicol, S.J., and Todd, C. R. (In press) Adaptive management: the way forward or an excuse for ad-hoc, unplanned changes in monitoring? *Ecological Management and Restoration*.

Sheldon, F., Boulton, A.J. and Puckridge, J.T. 2003. Variable connection structures invertebrate composition in dryland rivers. *Records of the South Australian Museum Monograph Series* **7**, 119-130.

Shiel, R.J., Green, J.D. and Duggan, I. (In press). Biogeography of southern Australia-New Zealand rotifers: sweepstakes dispersal or Gondawanan connection? *Developments in Hydrobiology*.

Siebentritt, M., Ganf, G.G. and Walker, K.F. (In press) Effects of an enhanced flood on riparian plants of the River Murray, South Australia. *River Research & Applications*.

Sloane, P.I.W. and Norris, R.H. 2003. Relationship of AUSRIVAS-based macroinvertebrate predictive model outputs to a metal pollution gradient. *Journal of the North American Benthological Society* **22**, 457-471.

Smith, B.B. and Walker, K.F. 2003. Validation of the aging of 0+ carp (*Cyprinus carpio* L). *Marine and Freshwater Research* **54**, 1005-1008.

Smith, B.B. and Walker, K.F. 2004. Spawning dynamics of common carp in the River Murray South Australia, shown by macroscopic and histological staging of gonads. *Journal of Fish Biology* **64**, 336-354.

Smith, B.B. and Walker, K.F. (In press) Reproduction of common carp in Australia, shown by young-of-the-year samples and histological staging of ovaries. *Transactions of the Royal Society of South Australia*.

Taylor S. L., Roberts S. C., Walsh C. J., and Hatt B. E. 2004. Catchment urbanisation and increased benthic algal biomass in streams: linking mechanisms to management. *Freshwater Biology* **49**, 835-851.

Thoms, M.C. 2003. Floodplain-river ecosystems: lateral connections and the implications of human interference. *Geomorphology* **56**, 335-349.

Thoms, M. C. and Parsons, M. 2003. Identifying spatial and temporal patterns in the hydrological character of the Condamine-Balonne River, Australia, using multivariate statistics. *River Research and Applications* **19**, 443-457.

Todd, C.R., Nicol, S.J. and Koehn J.D. 2004. Density-dependence uncertainty in population models for the conservation of trout cod, *Maccullochella macquariensis*. *Ecological Modelling* **171**, 359-380.

Walsh, C. J. 2004. Protection of in-stream biota from urban impacts: to minimize catchment imperviousness or to improve drainage design? *Marine and Freshwater Research* **55**, 317-326.

Walsh, C.J., Papas, P.J., Crowther, D., Sim, P.T. & Yoo, J. 2004. Stormwater drainage pipes as a threat to a stream-dwelling amphipod of conservation significance, *Austrogammarus australis*, in south-eastern Australia. *Biodiversity and Conservation* **13,** 781-793.

Westwood, K.J. and Ganf, G.G. 2004. Effect of mixing and light dose on the growth of *Anabaena circinalis* in a turbid lowland river. *River Research and Applications* **20**, 115-126.

Wishart, M.J., and Davies, B.R. 2003. Beyond catchment considerations in the conservation of lotic biodiversity. *Aquatic Conservation-Marine and Freshwater Ecosystems* **13**, 429-437.

Wishart, M.J. and Hughes, J.M. 2003. Genetic population structure of the net-winged midge, *Elporia barnardi* (Diptera: Blephariceridae) in streams of the south-western Cape, South Africa: implications for dispersal. *Freshwater Biology* **48**, 28-38.

Non-refereed publications

Adams, J. 2004. *Narran Lakes Ecosystem Project Newsletters* numbers 2–5. CRC for Freshwater Ecology, Goondiwindi, Queensland. Available at: http://mooki.canberra.edu.au/narran

Bald, M. and Sinclair, R. 2004. Freshwater schools popular. *Watershed*, April 2004, p. 6. CRCFE.

Bunn, S.E. 2003. Monitoring river ecosystem health. *Portal* **29**, 34-35.

CRCFE 2003. Snags shape river ecosystems. *Canberra Times* 'Water' supplement, 22 October 2003, p. 18 (taken from CRCFE 'Snags' brochure).

CRCFE. 2004. Blue-green algae. Fact sheet, CRC for Freshwater Ecology. Available at http://freshwater.canberra.edu.au > publications

Doody, S. and Osborne, W. 2003. Animal ways in rice bays a year spent with vertebrates on rice farms. *In a Rice Hull. IREC Farmers' Newslettetter, Rice R&D Edition* **162**, Summer 2003.

Doody, S., Osborne, W. and Bourne, D. 2004. Reconciling farming and wildlife - vertebrate biodiversity in Riverina rice fields, *In a Rice Hull. IREC Farmers' Newslettetter, Rice R&D Edition* **165**, Summer 2004, 21-23.

Gigney, H. 2004. *Extra winter flow in the Murrumbidgee restores function to the ecosystem*. Brochure. CRCFE, Canberra.

Gigney, H. and Gawne, B. 2003. Use of stable isotopes of carbon and nitrogen to interpret food webs in three Australian lowland rivers with different flow regimes. Component of final report to CRC Freshwater Ecology.

Humphries, P. 2003. Blandowski misses out: ichthyological etiquette in 19th century Australia. *Endeavour*, Dec. 2003.

Jones, G. 2003. Towards a national river classification scheme based on human values. *Watershe*d, September 2003, p.1. CRC for Freshwater Ecology.

Jones, G. 2003. Recovering from the Australian drought. *SIL News* 40, September 2003, p.6. (Reprinted, abridged, from *Watershed*, December 2002.)

Jones, G. 2003. Science not the sole decider of river health. *Canberra Times* 'Water' supplement, 22 October, p. 6. Rural Press.

Jones, G. 2003. The scientific journey behind the Living Murray process. *Watershed*, December 2003, p. 1. CRCFE.

Jones, G. 2004. Murray advice 'the best ever'. *The Land*, 22 April, p.18. Rural Press.

Jones, G. 2004. A proposed new integrated CRC to address Australia's water future. Watershed, April 2004, p. 1. CRCFE.

Jones, G. 2004. From science to adoption: the Living Murray experience. *SIL News* 42, May 2004, p. 10.

Lintermans, M. 2003. Perch relocation a good move. *Canberra Times* 'Water' supplement, 22 October 2003, p. 19.

Marchant, R. 2004. Book review: Bioassessment of Freshwater Ecosystems using the Reference Condition Approach. *Watershed*, April 2004, p. 8. CRCFE.

Milligan, A. 2003. Earth, air, fire and water. *Canberra Times* 'Recovery' supplement, 24 August 2003, p.56. Rural Press.

Milligan, A. 2003. Online training for measuring river health with AUSRIVAS. *Watershed*, September 2003, p.4. CRC for Freshwater Ecology.

Milligan, A. 2003. Developing a northern river having learnt from the past. *Watershed*, September 2003, p.8. CRC for Freshwater Ecology. Reprinted in *Irrigation and Water Resources*, Summer issue 2003.

Milligan, A. 2003. Sustainable environment = sustainable economy. *Watershed*, December 2003, p. 8. CRCFE

Milligan, A. 2004. CRC for Freshwater Ecology: Innovative approaches in large-scale river management. Case study in: Bowmer, K. (ed.) *Water Innovation: A New Era for Australia*. CL Creations Pty Ltd, Lane Cover NSW. p. 98.

Milligan, A. 2004. CRCs Water Forum: Researchers putting the water industry in front. In: Bowmer, K. (ed.) *Water Innovation: A New Era for Australia*. CL Creations Pty Ltd, Lane Cover NSW. p. 37.

Nelson, T. and Milligan, A. 2003. Fires spark change. *Bendigo Advertiser*, 24 July. (Reprinted, abridged, from *Watershed* May 2003.)

Nielsen, D.L. and Brock, M. A. 2003. Wetland salinity: predicting the ecological consequences. Fact Sheet No. 2 – Aquatic Invertebrates. Department of Infrastructure, Planning and Natural Resources, NSW.

Norris, R. 2004. Decision on ACT's water future cannot be rushed. *Canberra Times* 12 Feb.

Rees, G., Baldwin, D. and Gigney, H. 2004. Mussel deaths in the Cattanach Canal: a desktop investigation into potential mechanisms leading to mortality. Murray Darling Freshwater Research Centre.

Rennie, B. 2004. Turtles a part of irrigated rice landscape. *Irrigation & Water Resources*, Winter 2004, p. 33. Rural Press.(Reprinted from *Watershed*, Feb. 2003.)

Scott, A. 2003. Tapping into local knowledge. *Watershed*, September 2003, p. 6. CRC for Freshwater Ecology.

Scott, A., Milligan, A., Rennie, B. 2003. MFAT: transparent in process if not in name. *Watershed*, Dec. 2003, p. 4. CRC for Freshwater Ecology.

Sellens, C. and Milligan, A. 2004. Good management practice as a benchmark for river assessment. Watershed, April 2004, p. 4. CRCFE.

Sheldon, F. and colleagues. 2003. *Dryland River Refugia*. Newsletter no. 2, December 2003. CRC for Freshwater Ecology, Griffith University, Queensland. Available at: http://freshwater.canberra.edu.au > publications

Sheldon, F. 2003. *Quantifying Health in Ephemeral Rivers.* Newsletter no. 1. CRC for Freshwater Ecology, Griffith University, Queensland. November 2003.

Sheldon, F. 2004. *Quantifying Health in Ephemeral Rivers.* Newsletter no. 2. CRC for Freshwater Ecology, Griffith University, Queensland. May 2004.

Southwell, M. and McGinness, H. 2004. Anabranch channels of the Macintyre River. Fact sheet, CRC for Freshwater Ecology, Canberra. Available at http://freshwater.canberra.edu.au > publications

Storey, A.W., Halse, S.A. and Shiel, R.J. (In press) Aquatic fauna and water chemistry. CALM Science. Dept of Conservation and Land Management, W.A.

Tarte, D., Bunn, S., Abal, E. and Curtis, L. 2003. Moreton Bay Waterways and Catchments partnership: implementing an adaptive management framework. Moreton Bay Waterways and Catchments Partnership, Science update, 8pp.

Consultancy and technical reports

Anon. 2004. *Decision-support framework for urban stormwater management to protect the ecological health of receiving waters*. CRC for Freshwater Ecology and CRC for Catchment Hydrology. Report to New South Wales Environment Protection Authority.

Baldwin, D.S., Campbell, B., Frankenberg, J., Hillman, T., King, A., Koehn, J. and Ward, K. 2003. *Final Report Living Murray Regional Evaluation Group B (Hume Dam to Yarrawonga Weir)*. Report to MDBC.

Barlow, A., Nichols, S. and Norris, R. 2003. *AUSRIVAS Training Resources: Final Report*. CRC for Freshwater Ecology. Report to Environment Australia.

Barlow, A., Nichols, S. and Norris, R. 2003. *Australian River Assessment System (AUSRIVAS) Site Selection: A Guide for Regional Managers and Community Groups*. Environment Australia.

Barlow, A., Nichols, S. and Norris, R. 2003. *Australian River Assessment System (AUSRIVAS) Internal Quality Assurance and Quality Control (QA/QC): A Guide for Regional Managers and Community Groups*. Environment Australia.

Barlow, A., Dann, R., Kotlash, A., Norris, R., Thoms, M. 2003. *Environmental position of Lake Keepit, the Namoi River and the potential influence of proposed Dam upgrade works*. Literature review for State Water, Minister of Energy and Utilities.

Bunn, S., Cottingham, P., Brooks, A., Croker, K., Davies, P.M., Glaister, A., Hughes, V., Jackson, M., Koehn, J., Lake, S., Marsh, N., Nicol, S., Rutherfurd, I., Seymour, S. and Treadwell, S. 2003. *Managing Large Woody Debris in Australian Streams and Rivers*. Riparian Land Management Technical Guide Update Number 3, May 2002. CRC for Freshwater Ecology. Report to Land and Water Australia.

Conallin, A. and Hammer, M. 2003. *Temporal monitoring of selected fish communities in relation to environmental variability in the Mt Lofty Ranges, South Australia*. MDFRC Technical Report 7/2003.

Conallin, A., McCarthy, B., McCasker, N. and Walsh, R. 2003. *Aquatic Survey of Purda Billabong, Wentworth NSW*. MDFRC Technical Report 4/2003.

Cottingham P., Crook D., Hillman T., Roberts J., Rutherfurd I. and Stewardson M. 2003. *Flow-related environmental issues associated with the Goulburn River below Lake Eildon*. CRC Freshwater Ecology and CRC Catchment Hydrology. Report to DSE Victoria and the MDBC.

Dann, R., Norris, R. and Barlow, A. 2003. *Biological Assessment of River Health: A Summary for Regional Managers and Community Groups*. CRC for Freshwater Ecology. Summary report to Environment Australia.

Dickson, A., Lemann, C. and Norris, R.H. 2003. ACT Water quality monitoring program. Macroinvertebrate component. Autumn 2003. ACT Monitoring. CRC for Freshwater Ecology. Report to Environment ACT, Department of Urban Services.

Dickson, A., Lemann, C. and Norris, R.H. 2003. ACT Water quality monitoring program. Macroinvertebrate component. Spring 2003. CRC for Freshwater Ecology. Report to Environment ACT, Department of Urban Services.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. February 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Tech. Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. March 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development, Euan Diver. CRCFE Technical report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. April 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. May 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. June 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. July 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. Aug 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dickson, A., Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River. September 2003.* Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRC for Freshwater Ecology Technical Report.

Dyer, F., and Davis, J. 2003. *Evaluation and management of shoreline erosion potential in Lake Wivenhoe and Lake Somerset.* A report to SEQ Water, Aug. 2003.

Dyer, F., Thoms, M.C. and Norris, R.N. 2003. *Cudgegong River Baseline Monitoring*. Report to the NSW Department of Land and Water Conservation. 80pp.

Erskine, W.D., Begg, G.W., Jolley, P., Georges, A., O'Grady, A., Eamus, P., Rae, N., Dostine, P., Townsend, S. and Padovan, A. 2003. *Recommended environmental water requirements for the Daly River, Northern Territory, based on ecological, hydrological and biological principles*. Supervising Scientist Division, Supervising Scientist, Darwin, NT. Report to Northern Territory Department of Infrastructure, Planning and Environment.

Gehrke, P., Bristow, K., Bunn, S., Douglas, M., Edgar, B., Finlayson, M., Hamilton, S., Loneragan, N., Lund, M., Pearson, R., Prosser, I. and Robson, C. 2004. *Sustainable Futures for Australia's Tropical Rivers*. CSIRO Land and Water Technical Report 17/2004.

Georges, A., Webster, I., Guarino, E., Thoms, M., Jolley, P., and Doody, J.S. 2003. *Modelling dry season flows and predicting the impact of water extraction on a flagship species*. Applied Ecology Research Group and CRC for Freshwater Ecology. Final Report for Project 23045.

Jones, G., Arthington, A., Gawne, B., Hillman, T., Kingsford, R., Thoms, M., Walker, K. and Young, B. 2003. *Ecological Assessment of Environmental Flow Reference Points for the River Murray System*. Interim Report prepared by the Scientific Reference Panel for the Murray-Darling Basin Commission, Living Murray Initiative. 164 pp.

King, A. and Koehn, J. 2003. *Ecological Assessment of Various Flow Scenarios in Regional Evaluation Group A (Mitta Mitta River), of the Living Murray Initiative*. Report to the Murray-Darling Basin Commission.

King, A., Brooks, J., Quinn, G., Sharpe, A., McKay, S. 2003. *Monitoring programs for environmental flows in Australia — a literature review*. Dept Sustainability and Environment, SKM and CRCFE.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River*. November 2002. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of the Thredbo River*. October 2003. Kosciuszko Thredbo Pty. Ltd. Manager of Property and Development – Euan Diver.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW*. Report for sampling period November 2002. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW*. Report for sampling period February 2002. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW.* Report for sampling period May 2002. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2003. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW*. Report for sampling period August 2003. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW*. Report for sampling period February 2004. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of water quality in four streams in Kosciuszko National Park, NSW*. Report for sampling period November 2003. NSW National Parks and Wildlife Service. KNP.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of the Thredbo River.November 2003*. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of the Thredbo River. December 2003*. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of the Thredbo River. January 2004*. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver.

Lemann, C. and Norris, R.H. 2004. *Biological monitoring of the Thredbo River. February 2004*. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver. CRCFE Technical Report.

Lemann, C. and Norris, R.H. 2004. *Burrangong Creek, Young. Macroinvertebrate identification and AUSRIVAS model results*. Terra Consulting, Orange, Dave Moore.

Lemann, C., Tingle, F. and Norris, R.H. 2004. *Biological monitoring of the Thredbo River. April 2004*. Kosciuszko Thredbo Pty. Ltd.Manager of Property and Development – Euan Diver.

Linke S., Ransom, G., and Norris, R.H. 2003. *Integration of ANNA into the AUSRIVAS software platform*. Report to Environment Australia.

Marshall J., Steward A., McGregor G., Marshall C., Negus P., Johnson D., Lobegeiger J., Davies P., Harch B, Winning M., Choy S., and Cockayne B. 2003. *Condamine-Balonne Integrated Monitoring Pilot Project: Methods*. Queensland Department of Natural Resources and Mines. Aquatic Ecosystems Technical Report No. 41.

McCarthy, B., Conallin, A. and Walsh, R. 2003. *Aquatic Survey of Bottle Bend Lagoon, near Buronga NSW: Salinisation and Acidification Impacts*. MDFRC Technical Report 2/2003.

McCarthy, B., Gawne, B., Meredith, S., Roberts, J. and Williams, D. 2004. *Effects of Weirs in the Mallee Tract of the River Murray*. Report to the Murray-Darling Basin Commission.

Nicol, S., Todd, C., Bearlin, A., Koehn, J., O'Mahony, J., McKenzie, J., Barker, R., Burgman, M., Reynolds, J. and Kolz, L. 2003. *Application of adaptive management to Australian freshwater fish: recovery of threatened Trout cod*. CRC for Freshwater Ecology. Final report Project C 210.

Norris, R.N and Thoms, M.C. 2003. *The condition of the Cudgegong River*. Report to the NSW Department of Land and Water Conservation. 68pp.

Oliver, R.L., Hart, B.T. and Olley, J. 2003. *Darling river algal growth and cycling and sources of nutrients*. CRC for Freshwater Ecology. Technical Report, 2003.

Ransom, G. (In press). *AUSRIVAS Mapping and Reference Site Screening Module Software User Manual.* CRC for Freshwater Ecology.

Roberts, J. and Williams, D.G. 2004. *Euston Lakes: River Red Gum Investigations*. Research Report 8 on the Effects of Weirs in the Mallee Tract of the River Murray. Report to the Murray-Darling Basin Commission.

Roberts, J. and Williams, D.G. 2004. *Littoral Vegetation in the Mallee Tract of the Murray River*. Research Report 6 on the Effects of Weirs in the Mallee Tract of the River Murray. Report to the Murray-Darling Basin Commission.

Arthington, A.H., Brizga, S.O., Choy, S.C., Kennard, M.J., Scholz, O. 2003. *Cyanobacterial blooms within the Mildura Weir pool 1996-2003*. MDFRC Technical Report 3/2003.

Scholz, O. and Gawne, B. 2004. *Guidelines for the management of ephemeral deflation basin lakes*. Report to the Murray-Darling Basin Commission.

Scholz O., Conallin, A., Sharpe, C., Meredith, S., McCasker, N. and Hoggard, B. 2003. *Monitoring the Darling Anabranch, NSW: a pilot study*. MDFRC Technical Report 1/2003.

Sharpe, C.P. and Meredith, S. 2003. *Measuring the Effects of Environmental Flows on Lindsay and Wallpolla Islands: Water Quality Monitoring Program 2003*. MDFRC Technical Report 9/2003.

Sharpe, C., Conallin, A., Walsh, R. and Roennfeldt, B. 2003. *Fish Survey of the Cardross Lakes 2003*. MDFRC Technical Report 8/2003.

Sheldon, F., Balcombe, S., Brunner, P. and Capon, S. 2003. *Ecological and Geomorphological Assessment of the Georgina-Diamantina River System*. Report to Queensland Department of Natural Resources and Mines.

Southwell, M.R and Thoms, M.C. 2004. *Bank erosion along the River Murray: processes, causes and management options*. A technical report to the Waterways Authority of New South Wales. 33p.

Tingle, F., Lemann, C. and Norris, R.H. 2004. *ACT Water quality monitoring program. Macroinvertebrate component. Autumn 2004*. CRC for Freshwater Ecology. Technical report to Environment ACT , Department of Urban Services.

Walsh, C.J., Leonard, A.W., Ladson, A.R. and Fletcher, T.D. 2004. *Urban Stormwater and the Environment*. CRC for Freshwater Ecology and CRC for Catchment Hydrology. Report to New South Wales Environment Protection Authority. http://www.wsc.monash.edu.au/ ~cwalsh/pdfs/NSWEPAcouncil_handbook_appB.pdf

Webb, J.A. and Chan, T.U. 2004, *Ecological Risk Associated with Irrigation Systems in the Goulburn-Broken Catchment – Phase II: Priority Risk – Blue Green Algal Blooms*. Appendix to: Feehan P "Ecological Risk Associated with Irrigation in the Goulburn Broken Catchment – Stage 2".

Whiterod, N. and Meredith, S. 2003. *Cyanobacteria mitigation in the Mildura Weir Pool - literature review*. MDFRC Technical Report 5/2003. 41pp.

Williams, J., Baldwin, D.S. and Nielsen, D. 2004. *Wetland and Floodplain Monitoring Handbook: A review of Methodologies*. CRC for Freshwater Ecology. Report to the Murray-Darling Basin Commission.

Wilson, G.G. and Adams, J.C. 2003. *Review of Designated Fishing Activity of Stocking – Environmental Impact Statement, New South Wales Fisheries*. 56 pages of emailed comments and corrections. CRC for Freshwater Ecology.

Zukowski, S., Meredith, S., Whiterod, N. and Walsh, R. 2003. *Ecological Responses to Wetland Flooding, Deniliquin NSW*. MDFRC Technical Report 6/2003. 39pp.

Software

Ransom, G. 2004. *'AUSRIVAS Mapping and Reference Site Screening Module' 1.0*. CRC for Freshwater Ecology. http://ausrivas.canberra.edu.au.

Ransom, G. and Blackman, P. 2003. *'AUSRIVAS Macroinvertebrate Predictive Modelling Software' 3.3*. CRC for Freshwater Ecology. http://ausrivas.canberra.edu.au.

Walsh C. and Mac Nally, R. 2003. "*The hier.part Package" Hierarchical Partitioning. Documentation for R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Conference proceedings

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. and Petr, T. (eds). *Proceedings of LARS2 (Large Rivers Symposium on Fisheries)*. Mekong River Commission, Phnom Penh, Cambodia. 45 pp.

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. and Petr, T. (eds). *Proceedings of LARS2 (Second Large Rivers Symposium on Fisheries)*. Mekong River Commission, Phnom Penh, Cambodia. 24 pp.

Bunn, S.E. 2003. River and floodplain ecosystems of the Lake Eyre Basin. *Proceedings of the Lake Eyre Basin Ministerial Forum, Biennial Conference.* 25-26 October 2002, Birdsville Queensland. pp18-20.

Crossle, K., Nielsen, D.L., Brock, M.A. and Harris, K. 2003. Aquatic plant emergence from wetland seed banks exposed to increasing salinity. Proceedings of the scientific conference (poster session) Moscow, 19 June 2002. In: Aquatic Ecosystems and Organisms-4, Ecological Studies, Hazards and Solutions Vol. 6.

Georges, A., Arthington, A.A. and Horwitz, P. 2003. Special issue – Freshwater Biodiversity in Australia. *Proceedings of the Fenner Conference on the Environment*, Canberra, July 2001. Aquatic Ecosystem Health & Management Volume 6, No. 1/January-March 2003.

Harris, J.H. 2003. Fish stocking and translocation in the Murray-Darling Basin: issues, benefits and problems. Keynote Address, In: B. Phillips, (ed.) *Managing Fish Translocation and Stocking in the Murray-Darling Basin*. *Proceedings of a workshop held in Canberra*, 25-26 September 2002. pp. 11–27.

Jones, G.J. 2004 (In press). Key drivers of water resources management and science in Australia. *Proceedings of New Zealand Royal Society Water Symposium*, Auckland, November 2003.

Jones, G.J. 2004 (In press). The use of scientific knowledge in the development and implementation of public policy: experiences with the River Murray environmental flows allocation process so far. *Proceedings of the AATSE - Joint Workshop on Water Resources in Australia and South Africa*, April 2, 2003.

Koehn, J.D. 2003. Riverine aquatic protected areas: protecting species, communities or ecosystem processes? In: Beumer, J.P., Grant, A. and Smith, D.C. (eds). *Aquatic Protected Areas - What works best and how do we know? Proceedings of the World Congress on Aquatic Protected Areas*, Cairns, Australia-August 2002. pp.614-624.

Koehn, J. 2003. Rationale, results and management implications of recent carp research in Australia. *Managing invasive freshwater fish in New Zealand. Proceedings of a workshop hosted by Department of Conservation*, 10-12 May 2001. pp.11-19.

Koehn, J., Stuart, I. and Crook, D. (In press). Linking the ecological importance of downstream fish movements to management of Murray-Darling Basin fish populations. *Proceedings of the workshop on downstream fish movements*. Murray-Darling Basin Commission, Canberra 2004.

Lintermans, M. and Raadik, T. 2003. Local eradication of trout from streams using rotenone: The Australian experience. *Managing Invasive Freshwater Fish in New Zealand. Proceedings of a workshop hosted by the Department of Conservation*. Hamilton, New Zealand, May 10-11 2001. pp. 95-111.

Nichols, S., Barlow, A., Norris, R.H., Gray, B., and Evans, L. 2004. AUSRIVAS online: bringing education, research and the water industry together. *AWA Conference Proceedings - Education: The Key to Sustainable Water Management*, Canberra. January 2004.

Osborne, W. and Hunter, D. 2003. Frog declines in the snowy Mountains: What do we know after 15 years? In: J. Mackay (ed). *Celebrating mountains - and international year of mountains conference*. Jindabyne. Pp. 81-88.

Presentations: public and conference

Aldridge, K. T., Brookes, J. D. and Ganf, G. G. 2003. Benthic metabolism in streams; can it be used to reflect a rural-urban gradient? Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1 – 5 December.

Aldridge, K. T., Brookes, J. D. and Ganf, G. G. 2003. Phosphorus retention in two ephemeral streams; changes along a rural-urban gradient. Presented at the Symposium for Urbanization and Stream Ecology, Melbourne.

Atkinson, B., Grace, M. and Hart, B. 2003. Ecosystem function responses to stream rehabilitation in the Granite Creeks (poster presentation). Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1 – 5 Dec.

Bald, M. 2003. Stormwater Ambdassador Program: aquatic food webs and wetland ecology. Mildura Rural City Council, November.

Baldwin, D. 2004. Science and the Murray. Presentation to the Murray River Campaigners, Melbourne, May.

Baldwin, D., Mitchell, A. and Rees, G. 2003. Sediment drying and P dynamics. Presented at the Fourth International Symposium on Phosphate in Sediments, Sevilla Spain, 9-12 September 2003.

Baldwin, D.S., Howitt, J. and Beattie, J. 2003. Abiotic degradation of organic P Compounds. Presented at Organic P 2003, Ascona, Switzerland, 13-18 July 2003.

Baldwin, D.S., Mitchell, A.M. and Rees, G.N. 2003. The Interactions of the Anaerobic Nutrient Cycling Processes and phosphate release from freshwater sediments. Presented at 4th International Symposium on Phosphate in Sediments, Carmona, Spain 9-12 Sept. 2003.

Bickford, G., Nicholls, D. and Gawne, B. 2003. Effects of a drought on productivity along the Murray River, a highly regulated Australian lowland river. Presented at theNinth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6 - 11 July 2003.

Bjorke, A., Ask, B. and Heck, D. 2003. United Nations University / Global Virtual University: Global co-operation on e-learning. Presented at the International Conference on Network Universities and e-learning, 8-9 May 2003, Valencia, Spain (http://www.hsh.no/menu/).

Bond, N.R. and Lake, P.S. 2003. The ecology of drought refugia in a lowland Australian stream network. Joint 42nd Australian Presented at the Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1 – 5 December 2003.

Bond, N.R., Perry, G., Lake, P.S., Cousins, K., Ho, S., Bluff, L. and Durant, R. 2003. Population dynamics in intermittent streams: the role of refugia in fish population persistence (poster presentation). Presented at the 2003 World Congress of the International Association for Landscape Ecology, Darwin, July.

Bowen, P., Williams, D. and Rees, G. 2003. Responses of In-stream Microbial Communities to Flow-Induced Changes in Carbon Sources (Poster presentation). Presented at the 2nd International Conference on Enzymes in the Environment: Activity, Ecology & Applications, Prague, The Czech Republic, 14-17July 2003.

Bowen, P., Williams, D. and Rees, G. 2003. Temporal and spatial variability in inputs of macrophyte organic matter to some Australian lowland rivers. Presented at the Ninth International Conference on River Research and Applications, Albury, NSW, 6-11 July 2003.

Boys, C. A. 2003. Correspondence between the spatial variability in fish communities and geomorphological patterns in a large dryland river. Presented at Ninth International Conference on River Research and Applications, Albury, NSW, July 6-11 2003.

Boys, C. A., Esslemont, G. and Thoms, M.C. 2003. Geomorphology and fish habitat use in a large dryland river. Presented at Ecology 2003: 28th Annual Conference of the Ecological Society of Australia, University of New England, Armidale NSW, 8 - 10 December 2003.

Brock, M. and Jarman, P. 2003. The evolving intent. Coverage and use of threatened species legislation in Australia. Presented at Royal Zoological of NSW Forum 2003, 'Threatened Species Legislation - is it just an Act', Sydney, October.

Bunn, S.E. 2003. Ecosystem measures of river health. Presented at the 51st Annual Meeting, North American Benthological Society, Athens, Georgia, USA, May.

Bunn, S.E. 2003. Monitoring River Ecosystem Health. Presented at the Annual Symposium, Ecology and Civil Engineering Society of Japan, Kitakyushu, Japan, October, 2003.

Bunn, S.E. 2003. Riparian and river linkages: opportunities for restoring aquatic ecosystem health. Presented at the Annual Symposium, Ecology and Civil Engineering Society of Japan, Kitakyushu, Japan, October, 2003.

Bunn, S.E. 2003. River ecosystem health. Presented at the Queensland Academy of Arts and Science Annual Symposium, Brisbane, September.

Bunn, S.E. 2003. River floodplains in semi-arid and arid Australia: present state and future trends. Presented at the Future of Aquatic Ecosystem, 5th International Conference on Environmental Future, Zurich, Switzerland, 26 March 2003.

Bunn, S.E. 2004. Ecosystem process measures of stream and river health. Presented at the Stream Community Metabolism Workshop: Status and Future Directions of the Approach as a Biological Tool for River Health Assessment, Royal Botanic Gardens, Sydney, 18-19 May 2004.

Bunn, S., Balcombe, S., Fry, V., Fellows, C., Hamilton, S. and Sippel, S. 2003. Importance of phytoplankton to aquatic food webs in Australian dryland rivers. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Bunn, S.E., Thoms, M.C., Hamilton, S.K. and Capon, S. 2003. Variability in dryland rivers: boom, bust and the bits in between. Presented at the Ninth International Conference on River Research and Applications, Albury, Australia, July 2003.

Catford, J., Walsh, C. and Beardall, J. 2003. The effect of light on benthic microalgae in streams of different catchment urbanization. Presented at the Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 December 2003.

Chester, H. 2003. Dammed flow in the Cotter River ACT: effects on trophic structure and benthic metabolism. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Conrick, C. and Choy, S. 2003. Long-term changes in water quality and macroinvertebrate communities in Southeast Queensland urban streams. Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 December, 2003.

Conrick, D., Choy, S. and Bycroft, B. 2003. River Health in Queensland - State of the Environment Reporting 2003. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Davies, P.M. and Bunn, S.E. 2003. Biomonitoring temporary streams: Issues and methodologies. Presented at the workshop on "Water Quality Issues in Final Voids, Salt Lakes and Ephemeral Streams." Australian Centre for Mining Environmental Research (ACMER) and Centre for Sustainable Mine Lakes, Perth, Western Australia, May 2003.

Cottingham P., Stewardson M., Crook D., Hillman T., Roberts J. and Rutherford I. 2003. Developing Environmental Flow Recommendations for the Goulburn River. Goulburn Broken Science Day, Dookie, 5 August.

Cottingham, P. 2003. River health in Australia: grappling with knowledge exchange. Presented to the Canadian Health Services Research Foundation Symposium on Knowledge Brokering, Montreal, October.

Fellows, C.S., Bunn, S.E., Beard, N.J., Clapcott, J.E., Thoms, M.C. and Davis, L. 2003. Algal productivity in dryland river refugia. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1–5 Dec. 2003.

Gawne, B. 2003. Briefing on the scientific assessment of potential environmental flow scenarios for the Living Murray. Presented at public meetings at: Benalla, Cobram, Yarrawonga, Shepparton, Kerang; and to Ministers Warren Truss, Ian Macdonald and Neil Andrew and their advisers, and to the Living Murray Community Reference Panel and the Living Murray Community Advisory Committee and stakeholders.

Gawne, B. 2003. Is there sufficient scientific evidence to warrant substantial intervention in, and resetting the agenda for, natural resource management in Australia? Symposium Debate focusing on the Murray-Darling Basin and the Great Barrier Reef, part of the Sixth International River Management Symposium (Urban Rivers – Balancing the expectations), 5 September.

Gawne, B. 2004. Presentation to Bellbridge/ Lake Hume Rotary Club. February.

Gawne, B. 2004. The relationship between ecology and hydrology and its influence on catchment management. CSIRO Land and Water, CSIRO Christian Lab Seminar Room, 9th February.

Gawne, B., Nielsen, D., Oliver, R., Rees, G., Hawking, J., Bowen, P., Gigney, H., Whiterod, N., Watson, G., Lorenz, Z. and Williams, D. 2003. Spatial and temporal variability in patterns of productivity in some Australian lowland rivers. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Gehrig, S.L., Walker, K.F. and Ganf, G.G. 2003. Response of riparian red gums (Eucalyptus camaldulensis) and exotic willows (*Salix babylonica*) to a natural drawdown and low precipitation event on the Lower Murray, South Australia. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1–5 December 2003.

Georges, A. 2003. Biodiversity of Australasian freshwater turtles. Powdermill V. Manaus, Brazil. 1-2 July, 2003. Invited talk.

Georges, A., Guarino, E., Webster, I., Jolly, P. and Thoms, M. 2003. Modelling the impact of flow regulation on a flagship species, the pig-nosed turtle. Presented at the Joint Meeting of the American Society of Ichthyologists and Herpetologists American Elasmobranch Society, Herpetologists League, and the Society for the Study of Amphibians and Reptiles, Manaus, Brazil. 26 June - 2 July, 2003.

Gigney, H., Gawne, B. and Hawking, J. 2003. Use of stable isotopes carbon and nitrogen to interpret food webs in three Australian Rivers with different flow regimes. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Grace, M. 2003. Environmental factors affecting release of organic phosphorus from sediments. Presented at Organic P 2003, Monte Verità - Ascona, Switzerland, 13-18 July 2003.

Grace, M. 2004. Open-water metabolism. Technical Considerations. Presented at the Joint CRCFE-NSW DEC Symposium on Stream Metabolism, Sydney, 18-19 May 2004.

Grace, M., Taylor, S. and Walsh, C. 2003. Urbanization effects on the metabolism of small streams. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Grace, M., Taylor, S. and Walsh, C. 2003. Urbanization effects on the metabolism of small streams. Presented at the Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 December 2003.

Grace, M., Taylor, S. and Walsh, C. 2004. Urbanization effects on the metabolism of small streams. Presented at the Joint CRCFE-NSW DEC Symposium on Stream Metabolism, Sydney, May 18-19 2004.

Harbott, E., Hart, B. and Grace, M. 2003. Extracellular enzyme response to dissolved organic carbon in urban streams (poster presentation). Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December.

Harbott, E., Hart, B. and Grace, M. 2003. Extracellular enzyme response to dissolved organic carbon in urban streams. Presented at the Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8-10 Dec. 2003.

Harbott, E.L., Hart, B.T. and Grace, M.R. 2003. Extracellular enzyme response to dissolved organic carbon in urban streams. Presented at the International Symposium on Enzymes in the Environment: Activity, Ecology and Applications, Prague, Czech Republic, 14-17 July 2003.

Hawking, J.H. 2003. Biodiversity and ecology of dragonflies (Odonata) from Victoria, Australia. Presented at the WDA International Odonatology Symposium, Beechworth, Victoria, 11-18 Jan. 2003.

Hawking, J.H. 2003. Dr J.A.L. Watson: an outstanding contribution to Australian Odonatology. Presented at the WDA International Odonatology Symposium, Beechworth, Victoria, 11-18 Jan. 2003.

Hawking, J.H. 2003. Ecological partitioning along a watercourse. Plenary Seminar. Presented at the WDA International Odonatology Symposium, Beechworth, Victoria, 11-18 January 2003.

Hawking, J.H. and Gawne, B. 2003. Effects of flow regimes on the structure of macroinvertebrate communities. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society Warrnambool, Victoria, 1-5 December 2003.

Hawking, J., Gawne, B., Gigney, H. and Whiterod, N. 2003. The effects of flow regimes on the structure of macroinvertebrate communities in three lowland rivers of south-eastern Australia. Presented at the Ninth International Conference on River Research and Applications, Albury, NSW, 6-11 July.

Holland, D, Grace, M.R. 2003. The Effects of Light and Nutrients on Phytoplankton from the Lower Darling River, NSW (poster presentation). Presented at the 42nd Australian Society for Limnology Congress, Warrnambool, Victoria, 1-5 December 2003.

Hughes, V. and Thoms, M.C. 2003. Large woody debris character and habitat scale hydraulics in the Murray River. Presented at the 28th Annual Conference of the Ecological Society of Australia, University of New England, Armidale NSW, 8-10 December 2003.

Humphries, P. 2003. Creating a disturbance: manipulating flows in slackwater habitats in lowland rivers'. Presented at the 2003 Goulburn-Broken Catchment Authority Research Forum, Dookie College, August 2003.

Humphries, P. 2003. Migration of golden perch: Myth or reality? Presented at the Murray-Darling Freshwater Research Centre seminar, July 2003.

Humphries, P. 2003. Spawning and early life history of Murray cod. Presented at the Murray-Darling Freshwater Research Centre seminar, May 2003.

Humphries, P. and King, A. 2003. Drifting fish larvae in Murray-Darling rivers: composition, timing and distance drifted. Presented at the Downstream Movement of Fish in the Murray-Darling Basin Workshop, Canberra, 3-4 June 2003.

Humphries, P., Cook, R., Richardson, A. and Serafini, L. 2003. Creating a disturbance: manipulating flows in slack waters of an Australian lowland river. Presented at the Ninth International Conference on River Research and Applications, Albury, NSW, 6-11 July 2003.

Kellar, C. 2003. Macroinvertebrate assemblages in temporary ponds: effects of varying hydroperiod duration. Presented to the Society of Wetland Scientists, New Orleans, USA.

Jones, G. 2003. Briefing on the scientific assessment of potential environmental flow scenarios for the Living Murray. Presented at three public meetings along the River Murray, Victoria, July.

Jones, G. 2003. Presentation on water management issues, to Australian Water Association. September.

Jones, G. 2004. Keynote address to Integration conference, Land & Water Australia, May 2004.

Lake, P.S. 2003. River to rivulet and back: Rehabilitating the Snowy River. Presented at the Snowy River Rehabilitation Information Day, Orbost, August 2003.

Lake, P.S. 2004. Restoring our rivers: the need for environmental flows. Public lecture at University of Canberra, May 2004. See http://freshwater.canberra.edu.au

Lake, P.S., Bond, N., Glaister, A. and Cousins, K. 2003. Restoration ecology in sand-slugged' creeks. Presented at the Goulburn-Broken Catchment Management Authority, conference on "River & Catchment Health", August 2003.

Lake, P.S., Downes, B.J., Glaister, A., Bond, N., Davis, J., and Rutherfurd, I.D. 2003. Catchments, streams and sand slugs—A study in scape ecology. Presented at the 2003 World Congress of the International Association for Landscape Ecology in Darwin, July 2003.

Linke S. and Norris R.H. 2003. Biodiversity: Bridging the GAP between condition and conservation. Presented at the NRHP workshop, Adelaide.

Linke S., Norris R.H. and Nelson, T. 2003. Comparing real and simulated impacts on aquatic communities. Presented at the North American Benthological Society annual conference, Athens, GA, U.S.A.

Lloyd, N., Quinn, G.P., Thoms, M.C., Arthington, A.H., Gawne, B., Humphries, P. and Walker, K.F. 2003. Ecological and geomorphological responses of rivers to flow modification for irrigation: an Australian perspective. Presented at the Ninth International Conference on River Research and Applications, Albury, NSW, 6-11 July 2003.

Matveev, V., Matveeva, L. and Jones, G. 2003. Biomanipulation: non-linear response of cyanobacteria to reservoir fish stocking. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

McCarthy, B. 2003. Quantifying the effects of weirs in the Mallee Tract of the Murray River. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

McCasker, N. and Meredith, S. 2003. Linking life history traits of native fish to flow habitat characteristics: plausible or just pooh-pooh? Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

McNeil, D.G. 2003. Floodplain drying and the influence of environment on billabong fish habitats. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Meredith, S., Gawne, B., Sharpe, C., Whiterod, N., Conallin, A., Zukowski, S. and McCasker, N. 2003. Spatial analysis of the Low-Flow Recruitment Hypothesis: implications for the use of environmental flows for the management of native fish. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Metzeling, L., Robinson, D., Perriss, S. and Nichols, S. 2003. Detecting environmental gradients using RBA data – possible enhancements by greater taxonomic resolution. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Mitchell, A. 2003. Interactions between P, C, N and S cycles in aquatic systems. Presented at Organic P. 2003, Ascona, Switzerland, 13-18 July 2003.

Mitchell, A. 2004. Super models and conceptual models: similarities, differences and the way forward. Presented to DPI Rutherglen, Victoria, May.

Mitchell, A. and Baldwin, D.S. 2003. Organic phosphorus in the aquatic environment: speciation, transformations and interactions with nutrient cycles. Presented at Organic P 2003, Ascona, Switzerland, 13-18 July 2003.

Mitchell, A., Baldwin, D. and Rees, G. 2003. The interactions of the anaerobic nutrient cycling processes and phosphate release from freshwater sediments. Presented at the 4th International Symposium on Phosphate in Sediments, Sevilla Spain, 9-12 September 2003.

Mitchell, A.M, Baldwin, D.S., Rees, G.N., Watson, G.O. and Williams, J.L. 2003. Nitrogen processing and indigenous biofilm community structure: linkages for the upper, middle and lower reaches of an Australian lowland river. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Muschal, M. 2003. Assessment of the risk to aquatic biota of the Hunter River (NSW, Australia), from elevated salinity. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Muschal, M. 2003. Assessment of the risk to aquatic biota of the Hunter River (NSW, Australia), from elevated salinity. Presented at the Society for Environmental Toxicology and Chemistry (SETAC) Asia/Pacific and Australasian Society for Ecotoxicology (ASE), Joint Congress: "Solutions to Pollution", Christchurch, New Zealand, 28 Sept – 1 Oct 2003.

Nelson, T., Norris, R., Maher, B. and Olley, J. 2003. Fire and water: Stream ecosystems respond to ACT bushfire disturbance. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1 – 5 Dec. 2003.

Nichols, S. 2004. Presentation to the AWA Water Education Conference, Canberra, January.

Nichols, S., Barlow, A., Norris, R.H., Gray, B. and Evans, L. 2004. AUSRIVAS online: bringing education and research into the 21st Century. North American Benthological Society Conference 2004 – Teaching in the 21st Century, Vancouver British Columbia, June 2004.

Nicol, J.M., Ganf, G.G. and Walker, K.F. 2003. Implications of managed variability: a model to describe plant recruitment in arid zone riverine lakes. Presented at the Ninth International Conference on River Research and Applications, Albury, New South Wales, 6-11 October 2003.

Nielsen, D.L. and Brock, M. 2003. Current research and future directions for aquatic salinity: what are the crucial questions? Presented at the 28th Annual Conference of the Ecological Society of Australia, University of New England, Armidale NSW, 8 - 10 December 2003.

Nielsen, D., Watson, G. and Petrie, R. 2003. Microfaunal refuges: the importance of backwaters in lowland rivers. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

O'Connor R.A., Ogden R., Norris R.H., and Cottingham P. 2003. A perspective on disasters in aquatic systems. Presented at the 2003 Australian Disaster Conference, Canberra, 10-12 September 2003.

Oliver, R., Merrick, C. and Lorenz, Z. 2003. Partitioning river metabolism to identify sources of energy to the River Murray and tributaries: what does it tell us about river function and river management? Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Osborne, W.S. and Hunter, D.A. 2003. Frog declines in the snowy mountains. What do we know after fifteen years? Celebrating Mountains. Presented at the International Year of Mountains Conference, Jindabyne, 24-28 November 2002.

Perryman, S., Walsh, C., Rees, G.N., Grace, M. 2003. Different sites, different denitrifiers: variation in the denitrifying community structure from streams in an urban and a non-urban catchment. Presented at the Ninth International conference on river research and applications, Albury, NSW, 6-11 July 2003.

Perryman, S., Rees, G. and Walsh, C. 2003. Variation in the denitrifying community structure from streams in an urban and non-urban catchment. Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 Dec. 2003.

Philibert, A., Newall, P., Gell, P., Bate, N. and Chessman, B. 2003. Development of diatom-based tools for assessing stream water quality in south eastern Australia: assessment of environmental transfer functions (poster presentation). Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Pollino, C.A., Feehan, P., Grace, M.R., Hart, B.T. and Webb, J.A. 2003. Quantifying the risks to fish in the Goulburn Broken Catchment (poster presentation). Presented at the Ninth International Conference on River Research and Applications, Albury NSW, July 2003.

Porter, J., Brock, M. and Kingsford, R. 2003. Seed bank dynamics in an arid zone saline wetland. Presented at the 28th Annual Conference of the Ecological Society of Australia, University of New England, Armidale NSW, 8-10 December 2003.

Raadik, T.A. and Adams, M. 2003. Systematic review of the widely distributed mountain galaxias (Galaxias olidus) species complex in eastern Australia: biodiversity loss before our eyes! Presented at the Australian Society for Fish Biology, Annual Conference, Wellington, New Zealand, 29th June - 4th July 2003.

Raadik, T.A., Lintermans, M., Jackson, J. and Hammer, M. 2003. Impacts of Alien salmonids on freshwater biota in Australia: Part 2 - impedimants to effective management, and future directions. Presented at the Australian Society for Fish Biology, Invasive Species: Fish and Fisheries Workshop, Wellington, New Zealand, 30 June - 1 July 2003.

Rees, G., Bowen, P. and Watson, G. 2003. Variability in benthic respiration across three South Eastern Australian lowland rivers. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Rees, G.N., Baldwin, D.S., Mitchell, A. and Watson, G. 2003. Acute effects of salt on sediment biogeochemistry and microbial community structure. Presented at the 28th Annual Conference of the Ecological Society of Australia, University of New England, Armidale NSW, 8 - 10 December 2003.

Sellens, C., Norris, R. and Chessman, R. 2003. A comparison of reference conditions for urban streams (poster presentation). Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Sellens, C., Norris, R. and Chessman, R. 2003. AUSRIVAS Bioassessment: does it matter if the predictor variables are burnt to a crisp? Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Sellens, C.L., Norris, R. and Chessman, B., 2003. River Protection Using Good Management Practices Defining Condition for the Biological Assessment of Urban Streams. Presentation at the Symposium on Urbanization and Stream Ecology 8-10th December, U. Melbourne, Australia.

Sharpe, C. and Meredith, S. 2003. Comparing growth rates of gudgeon (*Hypseleotris* spp.) in the Lindsay River. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Smith, B. B. and Walker, K. F. 2003. Spawning dynamics of carp (*Cyprinus carpio* L.) in the River Murray, South Australia, shown by macroscopic and histological staging of gonads. Presented at the 2003 Australian Society for Fish Biology Annual Conference, Wellington, New Zealand.

Stojkovic, S. 2003. Freshwater biofilms and increased UVBR in streams with different P status. Presented at the Ecofizz 2003 meeting, Ecophysiology of Australasian Plants and Ecosystems, Melbourne University, October 2003.

Stojkovic, S. and Beardall, J. 2003. Response of benthic microalgae to interactions between UV and phosphorus availability in streams around Melbourne, Australia. Presented at the 3rd European Phycological Congress, Belfast, July 2003, pp. 52.

Tennant, W., Cottingham, P. and O'Dwyer, T. 2003. Towards healthy rivers: the Goulburn River — the multiple values provided by highly regulated rivers. Presented at annual ANCID conference.

Tewman, M., Walsh, C. and Quinn, G. 2003. The effect of macroinvertebrate grazers on benthic algae in an urban and forested stream in Melbourne, Victoria. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Vanderkruk, K., Hart, B. and Grace, M. 2003. Biogeochemical interactions within the hyporheic zone of a sand-slugged stream. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Vanderkruk, K.E.N, Hart, B.T and Grace, M.R. 2003. Biogeochemical interactions within the hyporheic zone of a sand-slugged stream. Presented at the Sediment Biogeochemistry Workshop, Lismore, NSW, Australia.

Vanderkruk, K.E.N, Hart, B.T and Grace, M.R. 2003. Heterogeneity in sand-slugged streams. Presented at the Ninth International Conference on River Research and Applications, Albury, NSW, Australia.

Wallace, T., Ganf, G. and Brookes, J. 2003. The role of in-stream structure in regulating DOC transport in the Torrens River Catchment. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Wallace, T., Ganf, G. and Brookes, J. Bioavailability of dissolved organic carbon in rural and urban streams of the Torrens River catchment. Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 Dec. 2003.

Walsh, C. 2003. How sensitive are the Victorian State Environment Protection Policy's biological objectives to stream degradation? Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Walsh, C. J. 2003. Stormwater drainage infrastructure: the key to conserving and restoring streams in urban catchments. Keynote address. Presented at the Symposium on Urbanization and Stream Ecology, Melbourne, Victoria, 8 -10 December 2003.

Walsh, C. J. 2003. Stream Ecology and the City: Identifying and managing the cause of poor ecological condition of streams in urban catchments. Presented at a Departmental Seminar, School of Biological & Chemical Sciences, Deakin University, Burwood, April 2003.

Walsh, C.J. 2003. Linking urban design to the conservation and restoration of stream ecosystems. Presented at the workshop on the Comparative Ecology of Cities and Towns, Australian Research Centre for Urban Ecology, Melbourne University, 20-22 July 2003.

Walsh, R. 2003. The zooplankton and their habitat types of Lindsay Island, Lower Murray River, Victoria. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

Walsh, C.J. and Ladson, A.R. 2004. Melbourne's streams: what's wrong with them and how can they be fixed?. Presented at the Water Engineering Branch of Engineers Australia (Vic Division) seminar series, Melbourne, 25 March 2004..

Walsh, C.J., Ladson, A.R. and Fletcher, T.D. 2004. Stream restoration by 'disconnecting' urban stormwater drainage in the watershed: predictive models and experimental design. Presented to the Meeting of the North American Benthological Society, Vancouver, Canada, June 2004.

Webb, J.A., Pollino, C.A., Hart, B.T. and Grace, M.R. 2003, Models for predicting algal blooms: how complex do they need to be? Presented at the Ninth International Conference on River Research and Applications, Albury NSW, July 2003.

Webb, J.A., Pollino, C.A., Hart, B.T. and Grace, M.R. 2003. Models for predicting algal blooms: how complex do they need to be? Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 Dec. 2003.

White, M. and Georges, A. Turtle responses to the boom and bust ecology in the channel country of arid Australia. Presented at the 2003 Joint Meeting of Ichthyologists and Herpetologists, Manaus, Brazil, June 26 - July 01.

Whiterod, N. and Gawne, B. 2003. Flow related variation in diets of small-bodied Murray-Darling fish species. Presented at the Ninth International Conference on River Research and Applications – the nature of variability in river systems, Albury, NSW, 6-11 July 2003.

Whiterod, M. and Meredith, S. 2003. Mitigation of cyanobacterial blooms within weir pools of the Murray-Darling Basin*:* an economic analysis. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.

Whiting, J., Lambert, M., Metcalfe, A. and Walker, K.F. 2003. Searching for persistence in unregulated River Murray stream flows. Presented at the 28th International Hydrology and Water Resources Symposium, Wollongong, November 2003.

Zukowski, S., Meredith, S. and Whiterod, N. 2003. Ecological responses to wetland flooding, Deniliquin NSW. Presented at the Joint 42nd Australian Society for Limnology Congress and 36th Congress of the New Zealand Limnological Society, Warrnambool, Victoria, 1-5 December 2003.