Biodiversity in Inland Waters -- Priorities for its Protection and Management

Recommendations from the 2001 Fenner Conference on the Environment

Arthur Georges CRC for Freshwater Ecology
Peter Cottingham CRC for Freshwater Ecology

Technical Report 1/2002

The Cooperative Research Centre for Freshwater Ecology is a national research centre specialising in river and wetland ecology. The CRC for Freshwater Ecology provides the ecological knowledge needed to help manage the rivers in a sustainable way. The CRC was established in 1993 under the Australian Government's Cooperative Research Centre Program and is a joint venture between:

ACTEW Corporation
CSIRO Land and Water
Department of Land and Water Conservation, NSW
Department of Natural Resources and Environment, Victoria
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
Natural Resources and Mines, Queensland
Sunraysia Rural Water Authority
Sydney Catchment Authority
University of Adelaide
University of Canberra

Ph: 02 6201 5168
Fax: 02 6201 5038
Email: pa@lake.canberra.edu.au
http://freshwater.canberra.edu.au

ISBN 1 876810 19 X

Printed in March 2002

Preface

The 2001 Fenner Conference on the Environment - *Biodiversity Conservation in Freshwaters* - brought together scientists, policy makers and managers to exchange ideas on the issues and challenges confronting the conservation of freshwater biodiversity in Australia.

More is known about biodiversity protection in terrestrial and, more recently, in marine systems than in freshwater systems. Biodiversity conservation has received significant attention over the past decade in National and State government strategies and legislation, however, action to protect or enhance biodiversity in freshwater systems has been limited. Despite the legislative frameworks, agencies and Governments have been reluctant to act.

This report summarises the final session of the 2001 Fenner Conference, *Biodiversity in Inland Waters - Priorities for its Protection and Management.* It identifies the major issues limiting successful biodiversity conservation, gaps in our knowledge or ability to address freshwater biodiversity issues, and priority areas of management and research that will lead to improved conservation of freshwater biodiversity.

This report intends to inform policy makers and those involved in natural resource management, as well as serving as a resource for those promoting or undertaking biodiversity conservation measures.

Table of Contents

1 PRIORITIES

1.1 Top National Priorities

Of the many important initiatives discussed at the Fenner Conference, the following four were considered to be of the highest priority for action at a national scale:

- The States and the Commonwealth should work together to establish an enduring national series of Special Catchments for the Management of Biodiversity (alternatively referred to as National Heritage Rivers or National River Reserves).

- An increased inventory effort (wetlands, streams, springs, groundwater) and validation of surrogates for freshwater biodiversity that may be used by resource managers to identify, manage and monitor areas of high conservation value. We need to stem the decline in our capacity to undertake taxonomic work in our universities, museums and research organisations. Molecular or genetic techniques, such as allozyme analysis and DNA sequencing, can offer many new insights in this area.

- The States and Territories need to take immediate additional actions to protect, and where necessary rehabilitate, high value systems such as wetlands of national significance and RAMSAR sites. We need to go beyond simply listing sites or planning recovery, and take action.

- The Commonwealth, States and Territories should jointly establish a national invasive species action plan, including rapid response plans for new or potential invaders.

1.2 Other Important Priorities

- We need to develop and apply methods to estimate the environmental, social and economic values of the ecosystem services provided by intact, biodiverse inland waters. Only then can these values be properly factored into cost-benefit assessments of development.

- We need to work harder to build the constituency behind initiatives to conserve or restore biodiversity in our inland waters. We need to develop educational tools to effectively promote understanding of the full social, economic and environmental value of biodiversity in inland waters in the broader society.

- Researchers and managers need to work together to clarify what we mean by biodiversity in operational terms, and to develop vigorous inventory, assessment and monitoring protocols across a range of spatial scales. This must be achieved in the context of a fundamental lack of taxonomic knowledge and limited funding for taxonomic research.

- Environment Australia should coordinate the development of an interim biogeographic regionalisation of inland waters to complement those already developed for terrestrial[16] and marine systems, as a basis for allocating priorities and resources at national and regional scales, and for reporting against agreed indicators[16].

- We need to undertake research to increase our fundamental understanding of the factors and processes that regulate biodiversity in freshwater systems so as to be better able to predict the likely impact of human-induced change, to ameliorate the effects of human activity and to plan effective restoration and rehabilitation initiatives.

- We need to establish a mechanism to enable better coordination of biodiversity conservation efforts across tiers of government and across agencies within governments. We need to develop and implement financial and other incentive structures between the Commonwealth and the States to foster biodiversity conservation and restoration of our inland waters.

- Koi is an ornamental strain of carp promoted by the ornamental-fish industry that rapidly reverts to wild-type form when released into our rivers. The strain is responsible for carp infestations in Tasmania, the Canberra region, the Shoalhaven River and the Clarence River of NSW. They should immediately be declared noxious in NSW (in line with other States).

- Trout should not be stocked as a recreational fish in our national parks and other high value areas where they eliminate some species of native fish, such as Mountain Galaxias, and where they impact upon stream biota such as frogs.

2 BACKGROUND

What is Biodiversity?

Biodiversity is the term used to encapsulate the many facets of the diversity of life. When we refer to biodiversity, we refer to the variety of plant, animal and microorganism species, to the different communities they form, and to the diversity of genes they contain. We also refer to the natural biological processes occurring within ecosystems that support species richness and genetic diversity, in both immediate ecological timeframes and longer-term evolutionary timeframes. The concept of biodiversity emphasises the interrelatedness of the biological world and the importance of those interrelationships in maintaining diversity. It covers the terrestrial, marine and other aquatic environments such as rivers, streams, wetlands and groundwater systems[2].

Biodiversity of inland waters is important to the sustained health and prosperity of our society[2]. It is important for the ecosystem services[25] it provides, in both natural and managed ecosystems, such as the provision of fresh water, flood mitigation, removal of nutrients and other pollutants, trapping of sediments, and the moderation of toxic algal blooms. These services, once lost, are prohibitively expensive to replace by technological means. Biodiversity of inland waters is also important for its economic value as habitat for species of commercial value, as a source of materials, medicines and biomolecules to feed technological advances, and for societal wellbeing. It is important for the rich and varied opportunities in recreation and tourism, and is important to many people for its intrinsic value, their lives being enriched by its presence.

Biodiversity is central to the societal issue of inter-generational equity, whereby we have a commitment to leave for future generations an environment that is at least as healthy and productive as it is now[3]. This is the principle that drives such government initiatives as the National Strategy for Ecologically Sustainable Development, the National Strategy for the Conservation of Australia's Biodiversity[2] and the Natural Heritage Trust (NHT). We need to ensure that our limited freshwater and other inland water resources are not degraded.

Loss of biodiversity is perhaps our most serious environmental problem[4]. Whether we look at wetlands or salt marshes, mangroves or bushland, inland waters or estuaries, the same story emerges: degradation of habitat, considered to be the major source of biodiversity loss since European settlement, is continuing at an alarming rate. Some 5% of Australia's higher plants, 9% of birds, 23% of marsupials, 7% of reptiles, 16% of amphibians and 9% of freshwater fish are extinct, endangered or vulnerable. Degradation

of wetland and riverine habitats and a decline in water quality are considered to be the primary causes for the decline of several species of frogs, freshwater tortoises and lizards[4]. Biological invasions have also contributed to biodiversity loss and have been identified as potentially the largest driver of biodiversity loss in lake ecosystems in the next century[28].

While policy-makers, managers and scientists develop their principles, modes of investigation and knowledge base, they are under increasing pressure to provide advice and expertise on an immense range of environmental crises, from ways to conserve endangered species or to assess the downstream effects of new dam proposals. Decisions regarding appropriate responses often need to be made on a time-scale of the immediate to the very near future. In this respect, the conservation of biodiversity is a crisis discipline. It demands an adaptive approach, where intervention and research, including monitoring and evaluation, go hand in hand to achieve improved conservation outcomes and improved knowledge as a basis for future action.

Interventions to achieve biodiversity conservation objectives have been most effective where they have taken a comprehensive and systematic approach that integrates social, economic and environmental aspects[4]. Negotiating a path to effective solutions requires input from a range of government bodies, non-government agencies, community groups and private land-holders whose activities influence the biodiversity of inland waters, whether positively or negatively. Science has an important and arguably central role in biodiversity conservation but its contribution is not always clear, being moderated by a range of socio-economic factors. We require prudent and precautionary use of the best available knowledge and decision-making frameworks, integrating scientific, social, economic and political dimensions, if we are to avoid well-intentioned and expensive management that is ineffective or even counterproductive.

The Fenner Conference on the Environment 2001 was organised in this context. It brought together 185 people with relevant scientific, administrative and policy expertise to consider current biodiversity problems in Australia's inland waters. Fresh approaches and perspectives were aired on biodiversity conservation in freshwaters and other inland aquatic systems, both modified and unimpacted, and on policies for biodiversity conservation and management. The conference concluded with an open forum discussion on the highest priorities for action, the outcome of which forms the basis for this document.

The purpose of the document is to identify the major issues limiting successful biodiversity conservation in inland waters, to identify gaps in our knowledge or ability to address aquatic biodiversity issues, and to identify priority areas of management and research that will lead to improved conservation of aquatic biodiversity. We hope that the document will be used as a resource to guide decisions of policy makers and those involved in natural resource management, as well as serving as a resource for those seeking to marshal support for new biodiversity conservation initiatives.

3 CONTEXT

Australia is party to a large number of international and national agreements that are relevant to the conservation of biological diversity. These range from agreements about wetlands of international significance[5], protection of the habitats of migratory species, World Heritage properties, Antarctica and the South Pacific region, to agreements on trade in wildlife to pollution control (Table 1).

Of particular importance is the Environment Protection and Biodiversity Conservation Act (1999), which recognises that the States have primary responsibility for on-ground management of natural resources. Most States and Territories have biodiversity protection enshrined in legislation or in biodiversity strategies[20].

A number of government corporations and agencies, below the level of State authorities and outside the ambit of local government, are responsible for water development. For example, water authorities in Victoria are governed by the Water Act (1989), the Flora and Fauna Protection Act (1988) and the Victorian Land Conservation Act, as both land owners and water managers. Melbourne Water is responsible for the management of public land in four heritage river areas as defined by the Victorian Heritage Rivers Act 1992. They must take all reasonable steps to ensure that conservation and other heritage attributes are protected and ensure that the relevant river sections are maintained in a free-flowing state.

Other state agencies have specific provisions in their enabling legislation. For example, the Sydney Catchment Authority (SCA) has responsibility for the protection of water quality, public health, public safety and the environment on lands under its control. The management of biodiversity in the Sydney water supply catchments is an important consideration in meeting these obligations, and the SCA is investing substantially in it[19]. However, the Sydney Catchment Authority may be an exception, and adding explicit responsibilities for environmental management and biodiversity conservation, beyond that seen to be directly related to water amenity, should be considered for the charter of a wider range of agencies.

About 70 per cent of Australia's land area is under the control of private landholders and resource managers, including indigenous peoples; their cooperation is essential for the success of conservation activities[2]. Rural industries are becoming more interested in biodiversity conservation in production lands, in part because of a genuine desire by an increasing number of landholders to be seen as good corporate citizens, caring for their land. It is also in part because these industries can see mounting negative perceptions of some rural industries as the Australian public become more aware of environmental problems and their potential solutions. It is imperative that best practice for the conservation and enhancement of biodiversity of inland waters is communicated effectively to the private sector[22,23]. High priority must be placed on developing and implementing integrated approaches to conservation that both conserve biological diversity and meet other community objectives[2].

Table 1: Examples of International and National Biodiversity Initiatives Recognised in Australia

Initiative	Objective	Comments
INTERNATIONAL		
Convention on Biological Diversity (1992)[6]	Conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from the use of genetic resources.	Ratified by Australia in June 1993
NATIONAL		
InterGovernmental Agreement on the Environment (1992)[7]	Establish formal protocols for interaction between Commonwealth, State and Territory and local governments.	Provides the basis for a cooperative national approach to the environment, a better definition of the roles of respective governments and greater certainty of government and business decision-making.
National Strategy for Ecologically Sustainable Development (1992)[3]	Provide a basis for governments to change their institutional arrangements to ensure that ESD principles and objectives are taken into consideration in relevant policy making processes.	
The National Strategy for the Conservation of Australia's Biodiversity (1996)[2]	Protect biological diversity and maintain ecological processes and systems.	Principle Eight of the biodiversity strategy is of particular importance. It contains the two fundamental building blocks of biodiversity conservation programs, as set out in the International Convention on Biological Diversity, (a) the development of systems of reserves protecting representative examples of major ecosystems, and (b) sympathetic management of biodiversity values in utilised ecosystems

The Australia State of the Environment report (1996)[4]	The first stage of an ongoing evaluation of how Australia is managing its environment and meeting its international commitments to the environment.	The State of the Environment Advisory Council identified biodiversity loss as probably the most urgent issue for environmental management. A number of other influential State of Environment reports have been produced, with a State[9], regional[10] or local[11] focus.
The Wetlands Policy of the Commonwealth Government of Australia (1997)[15]	Bring together different strands of government policy on wetland protection and management to fulfill Australia's obligations under the RAMSAR Convention[5] on Wetlands.	
State of the Environment Advisory Council Environmental Indicators for National State of the Environment Reporting (1998)[12]	Seven documents provided indicators for State of the Environment reporting.	Two documents are particularly relevant to biodiversity conservation in inland waters: biodiversity[14] and inland waters[13].
National Local Government Biodiversity Strategy (1998)[24]	Provide the basis for local action to achieve State and National biodiversity conservation goals.	An important initiative as natural resource management and local government functions of land use planning and development are inextricably related. It has driven a number of draft regional biodiversity strategies[8] and provides a link between local government and state initiated catchment management plans[26].
Environment Protection and Biodiversity Conservation Act (1999)	Clarify the national interest in matters of environmental significance, streamline environmental assessment and approval processes, and establish an integrated regime for biodiversity conservation and the management of protected areas[1].	Promotes the conservation of biodiversity and ecologically sustainable development through the conservation and ecologically sustainable use of natural resources.

4 KEY BIODIVERSITY ISSUES AND CHALLENGES

The following are key issues related to biodiversity conservation in inland waters:

- Changes to land and water management since European settlement have resulted in a substantial loss of biodiversity, and the remaining biodiversity values are at risk;

- It is unclear how much biodiversity remains in our inland waters and we have difficulty in measuring its distribution over time and space;

- Most Australian States are committed to the development of systems of protected areas containing representative examples of major freshwater ecosystems – however, with the exception of Victoria and the ACT, these commitments remain unfunded;

- We have limited understanding of how human activity has influenced ecosystem function and its relationship to biodiversity or, conversely, the influence of biodiversity loss on ecosystem function;

- We have yet to develop management systems that effectively conserve or improve inland water biodiversity values at scales ranging from river catchments to the continent. The management of the effects of invasive species presents one of the most intractable problems in this regard.

The following fundamental questions provide a structure for considering the policies, management initiatives and research needed to support the conservation, restoration and sustainable use of biodiversity in inland waters of Australia.

Value and Perceptions

(a) Can we estimate the economic, social and environmental value of biodiversity of inland waters, to achieve a true cost accounting of the ecosystem services and other benefits biodiverse aquatic systems provide?[1]

(b) Can we establish explicit links between biodiversity and ecosystem services, so as to provide incentives for resource management agencies to factor biodiversity conservation into their operations?

Pattern

(c) What do we have left? What of our natural biodiversity in inland waters remains relatively intact, how much of value still resides in impacted systems, how do we measure biodiversity, and how is it distributed across the landscape?

Process

(d) How do the inland water ecosystems work – what are the factors that regulate biodiversity in natural and modified inland water ecosystems? We need an understanding of environmental processes if we are to anticipate the effects of human activities on biodiversity and choose to avoid or ameliorate environmental damage[1].

(e) What impacts are we having – what pressures are we bringing to bear on biodiversity, and by what mechanisms do they act? From a scientific point of view, are we doing enough, quickly enough?

Policy and Management Action

(f) What are the most effective policy frameworks and management options needed to avoid or ameliorate environmental damage leading to loss of biodiversity in inland waters?

(g) What are the priority areas of research required to support policy and management actions?

The questions outlined above and key responses are considered in more detail in the following sections.

4.1 Value and Perceptions

There are many reasons for valuing biodiversity conservation, ranging from philosophical to utilitarian views, including the maintenance of:

- Cultural values;
- Recreational values;
- Aesthetic values;
- Ecological integrity and ecosystem services;
- Natural capital, such as a source of future materials or medicines.

While most in our community can identify social and economic values and benefits of inland waters, far fewer recognise the importance of biodiversity conservation to these values. Promoting the importance of biodiversity conservation with respect to social and economic values remains a challenge. Identifying and adopting measures to estimate the economic, social and

environmental value of the biodiversity of inland waters, will allow us to achieve a true cost accounting of ecosystem services and better promote the benefits of biodiverse aquatic systems.[1]

4.1.1 We need to develop and apply methods to estimate the environmental, social and economic values of the ecosystem services provided by intact, biodiverse inland waters. Only then can these values be properly factored into cost-benefit assessments of development.

Resource managers are more likely to incorporate biodiversity conservation into their operations if the links between biodiversity and the economic, social and environmental value of freshwater systems are clarified. By establishing explicit links between biodiversity and the services ecosystems provide, it will be possible for resource management agencies to factor biodiversity conservation into their operations. Improved value measures will enable a true cost accounting of the ecosystem services and other benefits biodiverse systems provide[1].

Biodiverse systems are generally regarded as better able to sustain ecosystem services than degraded systems[25]. Such services include provision of fresh water, flood mitigation, removal of nutrients and other pollutants, trapping of sediments, and the moderation of toxic algal blooms. Maintaining biodiversity and ecological integrity is considered to be the best strategy for delivering ecosystem services[19]. Conversely, degraded systems often have reduced capacity to deliver ecosystem services, a reduced capacity that needs to be met by expensive technological “fixes”.

However, it is not possible to keep all existing unimpacted systems quarantined from development, nor is it possible to restore degraded systems to their former pre-European state. Questions of degree arise. What is the actual contribution of biodiversity to ecosystem services? Is it that diverse systems are more resistant and resilient to human induced perturbation than depauperate systems? If so, how far can biodiversity be pushed (i.e. species or processes lost) before ecosystem services are compromised? Conversely, how much effort must we expend in restoring biodiversity in order to restore ecosystem services. Are some species or processes redundant to the provision of ecosystem services?

Research is required to examine the links between biodiversity and ecosystem services. This will clarify the role of biodiversity in providing services, in both impacted and unimpacted systems. It will allow society to better include the value of biodiversity in benefit-cost assessments of the systems they manage for restoration or conservation. We also need to consider that humans are part of ecosystem and emphasise the link between biodiversity and community health in our assessment of ecosystem services. Achieving useful outcomes from this research will require input from

ecologists, economists and public health practitioners working closely together to better assess and promote values associated with biodiversity (environmental, social, and economic).

4.1.2 We need to work harder to build constituency behind initiatives to conserve or restore biodiversity in our inland waters. We need to develop educational tools to effectively promote understanding of the full social, economic and environmental value of biodiversity in inland waters in the broader society.

Local communities may sometimes be more concerned with public health, rather than biodiversity issues (i.e. whether it is safe to swim in a river rather than what lives in it). However, many local governments and communities are willing to support biodiversity conservation initiatives. A challenge is to inform, engage and empower communities so that we can capitalise on the human resources they represent.

The community needs to be informed of:

- The biodiversity that exists in our inland waters - the species present and how they interact to form functioning biotic communities - so as to build a greater appreciation of its intrinsic value;
- The connections between biodiversity and the community's quality of life, psychologically, culturally and economically;
- The perilous state of biodiversity in our inland waters and the causes of biodiversity decline;
- The actions required to address the issue of biodiversity decline in inland waters;
- The important contribution that can be made though a combination of individual action, local community action and government action.

This may be best achieved via a large-scale and coordinated approach to biodiversity conservation that recognises the factors that limit community participation (e.g. distal and intermediate pressures, such as the impact of trade globalisation on farm income).

Education takes on many forms. Community engagement in on-ground action can serve the dual purpose of effective conservation and effective education, building strong support behind conservation initiatives. Additional efforts are required to measure current community views on biodiversity issues, including the views of decision-makers such as politicians, to help guide future education campaigns. Community education programs such as Waterwatch are very successful at engaging the community in river health and water quality issues, and should be maintained and further developed. The Waterwatch program reaches a wide audience. Opportunities to extend the program to include or promote a wider range of biodiversity issues should be investigated.

We need also to consider stewardship to engage landholders, other resource managers and recreational users of waterways in biodiversity conservation (e.g. Victoria trial for managing vegetation communities). Successful demonstration projects involving sympathetic landholders in the first instance can greatly help to highlight the benefits of biodiversity conservation across the rural sector.

Opportunities for a career in limnology and associated sciences should be promoted in tertiary courses to encourage and train future generations of water resource managers and aquatic scientists. This will require the promotion of biodiversity issues and the rearrangement of curricula to allow students to study limnology earlier in undergraduate courses than is currently the case.

4.2 Pattern

A major issue for future biodiversity conservation is assessing the pattern or distribution of the biodiversity that remains in inland waters. Key questions include:

- What of the natural biodiversity in inland waters remains relatively intact?
- How much of value still resides in impacted systems?
- How do we measure biodiversity?
- How is it distributed across the landscape?

Implicit in answering these questions is the assumption that we have the skills and expertise available to measure biodiversity, including agreed methods for measuring biodiversity at appropriate scales (e.g. bioregions) and experienced taxonomists available to undertake assessments.

4.2.1 Researchers and managers need to work together to clarify what biodiversity means in operational terms, and to develop vigorous inventory, assessment and monitoring protocols across a range of spatial scales. This must be achieved in the context of a fundamental lack of taxonomic knowledge and limited funding for taxonomic research.

Researchers and managers need to work together to provide sound operational definitions of biodiversity, incorporating the realities of its measurement in inland waters. These operational definitions should apply to a range of spatial scales from the river reach to drainage basins to bioregions.

A fundamental issue in biodiversity conservation is how to measure biodiversity in order to assess the state of the resource, to monitor trends over time, and to monitor and evaluate the effectiveness of our restoration activities. In the context of poor taxonomic and distributional knowledge, many

State and Federal conservation agencies rely on surrogates for assessing biodiversity. Current reliance on biodiversity surrogates based on rapid assessment approaches, the use of single species, and the reapplication of river health or water quality surrogates have not been adequately validated. They should be viewed as interim approaches to govern immediate "best guess" action. They are not a long-term solution to biodiversity assessment.

Biodiversity assessments undertaken by State and Federal agencies should include an explicit component to validate the presumed links between the biodiversity measures they are using and resident biodiversity. The results of such validation should be placed in the public arena through publication. This is a high priority for future research.

Until such time as adequate surrogate measures have been identified and validated, State and Federal agencies need to increase efforts on inventory, and place lesser reliance on un-tested surrogate measures of biodiversity when assessing conservation value, the impact of processes that threaten biodiversity and the effectiveness of interventions to bring about restoration of biodiversity.

4.2.2 We need a greater effort on inventory to document the biodiversity that remains in inland waters. We need to stem the decline in our capacity to undertake taxonomic work in our universities, museums, herbaria and research organisations.

Assessment of inland water biodiversity, in Australia in particular, is compounded by the slow accumulation of taxonomic and distributional knowledge compared with that of terrestrial systems. We are frighteningly ignorant of our freshwater biodiversity and run the risk of many species becoming extinct before their existence becomes known, or misinterpreting current rates of extinction. Cryptic species commonly emerge when what we think are well known taxa are examined with molecular techniques. Our taxonomic ignorance is a major impediment to effective biodiversity assessment and protection of high value areas and ecosystems.

It is in this context that we are seeing a withdrawal of support for taxonomic work in our universities, as they strive to become more commercially relevant at the expense of public-good research and education, and in our museums as they shed curatorial staff. We need to provide better career opportunities for prospective young researchers wishing to engage in taxonomic research.

Our museums and herbaria should be funded to maintain their core function for taxonomic research and curation of national biodiversity collections in addition to developing their more recent and welcome focus on engaging the public to achieve educational goals. The push for greater public involvement in what museums have to offer and the production of modern and effective exhibitions should be additional to and not at the expense of curatorial and

taxonomic capacity. Museums and herbaria have a key role to play in biodiversity conservation, both in research and education.

The assessment of aquatic biodiversity and its distribution across Australia will be greatly assisted by a coordinated approach to building national taxonomic data sets. This will require cooperation between State agencies, those conducting aquatic surveys and curators of fauna and flora collections, so that databases of various holdings may be consolidated and made widely available to researchers and natural resource managers. State agencies should require that those undertaking aquatic surveys on their behalf lodge voucher specimens with relevant State museums and herbaria. Reference collections of undescribed taxa should, at the end of studies, be appropriately labeled and lodged with museums and herbaria for future cross-reference.

Modern molecular techniques have the potential to revolutionise the way we assess biodiversity. Where possible, researchers should store tissue samples in a medium appropriate for future molecular analysis and lodge these samples with a facility specialising in such collections. The Australian Research Council (ARC) should fund a national facility or consortium to establish a biodiversity tissue bank to facilitate biodiversity and systematics research. Freshwater biodiversity should form an important component of such a collection.

A large proportion of the biodiversity in inland waters comprises small, anonymous or cryptic organisms or systems that have been little studied (e.g. springs, subterranean systems). These groups should be a high priority for taxonomic research and the development of biodiversity assessment methods. The Australian Biological Resources Study (ABRS) should be encouraged to add an ecosystem focus to its priorities for funding taxonomic research, and assign a high priority to taxonomic research of inland waters considered to be particularly imperiled. The surprisingly rich but poorly studied communities of our groundwater systems are one example.

4.2.3 Environment Australia should coordinate the development of an interim biogeographical regionalisation of inland waters to complement those already developed for terrestrial[16] and marine systems, as a basis for allocating priorities and resources at national and regional scales, and for reporting against agreed indicators[16].

Regionalisations are important frameworks for allocating priorities and resources at a national scale, for brokering the trade-offs necessary to reconcile production and conservation objectives, and for providing a basis for monitoring against agreed indicators[16].

Most regionalisations in common use are constructs drawn up for social or political reasons; State, Territory and local government boundaries are good

examples. Regions of this kind are important for reporting social, political and demographic statistics, but unfortunately biota do not recognise them. Evolution, climate, substratum, landform, and the interplay historical pattern of connectivity of inland water systems and the dispersal capabilities of organisms together determine patterns in biological diversity.

An ecosystem approach to bioregionalisation of the terrestrial landscape, drawing on both biotic and abiotic data, has been implemented in the Interim Biogeographic Regionalisation of Australia (IBRA)[16]. In the marine context, there is the Interim Marine and Coastal Regionalisation for Australia. It too draws upon both biological and physical attributes of the environment in its definitions of bioregions.

The most meaningful regionalisations for inland waters are based on drainage basin boundaries[13]. This is because surface waters are arranged spatially as a network throughout the landscape effectively controlled by topography. However, with the exception of the island state of Tasmania, there is no natural unit of management between the scale of the drainage basin and the scale of the continent. The IBRA[16] is inadequate as a tool for defining natural inland water regions, as the regions defined on terrestrial attributes do not reflect patterns in the distribution of aquatic biota[30]. We do not have an adequate bioregionalisation for inland waters or well-established means for defining one.

Approaches to bioregionalisation vary on the spectrum from descriptive tools to predictive tools. Traditional approaches to bioregionalisation map the distribution of aquatic species across the landscape and define the bioregions on the basis of concordant patterns in those distributions. The approach is hampered by our ignorance of what species exist in our inland waters, with the exception of a few well-known groups or well worked areas, and our equal ignorance of the distributions of many species.

Modern methods of surveying genetic diversity across wide-ranging species promise to provide an alternative or complementary approach to defining natural bioregions, with greater levels of predictability than traditional approaches that map and analyse patterns in the distribution of species, genera or families. In the context of poor taxonomic knowledge across most aquatic groups, predictability across taxonomic levels and boundaries is highly desirable.

Ideally, a bioregionalisation should be attempted using a combination of both approaches.

4.3 Process

Our ability to predict the effects of human activity on biodiversity or take appropriate action to ameliorate environmental damage is hampered by our limited understanding of ecological processes and how they regulate biodiversity in inland waters, including both natural and modified systems.

4.3.1 We need to undertake research to increase our fundamental understanding of the factors and processes that regulate biodiversity in freshwater systems to better predict the likely impact of human-induced change, to ameliorate the effects of human activity and to plan effective restoration and rehabilitation initiatives.

The pressures that bear on our inland waters are well documented and include:

- Inadequate provision of surface and groundwater to yield satisfactory environmental benefits;
- Alteration of the timing and intensity of flows such that flow regimes are mismatched with faunal and floral life histories;
- Fragmentation of previously connected systems; simplification of structural attributes of aquatic habitat;
- Pollution and contamination;
- Salinisation;
- Drainage and infilling of wetlands;
- Grazing of wetlands;
- Inadequate protection of riparian zones;
- Impacts of invasive species;
- Climate change and sea level rises.

We need to improve our fundamental understanding of how these pressures affect the processes that regulate biodiversity in modified and unmodified aquatic ecosystems if we are to effectively rehabilitate degraded areas to meet biodiversity objectives, or to undertake restoration. In particular, we need to be able to predict the likely impact of invasive species, identified overseas as the single most influential factor in the decline of native biodiversity in lakes and the third most influential factor in biodiversity decline in rivers[28]. Such understanding is necessary for undertaking risk assessments that incorporate estimates of the economic and ecological consequences of establishment. Such risk assessments influence Commonwealth government policy on the importation of species.

High priority should be given to the following research areas:

- Establishing predictive links between terrestrial, riparian and in-stream habitat and aquatic biodiversity. For example, how important are attributes of riparian habitat to in-stream biodiversity, and what are the causal links.

- Establishing the current and potential role of exotic invaders in the degradation of biodiversity in lakes and streams. For example, biological invaders are among the top causes of biodiversity decline in North American systems. Is this true of Australian freshwater systems?

- Establishing explicit links between the timing and magnitude of environmental flows and aquatic biodiversity. Environmental flows are important for maintaining freshwater biodiversity, but we are remarkably ignorant of the linkages between attributes of flow regimes and the biota, an ignorance that is impeding commitment to and effectiveness of action.

- The role of the interplay of connectivity and dispersal in determining the pattern of biodiversity distribution, and the impact of human activity on this dynamic (interbasin transfers, assisted movement of species or genetic stocks, etc).

4.4 Management and Policy Action

Australia has few 'intact' surface water systems left. Without coordinated and effective management efforts, the remaining intact freshwater ecosystems of high biodiversity value are at risk. However, much of Australia's natural resource management is the responsibility of State and Territory governments and jurisdictional boundaries do not usually coincide with the natural scales of freshwater ecosystems, which range from small-scale (local) to broad-scale (region) and often across jurisdictional boundaries

Clearly, a coordinated framework is required for biodiversity conservation in inland surface and ground waters, along with immediate steps to protect our remaining high-value systems, if we are to protect them from further degradation. Such an approach will require a suite of policy, management and research initiatives to address both current and future biodiversity issues and ensure that our freshwater systems are managed sustainably on behalf of current and future generations.

4.4.1 The States and the Commonwealth should work together to establish an enduring national series of Special Catchments for the Management of Biodiversity (alternatively referred to as National Heritage Rivers or National River Reserves).

The establishment of parks and reserves has long played a part in managing terrestrial ecosystems, and more recently for managing marine ecosystems. A similar effort is required to promote biodiversity conservation for freshwaters. This should be undertaken in a coordinated fashion so that any special management areas are representative of the range of freshwater ecosystems that exist across Australia, and address the range of threats or degrading influences that may impact on biodiversity values of inland waters.

All States and Territories are already committed to the establishment of systems of representative freshwater reserves through the IGAE 1992, and all jurisdictions except SA have moved to expand this commitment through policy statements. Tasmania's policy statement remains in draft form at this time. Unfortunately, programs to implement these commitments have at this stage only been developed in Victoria and the ACT.[21]

Each of the States and Territories are moving to identify and protect rivers of conservation value from further development. Examples of this are the Paroo River and Coopers Creek in Queensland, the Ovens River in Victoria, the Clarence River in NSW, the East Alligator River in NT and the Fitzroy River in WA. The moves to protect these and other rivers is admirable but their long-term status is vulnerable to changes to government and other pressures.

A national system of biodiversity management areas, including Heritage Rivers such as those listed above, should be established to protect high value systems from further development. Special management areas should be established through a comprehensive, adequate and representative system of reserves.

The establishment of special management areas such as Heritage Rivers does not necessarily mean that these systems will be 'locked away' from human activity. In many instances the current levels of usage and catchment activity can remain but the designated systems will be protected from further development, for example from:

- Further licenses to extract water;
- Construction of new dams and weirs or other similar structures;
- Further de-snagging or other 'river improvement' activities;
- Further drainage of wetlands;
- Further clearance of riparian vegetation;
- Construction of new levees;
- Stocking with alien aquatic species.

Biodiversity management areas should be selected to protect representative examples of natural ecosystems, features or phenomena. Such areas will be important for the:

- Protection of biodiversity against threatening processes;
- Provision for the conservation of special groups of organisms – for example, species with complex habitat requirements, mobile or migratory species, or species vulnerable to disturbance;
- Provision for the special needs of rare, threatened or depleted species, and threatened ecological communities;
- Provision of biodiversity 'banks' to recolonise damaged or degraded environments;
- Provision of scientific reference sites, either for research, or to provide benchmark indicators by which sustainable management may be judged;
- Protection of areas of high conservation value including those containing high species diversity, natural refugia for flora and fauna, and centres of species endemism; and
- Within the constraints of the above, provision for the recreational, aesthetic and cultural need of indigenous and non-indigenous people.

Biodiversity management areas created to protect representative ecosystems should be ecologically viable, in that they should be large enough to support species at the top of the food chain, such as the peak predators, and should be of sufficient size to permit ongoing evolutionary processes to occur. In the words of the International Convention on Biological Diversity, they should be *comprehensive, adequate and representative*.

Most States have existing policy commitments to establish systems of biodiversity management areas, but these commitments have not been fully implemented. The continuing degradation of most of the Australia's freshwater ecosystems makes the concept both more relevant and more urgent. The continuing decline of freshwater ecosystems over much of Australia means that the establishment of biodiversity management areas is now urgent. Two central recommendations are that:

- Agreed national methods for the classification of freshwater ecosystems into 'representative' categories should be established, which can be incorporated into a comprehensive national inventory; and
- A national approach should be developed to enable the identification of gaps in the existing reserve system relating specifically to freshwater ecosystems.

These undertakings should be initiated within the cooperative frameworks of the National Reserve System and ANZECC, assisted by agencies such as

AFFA, EA (wetlands program), the National Land & Water Audit and Land & Water Australia, including involvement by the National Rivers Consortium.

4.4.2 The States and Territories need to take immediate additional actions to protect high value systems such as wetlands of national significance and RAMSAR sites. We need to go beyond simply listing sites or planning recovery.

While the establishment of biodiversity management areas and biogeographic regions are important initiatives for managing freshwaters in the future, there is a need for urgent action to protect already-recognised high-value systems from further degradation. For example, we declare RAMSAR Wetlands under international conventions but without action to protect their nationally important biodiversity values from continued degradation, such declaration is seen by many as an epitaph rather than an instrument for their protection.

We have action plans and recovery plans for endangered species, where their population trends and plight is well documented, but without action we run the risk of competing for the best-documented extinctions in history.

The protection of wetlands of national significance and freshwaters in National parks are issues that can be addressed immediately while the priorities and actions associated with a nationally coordinated biodiversity conservation effort are developed. Approximately 700 wetlands of national significance have already been identified for protection[31], including RAMSAR wetlands. Many of these wetlands are at risk, as current management arrangements rarely include the catchments in which the wetlands are located. Thus the source of the threats (e.g changed flow regime, water borne pollutants, invading species etc.) may be beyond the control of the agency responsible for the wetland.

Most national parks have been established to protect aspects of the terrestrial landscape. However, this does not ensure the protection of freshwaters. An example is the management of Kosciusko National Park, where almost all of the major rivers – the Geehi, Tumut, Tooma, Snowy, Eucumbene, Murrumbidgee - have been dammed, diverted, and damaged. Freshwaters in national parks, including streams, wetlands and groundwater dependant systems, should be afforded the same level of protection as the terrestrial systems the parks were established to protect.

The scientific community should take a lead role in the call for protection of intact waterbodies. By the time there is widespread community support for biodiversity conservation, high value systems have often already been severely damaged.

Immediate opportunities for action include:

- The application of RAMSAR criteria, including habitat criteria, to get a nationally representative listing of RAMSAR Wetlands.
- The protection of the 700 nationally important wetlands noted in the Environment Australia National Wetlands Program.
- Assigning to rivers and wetlands in National Parks the same level of protection afforded to terrestrial components.

The States have the constitutional responsibility for resource management under our federal system. They clearly have the responsibility to provide the necessary coordination across their agencies for effective on-ground action, with appropriate financial incentives provided by the Commonwealth.

4.4.3 Establish a mechanism to enable better coordination of biodiversity conservation efforts across tiers of government and across agencies within governments. We need to develop and implement financial and other incentive structures between the Commonwealth and the States to foster biodiversity conservation and restoration of our inland waters.

Much of the existing biodiversity legislation has been developed by the Commonwealth government but is to be applied by State and Territory government agencies, which often have different priorities and scales of response to a particular issue. This can lead to a lack of coordination when the scale of biodiversity issues extend beyond State boundaries. The best outcomes will be achieved if management responses are pitched at a scale commensurate with that of the issues or threats being addressed and that include links between freshwater, terrestrial and marine systems. This is an issue, which could be addressed by the recently established Natural Resource Management Ministerial Council, comprising State and Federal Ministers.

The development and application of tools such as Root Cause Analysis will assist in identifying proximate, intermediate and distal economic determinants that threaten biodiversity value. For example, poor terms of trade for farmers can affect their ability to control pest species, which in turn impact on aquatic ecosystems and biodiversity values.

Considering distal economic drivers and their potential impact on biodiversity values enables the promotion and implementation of schemes such as conservation stewardship, environmental management systems, or the development of water efficient agricultural systems and crops (cf current emphasis on developing more productive crops using current or increased water volumes).

Subsidisation should be removed from water resource developments and only those developments that yield a net surplus to society when all costs and benefits are calculated should be approved in the future.

While management responses are being developed and implemented to address the current pressures on our inland waters (see section 3.2), we have yet to come to terms with global pressures such as increased globalisation in trade (e.g. increased risk of invasive species) and global climate change (e.g. changes to flow regimes; changes to carbon balance). It is possible that global pressures may override management efforts aimed at addressing the current local pressures on our inland waters. It is important that adaptive management of our inland waters acknowledges that globalised trade and climate change may affect all other environmental and socio-economic drivers and their impact on biodiversity conservation.

4.4.4 The Commonwealth, States and Territories should jointly establish a national invasive species action plan, including rapid response plans for new or potential invaders.

We grossly underestimate the impact of invasive species, ranging from exotic riparian plants to bacterial pathogens to iconic invaders such as carp. Introduced species are the single most important factor in biodiversity loss in lakes overseas, and among the top three in rivers[28]. We import many hundreds of exotic fish species into Australia under license, with varying potential for establishment in our inland waters.

Carp are recognised by the community as a problem species, and are a major biodiversity threatening process. Although declared noxious in Victoria, Queensland and South Australia, carp are freely distributed throughout New South Wales as Koi. Koi is an ornamental strain of carp promoted by the ornamental-fish industry that rapidly reverts to wild-type form when released into our rivers. The strain is responsible for carp infestations in Tasmania, the Canberra region, the Shoalhaven River and the Clarence River of NSW. They should immediately be declared noxious in all Australian jurisdictions.

Trout have established breeding populations in many river systems. However, they should not be stocked as a recreational fish in our national parks and other high value areas where they eliminate some species of native fish, such as Mountain Galaxias, and where they impact upon stream biota such as frogs. Rampant restocking and translocation of fish to support recreational fishing carries with it the real risk of accidental introduction of unwanted invasive species such as carp.

We clearly need a coordinated approach to managing the impact of invasive exotic species on our freshwater biodiversity, and to place it higher on the agenda among the factors that bring pressure upon our freshwater

biodiversity. Numerous invaders have already affected Australian freshwaters and increasing globalisation of trade and the movement of goods increases the risk of additional invaders.

We need a well-funded and nationally coordinated program for managing invading species and the damage they cause. The program should include:

- An inventory of species already introduced, flagging those species that are or may potentially be invaders.
- Compilation of potential new species likely to be imported and ecological risk assessment to assess their potential as an invading species.
- Agreement with the aquarium fish industry on restricting or eliminating the trade in those species of greatest concern. We need to acknowledge that this multi-million dollar industry cannot be stopped (to attempt to do so would drive the trade underground, and perhaps increase the frequency by which exotic species were released into the wild), and that we need to work with the industry to achieve control objectives.
- Rapid response plans that streamline approvals and spell out responsibilities to deal with infestations before they get a secure foothold. Unfortunately, examples of tardy responses with sad endings abound.
- Implementation of the National Carp Management Strategy, including the listing of all strains of carp as a noxious species and biodiversity threat in NSW (in line with other States).
- Better coordination of agencies such as Biosecurity Australia, Environment Australia and the Vertebrate Pest Committees to ensure proper coordination of risk assessments from the perspectives of potential economic damage, disease, and ecological impacts (including impacts on biodiversity).
- Research to better understand the role of exotic invaders in degradation of biodiversity in lakes and streams.

APPENDIX 1 CONFERENCE PARTICIPANTS AND ADVISERS

The following people made special contributions that promoted discussion at the final workshop session of the Fenner conference:

Jane Madgewick	World Wide Fund for Nature Australia
Sam Lake	Monash University, CRC for Freshwater Ecology
Margaret Brock	NSW Department of Land and Water Conservation

The following people provided comments and advice that greatly assisted the preparation of this report:

Ben Cook	Griffith University
Tim Entwistle	Royal Botanic Gardens, Sydney
Tom Grant	University of New South Wales
Jane Hughes	Griffith University
Jon Nevill	Only One Planet Consulting
Bill O'Connor	Victorian Department of Natural Resources and Environment
Winston Ponder	Museum of Australia, Sydney
Anthony Ricciardi	McGill University, Montreal, Canada

Conference Participants

Dr Ross Alford, School of Tropical Biology
Mr Craig Allen, Corangamite OMA
Mr Dean Ansell, Applied Ecology Research Group
Ms Louise Armstrong, National Parks and Wildlife Service
Professor Angela Arthington, Centre for Catchment and Instream Research
Professor John Avise, University of Georgia
Dr Yeon Jae Bae, Monash University
Ms Joelle Bakker, Urban Services
Dr Leon Barmuta, University of Tasmania
Mr Jim Barrett, Murray Darling Basin Commission
Mr Alan Baxter, Fisheries Victoria
Professor Andrew Beattie, Key Centre of Biodiversity and Bioresources
Dr Stuart Blanch, Australian Conservation Foundation
Ms Chris A. I. Bloomfield, Charles Sturt University
Dr Andrew Boulton, University of New England
Mr Roland Bow, NSW Fisheries
Dr Margaret Brock, Centre for Natural Resources
Dr Felicity Bunny, Environment Australia
Ms Rhonda Butcher, Monash University

Mr Giovannella Carini, Griffith University
Miss Lydia Cetin, University of Adelaide
Mr Lindsay Chadderton, Department of Conservation
Ms Fiona Chandler, Brisbane City Council
Ms Rosie Chapman, Upper Snowy Landcare Committee
Dr Bruce Chessman, NSW Department of Land and Water Conservation
Ms Stephanie Clark, Invertebrate Identification
Dr Paul Clayton, Queensland Environmental Protection Agency
Mr Peter Coad, Hornsby Shire Council
Dr Kevin Collier, NIWA
Ms Sonia Colville, University of Ballarat
Mr Ben Cook, Australian School of Environmental Studies
Mr Robert Cook, CRC for Freshwater Ecology
Mr Justin Costelloe, CSIRO Sustainable Ecosystems
Mr Peter Cottingham, CRC for Freshwater Ecology
Mr David Crook, CRC for Freshwater Ecology
Professor Peter Cullen, CRC for Freshwater Ecology
Miss Catherine Cuteri, Ursula College
Dr Peter Davies, University of Tasmania
Ms Tracie Dean, Department of Conservation - Northern Regional Office
Mr Timothy Doeg
Dr Michael Douglas, Northern Territory University
Dr Helen Dunn, University of Tasmania
Mr Peter Ebsworth, International SOS
Mr Charles Ellway, Riverreach
Dr Tim Entwistle, Royal Botanic Gardens Sydney
Dr Richard Evans, Sinclair Knight Merz
Ms Rosie Evans, University of Melbourne
Mrs Sarah Fairfull, NSW Fisheries
Pat Feehan, Goulburn-Murray Water
Professor Frank Fenner
Dr Max Finlayson, ERISS
Mr Neal Foster, Department of Land and Water Conservation
Ms Judy Frankenberg, NSW Murray Wetlands Working Group
Ms Louise Gallagher, Environment ACT
Dr Adriana Garcia, University of Wollongong
Dr Peter Gehrke, NSW Fisheries
Dr Arthur Georges, CRC for Freshwater Ecology
Mr Jon Graftdyk, Charles Sturt University
Ms Natasha Grainger, Department of Conservation - Northern Regional Office
Dr Tom Grant, University of NSW
Mr Fiorenzo Guarino, Applied Ecology Research Group
Ms Simone Gunn, Corangamite OMA
Dr Stuart Halse, Department of Conservation and Land Management
Mr Gary Hamer, NSW Department Land & Water Conservation
Mr Michael Hammer, Adelaide University
Ms Michelle Handley, World Wide Fund for Nature

Mr Rendle Hannah, NSW Agriculture
Ms Lorraine Hardwick, NSW Department of Land and Water Conservation
Dr John Harris, Harris Research Pty Ltd
Ms Donna Hazell, Australian National University
Mr Adrian Hemens, NSW Fisheries
Dr Terry Hillman, CRC for Freshwater Ecology
Mrs Huong Hoang, University of Adelaide
Mr Sean Hoobin, World Wide Fund for Nature
Mr Theo Hooy, Environment Australia
Dr Pierre Horwitz, Edith Cowan University
Professor Jane Hughes, Australian School of Environmental Studies
Dr Paul Humphries, CRC for Freshwater Ecology
Mr Stephen Hunter, Environment Australia
Mr David Hurwood, Australian School of Environmental Studies
Dr Jean Jackson, Inland Fisheries Service, Tasmania
Dr Kimberley, James Deakin University
Professor Jacob John, Curtin University
Mr William Johnson, NSW National Parks and Wildlife
Professor Gary Jones, CRC for Freshwater Ecology
Mrs Minal Khan, University of Ballarat
Mr Tariq Khan, University of Ballarat
Mr Peter Kind, Queensland Department of Primary Industries
Ms Alison King, CRC for Freshwater Ecology
Dr Richard Kingsford, NSW National Parks and Wildlife
Dr John Koehn, Department of Natural Resources and Environment
Ms Amanda Kotlash, CRC for Freshwater Ecology
Mr Martin Krogh, Sydney Catchment Authority
Mr Ben Kropp, CRC for Freshwater Ecology
Professor Philip Lake, Monash University
Mr Geoff Larmour Wetlands Section, Environment Australia
Ms Rochelle Lawson, National Land and Water Resources Audit
Mr Cameron Lay, NSW Fisheries
Ms Linda Lee, Environmental Protection Agency
Mr Mark Lintermans, Wildlife Research and Monitoring
Mr Bill Logan, Environment ACT
Mr Greg Long, Murray Darling Basin Commission
Mr Terry Loos, Environmental Protection Agency
Ms Rachel MacKenzie, Department of Primary Industries
Ms Jane Madgwick, WWF Australia
Dr Michael Maher, NSW National Parks and Wildlife
Dr Michael Mahony, Newcastle University
Ms Sonia Mahony, Corangamite OMA
Dr Richard Marchant, Museum of Victoria
Ms Heather McGinness, University of Canberra
Mr Alex McNee, Bureau of Rural Sciences Australia
Dr Chris Moran, CSIRO Land and Water
Mr Warwick Moss World Wide Fund for Nature

Professor Peter Moyle, Department of Wildlife, Fish and Conservation Biology
Mr Jon Nevill, Only One Planet
Dr Deborah Nias, NSW Murray Wetlands Working Group
Dr Raymond Nias, WWF Australia
Ms Sue Nichols, CRC for Freshwater Ecology
Dr Conall O'Connell, Environment Australia
Mr Bill O'Connor, Department of Natural Resources and Environment
Mr Dennis O'Dowd, Centre for Analysis and Management of Biological Invasions
Mr Stan Orchard, World Wide Fund for Nature
Ms Glenda Orr, Department of Land and Water Conservation
Ms Keely Ough, Deakin University
Ms Melissa Parsons, University of Canberra
Professor Richard Pearson, James Cook University
Ms Kylie Peterson, Environment Australia
Mr Vincent Pettigrove, Melbourne Water
Dr Bill Phillips, Mainstream Environmental Consulting
Dr Ngaire Phillips, NIWA Australia Pty Ltd
Mr Nigel Philpot, Urban Services/ Environment ACT
Ms Belinda Pinker
Mr Jamie Pittock, Word Wide Fund for Nature
Dr Winston Ponder, Australian Museum
Janet Pritchard, Australian National University
Dr Brad Puse, CRC - Rainforest Ecology
Mr Tarmo Raadik, Arthur Rylah Institute
Ms Tanya Rankin, Institute of Wildlife Research
Ms Anne Reeves, National Parks Association/ Inland Rivers Network
Dr Anthony Ricciardi, Dalhousie University
Mr Greg Roberts, NSW Environment Protection Authority
Dr Jane Roberts, Applied Ecology Research Group
Mr Hugh Robertson, Deakin University
Mrs Elizabeth Rogers, NSW Agriculture
Dr Darren Ryder, Charles Sturt University
Ms Angela Rymer, Wetlands Section, Environment Australia
Dr John Schooneveldt, Nature and Society Forum
Dr Sabine Schreiber, Arthur Rylah Institute, DNRE
Mr Tom Scotney, Environmental Protection Agency
Ms Linda Selg, Wetlands Section, Environment Australia
Dr Melody Serena, Australian Platypus Conservancy
Mr Peter Serov, Department of Land and Water Conservation
Mr Martin Shafron, Environment Australia
Mrs Suman Sharma, Griffith University
Cr Brian Sharp, Murray Darling Association Inc
Mr Mark Siebentritt, CRC for Freshwater Ecology
Dr Kevin Simon, Universtiy of Otago
Mr Justen Simpson, NSW Environment Protection Authority
Ms Pam Soper, Wide Bay Burnett Conservation Council

Mrs Janet Stein, Australian National University
Ms Kath Stephens, Brisbane City Council
The Hon Dr Sharman Stone, Parliamentary Secretary to the Minister for the Environment and Heritage
Mr Jim Tait, National Land and Water Resources Audit
Mr Scott Thomson, Applied Ecology Research Group
Mr Charles Todd, Department of National Resources and Environment
Professor Colin Townsend, University of Otago
Mr Tom Vanderbyl, Department of Natural Resources and Mines
Mr Adam Vey, NSW Fisheries
Ms Jo Voller, Queensland Department of Natural Resources & Mines
Mr David Ward, NSW Fisheries
Mr Joel Waring
Dr Jonathan Waters, University of Otago
Dr Robyn Watts, Charles Sturt University
A/Professor Philip Weinstein, University of Otago
Mr Adrian Wells
Mr Damian Wells, Mallee Catchment Authority
Mr Harko Werkman, University of Newcastle
Dr David Williams, CRC for Freshwater Ecology
Mr Michael Wilson, University of Ballarat
Mr David Winfield, NSW Environment Protection Authority
Dr Marcus Wishart, University of Cape Town
Ms Sarah Young, Wetlands Section, Environment Australia

APPENDIX 2 TERMS AND ABBREVIATIONS

Terms

Biogeographic region:

An area with similar landform, soils, biota and climate.

Catchment management:

Natural resource management within catchment boundaries. Covers the integrated management of land, water and biological resources.

Ecosystem processes:

Processes related to the flow of energy and nutrients through food webs (e.g. primary productivity, community respiration).

Environmental flows:

Releases of water or periods of drying allocated to maintain or improve riverine and floodplain (including wetland) ecosystems.

Groundwater: All subsurface water.

Groundwater dependant ecosystems:

Include systems such as wetlands, springs, caves and the hyporheic (subsurface flow) zone of rivers.

Infrastructure: Includes dams, weirs, river off-takes, bores, agricultural drains, levee banks, evaporative basins, and irrigation schemes.

Protected areas: Areas of land and/or water “especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means” (World Conservation Union, IUCN 1994). The term “reserve” is used here in the sense of.

Representative freshwater reserves:

'Representative' can be taken as shorthand for 'comprehensive, adequate and representative' (Convention on Biological Diversity 1992 and the National Strategy for the Conservation of Australia's Biological Diversity 1996).

Includes representatives of all inland aquatic ecosystems: lakes, wetlands, karst and other underground ecosystems, springs, rivers and their associated channels, billabongs, and immediate surrounds (including sub-surface ecosystems). Where the ecologies of estuaries are dominated by inland water flows rather than marine influences, these too may be included.

Reserve: Tracts of land and/or water, over which particular management regimes are applied. Direct human intervention and modification are limited (IUCN classes I-IV)

State: Australia has six States and two Territories. The word '*State*' is used as shorthand to encompass all these jurisdictions.

Wetlands: The RAMSAR definition includes both still waters and flowing waters (e.g. rivers), but where the term 'wetlands' is used in this paper it is used in the sense more common in Australia, i.e. excluding flowing waters such as the main channels of rivers and streams.

Abbreviations

ABRS	Australian Biological Resources Study
ANZECC	Australia New Zealand Environment & Conservation Council
AFFA	Agriculture Forests Fisheries Australia
ARC	Australian Research Council
COAG	Council of Australian Governments
EA	Environment Australia
ESD	Ecologically Sustainable Development
IBRA	Interim Biogeographic Regionalisation of Australia
IGAE	Intergovernmental Agreement on the Environment
MDBCMC	Murray Darling Basin Commission Ministerial Council
NHT	Natural Heritage Trust
SCA	Sydney Catchment Authority

APPENDIX 3 REFERENCES AND BIBLIOGRAPHY

1. Biological Diversity Advisory Council (2000). *Biodiversity Research: Australia's Priorities. A Discussion Paper*. Available from the Biodiversity Convention and Strategy Section, Environment Australia, GPO Box 787, Canberra ACT 2601.

2. Commonwealth of Australia (1996). National Strategy for the Conservation of Australia's Biodiversity. http://chm.environment.gov.au/strategy/.

3. Council of Australian Governments (1992). National Strategy for Ecologically Sustainable Development. http://www.environment.gov.au/psg/igu/nsesd/.

4. Australia: State of the Environment (1996). http://www.environment.gov.au/soe/soe96/soe96.html.

5. RAMSAR Convention on Wetlands of International Importance especially as Waterfowl Habitat (1971). http://www.Ramsar.org/key_conv_e.htm.

6. Convention on Biodiversity (1992). http://www.biodiv.org/convention/articles.asp?lg=0.

7. Intergovernmental Agreement on the Environment (1992). http://www.environment.gov.au/psg/igu/igae.html

8. Eastern Metropolitan Regional Council (EMRC). Draft Regional Environmental Strategy. http://www.emrc.org.au/res/execsum.html.

9. New South Wales State of the Environment (1995). http://www.epa.nsw.gov.au/soe/95/index.asp

10. State of Environment Report. Australian Capital Territory (2000). http://www.envcomm.act.gov.au/Soe2000/ACT/index.htm

11. Shoalhaven City Council 2000 State of Environment Report (2000). http://www.shoalhaven.nsw.gov.au/council/pubdocs/soe/index.htm

12. Environmental indicators for national State of the Environment reporting. http://www.environment.gov.au/soe/envindicators/

13. Fairweather, P.G. and Napier, G.M. (1998). Environmental indicators for national State of the Environment reporting. Inland Waters. http://www.environment.gov.au/soe/envindicators/pubs/inland-ind.pdf

14. Saunders, D., Margules, C. and Hill, b. (1998). Environmental indicators for national State of the Environment reporting. Biodiversity. http://www.environment.gov.au/soe/envindicators/pubs/biodiversity-ind.pdf

15. Commonwealth of Australia (1997). The Wetlands Policy of the Commonwealth Government of Australia. http://www.environment.gov.au/water/wetlands/policy.htm

16. Thackway, R. and Cresswell, I.D. (1995). An interim biogeographic regionalisation of Australia: a framework for setting priorities in the National Reserves System Cooperative Program. Version 4. Australian Nature Conservation Agency, Canberra. http://www.dest.gov.au/bg/nrs/ibraimcr/ibra_95/

17. Commonwealth of Australia (1999). The Environment Protection and Biodiversity Conservation Act, 1999. http://www.environment.gov.au/epbc/index.html

18. Government of Victoria (1988). The Flora and Fauna Guarantee Act, 1988. Department of Natural Resources and Environment, Melbourne.

19. Cottingham, P. Georges, A., Briscoe, D., Butcher, R., Cullen, C., Deere, D., Harris, J., Hughes, J., Knowles, M., Lake, S., Lanertz, K., Paul, T., Reed, J., Williams, S. and Yates, D. (2000). Managing biodiversity in the Sydney water supply catchments. Outcomes of a workshop held at Warragamba Conference Centre, 12-13 October, 2000. CRC for Freshwater Ecology Technical Report No, 9/2000.

20. Nevill, J. (2001). Australian Society for Limnology representative aquatic reserves discussion paper working group. http://www.asl.org.au/asl_news_aquaticres.htm

21. Nevill, J. (2001). Freshwater biodiversity: Protecting freshwater ecosystems in the face of infrastructure development. Water Research Foundation of Australia, Australian National University, Canberra. http://www.netspace.net.au/~jnevill/freshwater-a.htm.

22. Mullins, B.J.D. and Sutherland, L.J. (2001). Scoping report for the development of a biodiversity strategy and plan for the rice industry. Johnstone Centre Research in natural Resources and Society (Charles Sturt University, Wagga Wagga. Environmental Consulting Report No. 11.

23. Naturally Resouceful Pty Ltd. (2001). Communications strategy and plan for the implementation of a biodiversity plan for the rice industry. Ricegrowers Association, PO Box 561, Leeton NSW 2705.

24. Australian Local Government Association (1998). National local government biodiversity strategy.

25. CSIRO (1999). The nature and value of Australia's ecosystem services. How much is a bit of Australia worth? CSIRO, Canberra.

26. Upper Shoalhaven Catchment Management Committee (1997). Natural resources management strategy. Upper Shoalhaven Catchment. TCM Coordinator, PO Box 9, Braidwood NSW 2622.

27. National Rivers Consortium (1999). Restoration and protection of Australian rivers. National Rivers Consortium Strategic Plan.

28. Sala, O.E. et al. (19 authors) (2000). Global biodiversity scenarios for the Year 2100. Science 287: 1770-1774.

29. Stone, M. K. and Wallace, J. B. (1998). Long-term recovery of a mountain stream from clear-cut logging: the effects of forest succession on benthic invertebrate community structure. Freshwater Biology 39, pp 151-169.

30. Williams, D. G. and Roberts, J. (2001). Sampling biodiversity in floodplain wetlands: how useful is 'bioregion' ? Paper presented to the Fenner Conference on the Environment: biodiversity and conservation in freshwaters (Abstract)

31. Environment Australia (2001). A directory of important wetlands in Australia. http://www.environment.gov.au/wetlands/wet2.html