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Wetland conservation

WILL ECOSYSTEM-LEVEL CONSERVATION PROTECT WETLAND BIODIVERSITY?

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ABSTRACT

The ecological, biological and hydrological diversity of wetlands has led to a variety of human uses and conflicting demands. If wetlands are to be managed for an ecologically sustainable future, we need to understand, manage and conserve them as functioning systems.

The number of national and international conservation initiatives has increased: the Ramsar Convention for protection of wetlands of international importance, the International Treaty on Biodiversity, the Australian Endangered Species Protection Act (1992), and a National/State agreed policy on Ecologically Sustainable Development, all aim to protect. The questions are what will each protect and how can each be used to ensure that wetland integrity remains?

If our wetlands can be managed by understanding the processes in them and making sure the integrity of each wetland stays intact, we have a higher chance of conserving the biodiversity at all levels; bacteria, protists, fungi, lower plants and invertebrates, as well as the better known vertebrates and higher plants.

By examining the parallels and contrasts between wetland systems across Australia we can understand the resilience, tolerances and vulnerability of our wetlands. All Australian wetlands have both features and human impacts in common. The need to manage whole catchments to achieve sustainable wetland systems is universal. Research in Australia's tropical wetlands plays, and will continue to play, an important role. The variety of wetland types and the organisms in them are described more completely than for many less remote wetlands. Perhaps research, management and conservation in our tropical wetland systems can act as a model for wetland management elsewhere.

Keywords: wetland management, species, community, ecosystem, threats, Endangered Species Protection Act (1992), biodiversity.

1 The need for managing wetlands

How to maintain wetland diversity is our fascination and our challenge. Most of us have specialised interests in particular aspects of wetlands. We all know something of the uses, the abuses and the threats. How to focus our research efforts to feed into useful management policy is the major question for all ecosystem managers and those concerned with conservation of diversity.

A holistic approach to the understanding of wetlands is needed; specific knowledge needs to be interpreted in terms of the interactions in the whole system and new research and management questions must be framed in terms of the dynamics of wetland ecosystems. If wetlands are to be managed for an ecologically sustainable future, we need to understand, manage and conserve them as functioning systems.

2 Wetland diversity: ecological, biological and hydrological

The ecological, biological and hydrological diversity of wetlands has led to a variety of human uses and some conflicting demands.

Wetlands have a public profile that varies from valued, to unhealthy mosquito ridden swamps that are wasted agricultural land. The 'if it is wet, drain it' mentality is not quite dead. However, the perception of wetlands throughout Australia has improved, mainly through awareness of the birds, mammals and even a water lily or two that evoke an emotional response from the non-scientific viewer. As scientists we are well aware that these species are the signs of a healthy system, a biologically complex system of interactions between abiotic factors and biotic components from all kingdoms: monera, fungi, protists, animals (both invertebrates and vertebrates) and plants (both non-vascular and vascular). Changes to the hydrology, biology or catchments of wetlands will change the balance of these biotic and abiotic interactions. It is our task to understand these changes and to predict the consequences for the whole ecosystem.

The dynamic nature of wetland hydrology provides a wide variety of wetland habitats. Even many wetland scientists have been lured by the wet and tend to disregard the important dry phase of many temporary wetlands. The wet and dry seasons in tropical wetlands are predictable, yet the detail of timing and extent of wetting within a season can be markedly variable. It is this variability at various scales of space and time that provides the basis for many of our scientific and management questions. How much change can these systems take? We will never manage to conserve these ecological systems or the species in them unless we understand the wetland processes and their resilience.

3 Conservation initiatives

The number of national and international conservation initiatives has increased: the Ramsar Convention for protection of wetlands of international importance, the International Convention on Biological Diversity, the Australian Endangered Species Protection Act (1992), and a National/State agreed policy on Ecologically Sustainable Development, all aim to protect. The questions are what will each protect and how can each be used to ensure that wetland integrity remains?

Most of these conservation initiatives aim at the species first, their habitat second, with little attention to the community and ecosystem. They rely on a knowledge of each species. If we do not know our species well enough to assess what is there and what species are endangered, lost or threatened, these conservation initiatives cannot protect species effectively and hence fail to protect the communities and systems.

The Ramsar Convention for protection of wetlands of international importance for waterfowl habitat is now over 20 years old. It was a forward-thinking initiative. It provides an international agreement on protection of habitats for particular species. In protecting habitats many other species will also be protected, but is this enough? If wetland ecosystem types were the target of conservation instead of species it would be a more efficient way to conserve.

The Endangered Species Protection Act has a mechanism for listing 'endangered ecological communities' and 'threatening processes' as well as 'endangered and vulnerable species'. This is a relatively new concept for Australia and as yet no ecological communities have been listed - not because there are no endangered communities but because the nomination process is just being developed. At present a discussion paper on the process for listing endangered ecological communities is open for comment (Endangered Species Scientific Subcommittee 1995). This legislation, like the Victorian Flora and Fauna Guarantee Act (1988) is innovative in recognising that there is more to protect than species and their habitats. However, it has a long way to go before it serves the function of providing protection for ecological communities. Before any wetland communities could be listed they would need to be nominated and the preparation of such nominations will depend on wetland ecologists like us knowing our systems well enough to recognise and justify their threatened status. Once listed, the law requires a plan to ensure the recovery of the community type. Both the recognition of non-sustainable wetland ecosystems and the making of plans for change to allow recovery will be two of the most challenging tasks we face from now into the future. How can we assess whether a system is 'sustainable' and what uses it will sustain?

4 Conservation of ecosystems and ecological processes rather than species

The approach to management of any wetland ecosystem will depend on the scale at which we aim to manage the biological diversity. If conservation of genetic diversity at a sub-specific level is the aim, then management will be directed towards a few target species often on a local scale. If species richness is the aim, species groups, related taxa or functional groups may be more appropriate. For the broader aim of conservation of the maximum sustainable diversity a community or ecosystem approach is more appropriate.

This requires delineation of communities and ecosystems as recognisable entities. This is scale-dependent and dynamic both spatially and temporally. Defining communities and ecosystem types can be a problem for scientists, managers, lawyers and politicians. It is difficult to protect ecosystems and their processes when delineation in concrete terms is not easy. Boundaries on a map can be interpreted by our legal system, but the breakdown of community processes has no definable boundaries. This may be why species conservation is easier to plan than ecosystem level conservation.

If our wetlands can be managed by understanding and maintaining the processes in them we have a higher chance of conserving the biodiversity at all levels: bacteria, protists, fungi, the lower plants and invertebrates as well as the better known vertebrates and higher plants.

It can be argued that it is too late for the most endangered species and that the little public money that is available would be better spent on 'vulnerable' rather than 'endangered' or 'presumed extinct' groups. Similarly it can be argued that if you can protect the ecosystem type then the ecological communities and the species in them have a maximum chance of survival and reproduction.

Increasingly the view is being expressed that an ecosystem view is necessary to ensure lasting conservation. In 1994 the need to focus research to address both management and political needs was expressed at both the International Congress of Ecology (INTECOL) in Manchester and at the meeting of the American Institute of Biological Sciences (Farnsworth 1995).

For wetlands and marine ecosystems the knowledge base is not nearly as good as for terrestrial systems. Because water is more dense than air it provides a habitat for a diverse suspended community, of invertebrates, lower plants, fungi, protists and monerans. Similarly benthic communities, attached to underwater surfaces, and communities of the air-water interface are diverse. These complex communities are not well enough known to understand whether individual species are endangered and if so how to manage for the recovery of each. A community or ecosystem approach to conservation and management will allow protection.

If research and management focus on the detection of patterns of biological diversity and their relationship to ecosystem function, rather than on individual species, more will be achieved for each conservation dollar. Such approaches are being proposed for conservation of marine diversity (Vincent & Clarke 1995). With our present knowledge of many wetland systems, for example the floodplain wetlands of the wet-dry tropics, we can contribute wetland insights to this approach.

5 Coping with complexity

The resource we have to manage is a complex, dynamic and diverse set of wetlands. We need to find ways to deal with the complexity of all ecological systems. Over the past decades we have tried by simplifying them, taking them apart, understanding the parts and the components in isolation. Putting the parts back together to understand how they contribute to the whole has not been so easy. Recent discussions about holistic approaches to ecosystems (Brown 1995) reiterate the need to find ways to study ecosystem complexity more directly. This indicates a need for a broad ecological conceptual framework that incorporates the needs of both conservation and management. In wetland systems we have been observing direct and indirect influences of organisms on their environments and environments on organisms for years. Perhaps we can constructively use environmental and biological manipulative experiments to help formulate an appropriate basis for the predictive management of our wetland systems.

6 The contributions that wetlands scientists and managers can make

By examining the parallels and contrasts between wetland systems across Australia we can understand the resilience, tolerances and vulnerability of our wetlands. All Australian wetlands have both features and human impacts in common. The need to manage whole catchments to achieve sustainable wetland systems is universal. Research in Australia's tropical wetlands plays, and will continue to play, an important role. The variety of tropical wetland types and the organisms in them are described more completely than for many less remote wetlands. Perhaps research, management and conservation in our tropical wetland systems can act as a model for wetland management elsewhere.

Wetland scientists and managers can apply ecosystem or community approaches to questions of wetland conservation without forgetting about the species that may have caught the public eye. In this way we can protect functioning systems and at the same time protect species, both the known and the unknown, and manage the processes that threaten the sustainability of both species and systems.

A challenge for wetland ecology is to offer our understanding of wetlands ecosystem function as a model that can be used in decision-making in the development of management, conservation and environmental education policy.

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7 References

Brown JH 1995. Organisms as engineers: a useful framework for studying effects on ecosystems? *Trends in Ecology and Evolution* 10 (2), 51–52.

Endangered Species Scientific Subcommittee 1995. *Listing ecological communities under the Endangered Species Protection Act (1992): Public discussion paper*. Australian Nature Conservation Agency, Canberra.

Farnsworth EJ 1995. Oikos and ethos: setting our house in order. *Trends in Ecology and Evolution* 10 (2) 56–57

Vincent A & Clarke A 1995. Diversity in the marine environment. *Trends in Ecology and Evolution* 10 (2), 55–56.

THE LWRRDC NATIONAL RIPARIAN PROGRAM: RESEARCH ISSUES AND OPPORTUNITIES FOR THE WET-DRY TROPICS

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ABSTRACT

A national program of research and development on riparian ecosystems has commenced, coordinated by the Centre for Catchment and In-Stream Research, the CRC for Catchment Hydrology and the Land and Water Resources Research and Development Corporation (LWRRDC). The broad research objectives of this program are (i) to identify and quantify the effects of riparian vegetation on channel morphology, bank stability, and the ingress of sediment and nutrients to rivers and other water bodies, and (ii) to identify key processes by which riparian zones influence in-stream ecosystems and their function. Where possible, more 'terrestrial' issues, such as factors influencing the recruitment and regeneration of riparian vegetation and the use of riparian zones by wildlife, will also be addressed within the ecological component of the program. The third broad aim of the program is to demonstrate practical, cost-effective and ecologically sound methods for the rehabilitation and management of riparian zones. The focus of the ecological component of the program is to address crucial gaps in our understanding of riparian/stream linkages. Before we can understand the full implications of threats to riparian systems in the wet-dry tropics (eg overgrazing, feral animals, weed invasions, fire), several fundamental research questions must be addressed. We cannot hope to manage the unique riverine and wetland systems in the wet-dry tropics within a framework of understanding developed from research in temperate forest ecosystems. In this context, research issues of particular relevance to the region are discussed.

Keywords: riparian vegetation, wet-dry tropics, streams and rivers, wetlands, ecological processes, food-webs, community metabolism, rehabilitation.

1 Introduction

The rehabilitation and management of riparian lands was recognised as an area of high priority in the 1992-97 R&D Plan of the Land and Water Resources Research and Development Corporation (LWRRDC). Although important ecological and geomorphological roles of riparian zones are well-accepted by ecologists and, increasingly, by managers (Bunn 1993, Catterall 1993, Cummins 1993), riparian lands in Australia have been long neglected and poorly managed, if at all. To address this concern, the LWRRDC commissioned independent reviews to identify priorities for research and management on the influence of riparian zones on in-stream processes (Bunn 1992), and their importance to terrestrial wildlife (Catterall 1992). These were followed by workshops on the role of riparian buffers in the management of waterway pollution (Woodfull et al 1993) and priorities for research and management on ecological issues (Bunn et al 1993). These reviews and workshop proceedings highlighted the need for a coordinated national approach to research and management of riparian zones in Australia.

2 The LWRRDC riparian lands program

In July 1994, the LWRRDC established a national program of research and development, in collaboration with the CRC for Catchment Hydrology and the Centre for Catchment and In-Stream Research, Griffith University (figure 1, Anon 1994). The structure of the overall program focuses on key riparian functions, with the intention that future management will be framed in similar terms (see Cummins 1993).

NATIONAL RIPARIAN LANDS R&D PROGRAM

PHYSICAL/CHEMICAL ISSUES	**ECOLOGICAL ISSUES**
PROGRAM A	**PROGRAM B**
CRC for Catchment Hydrology	Centre for Catchment and In-Stream Research
Conceptual framework (A1)	Sources of energy (B1)
Hydrologic regime (A2)	Energy and nutrient transport (B2)
Sediment and nutrient run-off (A3)	In-stream habitat (B3)
Channel erosion and stability (A4)	Rehabilitation, off-stream habitat (B4)
Riparian system model (A5)	

QUANTITATIVE GUIDELINES

PROGRAM C

LWRRDC

Figure 1 Overview diagram of the LWRRDC riparian lands R&D program

The broad research objective of Program A is to identify and quantify the effects of riparian vegetation on channel morphology, bank stability, and the ingress of sediment and nutrients to rivers and other water bodies. Program B aims to identify key processes by which riparian zones influence in-stream ecosystems and their function, although, where possible, more 'terrestrial' issues, such as factors influencing the recruitment and regeneration of riparian vegetation and the use of riparian zones by wildlife, will also be addressed. These broad, but inter-related, research programs are linked to Program C, which aims to demonstrate practical, cost-effective and ecologically sound methods for the rehabilitation and management of riparian zones (figure 1). Notable features of the program are (i) the emphasis on research directed at understanding important riparian processes, (ii) the focus on linkages between streams and riparian zones (and not other wetlands), (iii) an emphasis on issues associated with agricultural and pastoral industries, and (iv) a coordinated national approach. Negotiations with representatives from State agencies, research and community groups have taken place in Western Australia, Tasmania and Queensland, and will continue in the other States and Territories in 1995.

2.1 Research issues and priorities

To some extent, research priorities will vary from State to State and region to region. This reflects differences in (real and perceived) management issues (see State and Territory reviews in Bunn et al 1993). These include loss of riparian vegetation from salinisation, excessive clearing for agriculture, uncontrolled access of stock and feral animals, and competition from highly invasive weeds. Similar management issues have been identified in the wet-dry tropics, where degradation of riparian zones is extensive, particularly from overgrazing, land-clearing and severe exotic weed infestations (Sattler 1993).

The biggest impediment to management, and particularly rehabilitation, of riparian lands in Australia is a lack of understanding of key processes. Much of our knowledge of riparian processes comes from studies of temperate forest ecosystems in North America and Europe, and to a lesser extent from small forest streams in southern Australia (see Bunn 1993, Cummins 1993, Gregory et al 1991). In these systems, riparian vegetation clearly exerts a major direct influence as a supplier of energy and nutrients (as leaf litter and other organic debris), and as a regulator of in-stream processes through shading and reduction in water temperatures. Disruption of these linkages through clearing of vegetation, and associated increases in temperature and light (and often nutrients), often results in a marked increase in in-stream primary production (eg Feminella et al 1989). In particular, largely vascular plants and filamentous algae can proliferate, restricting flow, trapping sediment and ultimately resulting in marked changes to available habitat and lowered water quality. A spectacular example of this is the excessive growth of para grass in stream channels in the cane lands of northern Queensland.

2.2 Riparian research in the wet-dry tropics

How applicable is this knowledge likely to be, however, to the streams and associated riparian systems of the wet-dry tropics? Many of these systems, particularly in the savanna woodlands and shrublands, drain sparsely vegetated catchments and are characterised by a relatively open riparian canopy. Are in-stream sources of energy, such as algae or macrophytes, likely to be more important, or are aquatic food webs still driven by riparian inputs? Are these streams likely to be more sensitive to nutrient enrichment because they are less shaded than the more widely studied forest streams?

How important are other riparian inputs, such as terrestrial arthropods and fruits, to aquatic food webs? For example, herbivorous turtles (*Elseya dentata*) in the Daly River are found associated with dense riparian vegetation, particularly containing species of *Ficus* (see Sattler 1993). While most of the focus of research on riparian-stream linkages has been on the flux of energy and nutrients from the riparian zone to the stream, there may also be substantial movement of materials in the opposite direction. Riparian zones in the more arid regions of the continent undoubtedly offer an important refuge for wildlife, particularly during the dry season when animals are drawn to these areas for shade and water (Catterall 1993, Morton 1990). Aquatic insects (adults and larvae) and other invertebrates, fish and other stream vertebrates may represent a substantial source of energy and nutrients for wildlife in riparian areas. If so, changes in water quality and other forms of degradation to streams may have flow-on effects into adjacent terrestrial ecosystems. Substantial lateral exchange of materials between rivers and their riparian zones also may occur during high discharge events and this *flood pulse* (Junk et al 1989) may be of particular importance to the ecology of large floodplain rivers in the wet-dry tropics.

How important are logs and other large woody debris (LWD) to the maintenance of in-stream function and biodiversity? In many stream and systems, LWD regulates the downstream transport of energy and nutrients (eg Bilby 1981, Bilby & Likens 1980), and provides important habitat for invertebrates and fish (eg Bryant 1983, Jackson 1978). This is particularly true in large rivers with a sandy substrate, where logs and branches provide the major stable habitat for primary and secondary production (Wallace & Benke 1984, Benke et al 1984). Large woody debris is an important riparian input that is often removed from river channels by river 'improvement' trusts, to prevent flooding and erosion, and reduce hazards to navigation and obstructions to bridges and other structures.

Given the extensive degradation to riparian zones in the wet-dry tropics, particularly from overgrazing, trampling and weed infestations, research is needed to determine the major mechanisms of recruitment and regeneration of riparian vegetation. Rehabilitation of degraded riparian zones will not be possible without an understanding of these processes. The role of riparian zones as critical habitat for wildlife is also an area of high research importance in the wet-dry tropics (see Morton 1990, Sattler 1993). For example, trampling by stock and buffalo has been suggested as a major cause of failure of the sand-bank nests of pig-nose turtles (*Carettochelys insculpta)* in the Northern Territory (Georges & Kennett 1989). Woinarski & Braithwaite (1990) also have highlighted the importance of riparian zones as movement corridors for wildlife.

3 Conclusions

Riparian zones are critical components of aquatic and terrestrial ecosystems of the wet-dry tropics and, as in many other parts of the continent, are under considerable threat. Successful management of riparian lands and, particularly, rehabilitation of degraded areas, will depend on a sound understanding of key processes. We cannot hope to manage the unique riverine and wetland systems of the wet-dry tropics within a framework of understanding developed from research in temperate forest ecosystems. Excellent opportunities exist, in partnership with the LWRRDC program, for research directed at these issues.

4 References

Anon 1994. Rehabilitation and management of riparian lands. An Australia-wide program of research and development. Program manual. Unpublished report to the Land and Water Resources Research and Development Corporation, Canberra, pp 43.

Benke AC, Van Arsdall TC Jr, Gillespie DM & Parrish FK 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. *Ecological Monographs* 54, 25–63.

Bilby RE 1981. Role of organic debris dams in regulating the export of dissolved and particulate matter from a forested watershed. *Ecology* 62, 1234–1243.

Bilby RE & Likens GE 1980. Importance of organic debris dams in the structure and function of stream ecosystems. *Ecology* 61, 1107–1113.

Bryant MD 1983. The role and management of woody debris in west coast salmonid nursery streams. *North American Journal of Fisheries Management* 3, 322–330.

Bunn SE 1992. Riparian vegetation. A review of key ecological issues, deficiencies in basic understanding and priorities relating to the influence of riparian vegetation on the structure, function and management of Australian river ecosystems. Unpublished report to the Land and Water Resources Research and Development Corporation, Canberra, pp 11.

Bunn SE 1993. Riparian-stream linkages: research needs for the protection of in-stream values. *Australian Biologist* 6, 46–51.

Bunn SE, Pusey BJ & Price P (eds) 1993. *Ecology and Management of Riparian Zones in Australia*. Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper Series No 05/93, 212.

Catterall CP 1992. Remnant vegetation scoping paper. Unpublished report to the Land and Water Resources Research and Development Corporation, Canberra, pp 13.

Catterall CP 1993. The importance of riparian zones to terrestrial wildlife. In *Ecology and Management of Riparian Zones in Australia*. (eds) SE Bunn, BJ Pusey & P Price, Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper Series No 05/93, 41–52.

Cummins KW 1993. Riparian stream linkages: in-stream issues. In *Ecology and Management of Riparian Zones in Australia*. (eds) SE Bunn, BJ Pusey & P Price, Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper Series No 05/93, 5–20.

Feminella JW, Power ME & Resh VH 1989. Periphyton responses to invertebrate grazing and riparian canopy in three northern California coastal streams. *Freshwater Biology* 22, 445–457.

Georges A & Kennett R 1989. Dry-season distribution and ecology of *Carettochelys insculpta* (Chelonia: Carettochelydidae) in Kakadu National Park, northern Australia. *Wildlife Research* 16, 323–35.

Gregory SV, Swanson FJ, McKee WA & Cummins KW 1991. An ecosystem perspective of riparian zones. *Bioscience* 41, 540–551.

Jackson P 1978. Spawning and early development of the river blackfish *Gadopsis marmoratus* Richardson (Gadopsiformes: Gadopsidae) in the McKenzie River, eastern Australia. *Australian Journal of Marine and Freshwater Research* 29, 293–298.

Junk WJ, Bayley PB & Sparks RE 1989. The Flood Pulse Concept in river-floodplain systems. *Canadian Special Publications in Fisheries and Aquatic Sciences* 106, 110–127.

Morton SR 1990. The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. *Proceedings of the Ecological Society of Australia* 16, 201–213.

Sattler P 1993. Riparian zone management in Queensland and the Northern Territory: policy and practice. In *Ecology and Management of Riparian Zones in Australia*. (eds) SE Bunn, BJ Pusey & P Price, Land and Water Resources Research and Development Corporation, Canberra. Occasional Paper Series No 05/93, 157–171.

Wallace JB & Benke AC 1984. Quantification of wood habitat in subtropical coastal plains streams. *Canadian Journal of Fisheries and Aquatic Sciences* 41, 1643–1652.

Woinarski JCZ & Braithwaite RW 1990. *The terrestrial vertebrate fauna and vegetation of the Kakadu Conservation Zone*. Resource Assessment Commission Consultancy Series, AGPS, Canberra.

Woodfull J, Finlayson B & McMahon T (eds) 1993. *The Role of Buffer Strips in the Management of Waterway Pollution from Diffuse Urban and Rural Sources*. Land and Water Resources R&D Corporation, Occasional Paper Series No 01/93, pp 135.

WETLANDS RESEARCH AND MANAGEMENT IN THE WET–DRY TROPICS – SOME THOUGHTS ON ECOLOGICAL PATTERNS AND PROCESSES

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ABSTRACT

It is a simple but essential truth that the best foundation for effective ecologically sustainable management of natural resources and ecosystems is an ever-increasing pool of relevant ecological knowledge. This is gained from both short and long term descriptive and experimental ecological studies.

Wetlands of northern Australia are being exposed to human forces that damage their ecosystems long before there is even a rudimentary understanding of their ecology. As a precaution a provisional classification of tropical wetlands is needed coincident with protection of those wetlands that are unique, threatened and/or scarce.

For selected wetland types the major abiotic features and biotic constituents and their spatial and temporal variability require determination. Such information is crucial for effective monitoring. For floodplains the role of flooding and drying in stimulating and regulating key ecosystem processes is a vital research area.

To understand the mechanisms generating ecological patterns requires experiments that should range in scale from plots to catchments and from weeks to years. Standard experiments could be used to make comparisons with wetland ecosystems elsewhere.

Natural and/or human-induced disturbance to wetlands can either be directly or indirectly delivered via catchment disturbance. The scale of human-induced disturbance varies immensely. It may be possible to contain the effects of a mining operation but the effects of long-term catchment disturbance due to grazing and fire may be widespread, persist for a long time, and be difficult to remedy.

Keywords: tropical wetlands, northern Australia, wet-dry tropics, conservation, management for ecological sustainability, floodplain wetlands, flooding and drying, monitoring and experimentation, disturbance.

1 Introduction

Ecology as a science is increasingly becoming less of a descriptive science and more of an experimental and predictive one. By virtue of its very nature as an intellectual endeavour, it can provide knowledge crucial to the management of ecosystems and natural resources where long-term ecological sustainability is the primary aim. Ecological knowledge may also help in short-term exploitation but in many such cases the necessary knowledge comes after damage, often irreversible, has been inflicted. Dependent on the environments or organisms of interest, ecology has been split into basic and applied areas. Sadly this division carries with it notions that basic research is academic, esoteric and not dealing with the real world, whilst in some quarters applied research is seen as commercially oriented, tightly targeted, and driven by the clients' agenda. These notions carry some truth but regardless of the type of ecological research - whether 'basic or applied' - the primary evaluation of research work is whether it is good or humdrum or shoddy. Shoddiness can be caused by many things; in wetland research an area with a high shoddiness index is that of environmental surveys/environmental impact assessment whereby from very limited amounts of data seemingly firm yet untested (often untestable) predictions are made.

For this brief paper I am concentrating on freshwater wetlands, though saline wetlands such as mangroves are very important in northern Australia, and I am regarding freshwater wetlands as those of both running and standing waters and both permanent or intermittent in terms of the presence of water. In outlining some directions for ecological research on tropical wetlands I want to make it clear that I am not an expert on the ecology of tropical wetlands. I am involved in work on tropical woodland savanna streams at Kapalga in Kakadu National Park but most of my aquatic research has centred on temperate freshwater bodies. I am interested in wetland ecology and conservation in all parts of Australia and as a member of the CRC for Freshwater Ecology I have been involved in drawing up research agendas for wetlands in south-eastern Australia (eg Cullen & Harris 1994). This latter task has identified key areas of research. Investigations in some of these areas in both temperate and tropical Australia may not only allow exciting comparisons to be made, but could provide valuable insights (see Welcomme & Berkowitz 1991). Performing similar well designed experiments in different ecological settings could be very fruitful and yet has been a greatly neglected practice, largely it seems because of the interminable quest for originality.

In comparison with many wetland regions in Asia, there are many wetlands in northern Australia that are in a natural intact state. Research in such Australian wetlands could provide valuable baseline data to assist the management of wetlands in the rapidly developing Asian region. While there are wetlands in the intact state in northern Australia, it should be recognized that many wetlands, in common with those elsewhere in Australia, are being damaged by human disturbance long before there is even a rudimentary understanding of their ecology (see Finlayson et al 1988). An example of this situation comes from the Murray-Darling River, whereby the river was almost totally regulated before the ecological importance of flooding was realised let alone understood (Walker 1992). In the Murray River, main stem billabongs are widespread and numerous but of these only a tiny fraction are natural unregulated billabongs; how can we manage billabongs when we have only a scanty understanding of them in their intact state? Thus with future impending developmental pressures on northern Australian wetlands and accepting that ecological knowledge of them is fragmentary and very incomplete, it is essential that good representative examples of wetlands be at least set aside to allow subsequent investigation of wetlands in the baseline intact state. Such a bold but essential initiative is necessary to make sure that wetland ecological integrity and biodiversity are effectively conserved. Conservation of such protected wetlands will require ongoing research to formulate management guidelines for long-term ecological sustainability.

A first and vitally important step in implementing this strategy is to design a provisional classification of all types of non-marine wetlands, whether lotic or lentic temporary or permanent. Possibly the classificatory scheme in Finlayson et al (1988) could serve as the basis for this with supplementation and refinement from other Australian wetland classification schemes such as that used by Pressey (1986). Using the provisional classification, the next step would be by using existing data sets, visiting sites and seeking advice across a whole spectrum of parties interested in wetlands to establish an open, continuously updatable inventory (see Davies & Giesen 1994). Simultaneously sound and rigorous criteria for wetland conservation/ protection would need to be devised. Then using such procedures as those outlined by

Margules et al (1988), Pressey and Nicholls (1989) and Davies and Giesen (1994), a selection of wetlands requiring conservation/protection could be made. Such wetlands while being conserved could also serve a key sites of baseline research on intact wetlands in northern Australia.

Guided by their putative ecological values as wetlands and by the level of impending developmental pressures, a limited number of particular types of major wetlands should be selected and representative study sites set up. It seems in ecological research, major advances in how ecosystems work have come from work concentrated at particular sites, be they at Wytham Woods, Hubbard Brook, Barro Colorado, or Lake Tahoe. At such sites, such as at Jabiru, a basic description of the major climatic, geomorphological, pedological, geological and hydrological attributes could be compiled along with a basic description and diversity assessment of the major floral (terrestrial and aquatic) and faunal assemblages. In such a program, a key task would be to gauge the levels of spatial and temporal variability and to make provisional links between the various attributes and assemblage constituents. An assessment of the variability of the major attributes and constituents of particular wetland types would form a very useful basis for the design of rigorous monitoring especially where human disturbance may be involved (see Underwood 1994). Wetlands that come to mind for this basic investigation include freshwater floodplain wetlands and the intermittent streams and swamps of the savanna woodland.

With the strong acceptance of the need to assess and conserve biodiversity and recognition of the large and long-term scale of many ecological processes, such as those associated with global climatic change, the question of long-term monitoring and research arises. Long-term monitoring may be incredibly valuable provided that the data are rigorously collected and analysed and that data collection is not an end in itself but is preferably linked with hypothesised trends; valuable ecological insights rarely emerge from inspection of masses of aimlessly collected data (Cullen & Lake 1994). Many ecological processes affecting wetlands, such as ground water availability, are long term and this needs to be recognised.

Many ecological investigations are of small scale processes that occur rapidly. Many studies contain mismatches between the spatial and temporal scales (Wiens 1989). To understand ecological patterns and processes, so that predictions may be made, involves experimentation using manipulations and replication. Many ecological processes in wetlands are relatively rapid and thus may be experimented upon with short term small scale studies, but many of the major processes in wetlands are occurring at large spatial and temporal scales and it seems that it is these processes, such as the impacts of fire or the effects of flow regulation, that are very important to management agencies. Thus long term studies with large scale manipulations may have to be established. An example is the experiment at Kapalga involving spatial replication at the catchment level to investigate the effects of fire timing and frequency on terrestrial (Braithwaite 1990) and stream ecosystems (Douglas et al 1995).

In keeping with the name of the Wet-Dry Tropics and noting the development of the notion of the 'Flood Pulse Concept' (Junk et al 1989), flooding of wetlands appears to be a critical event that sets in train a relatively unexplored range and series of processes. Many of the processes, for example the release of nutrients and algal production, are linked and occur sequentially but as is clear both internationally (eg Ward 1989) and in an Australian context (eg Lloyd et al 1994), a clear scheme of the processes triggered, dependent on and augmented by flooding for any floodplain has not yet been compiled. Both in terms of basic ecological understanding and for management, the role(s) of flooding in determining tropical floodplain ecosystem structure and function awaits investigation.

Important processes that require study through the flood cycle include the physical movements and trophic pathways of detritus and major nutrients, the varying sources and levels of primary production, the shifting trophic dynamics of major consumers, and the levels and sites of major microbiological activity such as methanogenesis. Temperate wetlands are a major source of methane, a greenhouse gas, is this true for tropical floodplains? Further in encouraging comparisons between temperate and tropical floodplain ecosystems, the assessment of the importance of allochthonous and autochthonous carbon sources was deemed to be very important to understanding the integrity of the Murray-Darling River ecosystems (Cullen & Harris 1994). It would be instructive to compare the impacts of floods over good and poor wet seasons and to determine the persistence of the signal from one flood season to the next. In addressing floods it should be noted that chemical and biological events of the dry season may not only be fascinating ecologically but may be critical to the success of processes dependent on flooding. Finally on flooding, it is very evident that floodplain wetlands receive inputs (water, nutrients, sediments) from the upslope intermittent wetlands of the savanna woodland; assessment of these inputs especially in undamaged systems would be a very valuable set of baseline data.

Natural and/or human-induced disturbances to wetland ecosystems can either be directly (eg droughts) or indirectly delivered via catchment disturbance (eg fire) (Lake 1995). They can either be 'pulse' or 'press' disturbances and be sharply delimited or diffuse and large scale. The effects can range from being transient (ie the biota have a high resilience) to having long-term historical consequences. In such a highly variable environment as that of the 'Wet-Dry' Tropics, natural disturbances may be characterised by extreme events (eg cyclones), by changes in frequency of events (increase in fire frequency) and/or by long-term processes such as rising salinity.

The temporal and spatial scale of human-induced disturbances to wetlands varies immensely. The discharge of treated sewage may have very localised and short-term effects, a mining operation can have localised (ie within one river) but persistent effects, and the effects of long-term catchment/rangeland disturbance due to grazing and fire are very widespread, may persist for a long time, and may be very difficult to remedy. In order to understand the effects of human disturbance so that predictions can be made for effective ecologically sustainable management, it is necessary to have a reliable assessment of the baseline spatio-temporal variability of the abiotic and biotic components of the ecosystem type that may be subjected to disturbance, and to carry out manipulative field experiments prior to disturbance or at least plan the advent of the disturbance as a rigorously designed experiment (Underwood 1994).

In terms of the credibility of environmental science as a science, the days of hastily prepared, statistically flawed, poorly resourced environmental surveys or impact assessments are no more. Ecological sustainability is not compatible with hastily contrived, poorly assessed, development projects. For effective management of tropical wetlands the effects of the major types of human disturbance need to be understood. Not only will such an understanding provide a predictive capacity for future development but it will also provide the baseline data to guide the restoration and rehabilitation of damaged wetlands and their biota.

References

Braithwaite RW 1990. A new savannah fire experiment *Bulletin of the Ecological Society of Australia* 20, 47–48.

Cullen P & Harris G 1994. A research agenda for the lower Murray and Darling rivers. Report of the Cooperative Research Centre for Freshwater Ecology, Canberra.

Cullen P & Lake PS 1994. Towards a national program on long-term monitoring of Australian biodiversity: Inland aquatic systems. In *Options for a national program on long-term monitoring of Australian biodiversity,* (eds) T Redhead, J Mummery & R Kenchington. CSIRO, Canberra, 117–133.

Davies J & Giesen W 1994. Towards a methodology for identifying tropical freshwater wetlands for protection. *Mitteilungen Internationalis Vereinigung Limnologiae* 24, 27–39.

Douglas MM, Townsend S & Lake PS 1995. The role of fire in the management of tropical savanna streams. In *Proceedings of the International Conference on the Future of Tropical Savannas: Managing Resources and Resolving Conflicts, Townsville 1994.* CSIRO Press, Melbourne.

Finlayson CM, Bailey BJ, Freeland WJ & Fleming MR 1988. Wetlands of the Northern Territory. In *The Conservation of Australian Wetlands,* (eds) AJ McComb & PS Lake, Surrey Beatty & Sons Ltd., Sydney, 103–126.

Junk WJ, Bayley PB & Sparks RE 1989. The flood pulse concept in river-floodplain systems. *Special Publication of the Canadian Journal of Fisheries and Aquatic Science* 106, 110–127.

Lake PS 1995. *Understanding the ecology of Australian running waters: An assessment of current endeavours and of future priorities.* Land and Water Resources Research and Development Corporation, Canberra.

Lloyd L, Atkins B, Boon P, Jacobs T & Roberts J 1994. Natural processes within Murray-Darling floodplain wetlands. In *Murray-Darling basin floodplain wetlands management* In *Proceedings of the Floodplain Wetlands Management Workshop Albury NSW 20–22 October 1992,* (eds) T Sharley & C Huggan. Murray-Darling Basin Commission, Canberra, 6–23.

Margules CR, Nicholls AO & Pressey RL 1988. Selecting networks of reserves to maximise biological diversity. *Biological Conservation* 43, 63–76.

Pressey R 1986. *Wetlands of the River Murray below Lake Hume.* River Murray Commission, Canberra.

Pressey R & Nicholls AO 1989. Efficiency in conservation evaluation: scoring versus iterative approaches. *Biological Conservation* 50, 199–218.

Underwood AJ 1994. Spatial and temporal problems with monitoring. In *The Rivers Handbook. Volume 2,* (eds) P Calow & GE Petts. Blackwell Scientific Publications, Oxford, 101–123.

Walker KF 1992. The River Murray, Australia: A semiarid lowland river. In *The Rivers Handbook Volume 1,* (eds) P Calow & GE Petts. Blackwell Scientific Publications, Oxford, 472–492.

Ward JV 1989. Riverine-wetland interactions In *Freshwater Wetlands and Wildlife* Conf-8603101, DOE Symposium Series No.61, (eds) RR Sharitz & JW Gibbons. USDOE Office of Scientific and Technical Information, Oak Ridge, 385–400.

Welcomme R & Berkowitz AR 1991. Comparison between tropical and temperate ecosystems. In *Comparative Analyses of Ecosystems: patterns, mechanisms and theories,* (eds) JJ Cole, GM Lovett & SEG Findlay, Springer-Verlag, New York, 356–357.

Wiens JA 1989. Spatial scaling in ecology *Functional Ecology* 3, 385–395.