5 Wetland management

Implementing the Ramsar Convention in Australia

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1 International Law

First of all I am going to give you a crash course on International Law. This normally takes a little longer than five minutes, but we'll see how we go. I'll start with some generic International Law issues, then we will examine the Ramsar Convention and its implementation in Australia.

Why do we have treaties? It could be as a response to specific issues or to develop relations and trade. We have treaties on the environment, trade, defence, aviation and communications. We often hear about international law, particularly environmental and human rights law, as being aspirational rather than something that can regulate our actions. Yet treaties are binding instruments only not quite in the same way as municipal or domestic law. This is because there is no direct supra-national enforcement. Breaches of international law can be addressed by the International Court of Justice (ICJ), but it is for nation states to accept its jurisdiction; it is not mandatory, unlike domestic legal systems. The findings of the court also are not enforceable, it is expected that States will accept and act on its findings in good faith.

The force of international law is really predicated on States wanting to be a member of the international community, a good international citizen. This will be prey to domestic political, social and economic situations. For example, Australia usually likes to be seen as a good international environment citizen, but our present Commonwealth Government's hostility towards binding reductions in greenhouse gas emissions under the Framework Convention on Climate Change were justified on account of Australia's 'national interest'.

International law can only be negotiated and enforced *by* states (in this context meaning national, not provincial governments) and not individuals or corporations, and only enforced *against* states. States must therefore act on behalf of injured individuals. Personality is required in international law. Australia has personality. This doesn't mean that it is witty at dinner parties, it means that it is recognised as a Party. It is necessary to have 'standing' in law at all levels. If you wish to go to court, you need to have standing before that court will recognise you to bring that case. Under International Law, to be heard, to negotiate and agree to a Treaty, you need to be a Nation State. Constituent States are not recognised (eg New South Wales, Queensland, Victoria).

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[*] Adapted from transcript, July 1997

International Law is indifferent to the question of constitutional autonomy, or the division of powers, and regards persons exercising Governmental functions of any sort as agents of the international person.

That means the Commonwealth is vicariously liable in the international arena if the Australian states and territories do nasty things which breach Australia's international obligations.

The ICJ typically would not be the forum for, say, international environmental law. When it comes to enforcement of obligations under nature conservation treaties such as Ramsar, the emphasis is more on supervision through intergovernmental institutions – intergovernmental commissions, meetings of the parties (the Contracting States) – rather than state against state in a confrontational setting before the ICJ or arbitrators. These bodies fulfil a number of functions, not simple adjudication: developing the law, supervising its implementation, putting community pressure on individual states, resolving conflicts of interests. They gather information, receive reports on treaty implementation, act as a forum for reviewing the performance of states, and facilitate the negotiation of further measures. They become a forum for treaty compliance through discussion and negotiation, rather than by adjudication of questions of law. The aim is to secure compliance rather than to adjudicate on whether there has been a breach.

Where an issue is most likely to be arbitrated is with regard to conflicts over transboundary pollution or resource use, for example depletion of fish stocks. The crucial issue is whether the activities of one State affect another. This is less likely to be the case with regard to nature conservation unless a transboundary issue arises, such as deforestation in one Nation State affecting soil and water quality in a neighbouring State. We can see parallels with domestic environmental law where legal intervention into land use was developed in response to cases where pollution originating on one property caused damage to another.

Transboundary pollution was the subject matter of one of the foundation cases in international environmental law. In the Trail Smelter arbitration (1941 3 *R.I.A.A*. 1905) a tribunal awarded damages to the United States and prescribed a regime for controlling future emissions from a Canadian smelter which had caused air pollution damage. This case crystallised the international principle *sic utere tuo ut alienum non laedus* (so use your property as not to injure your neighbour's). This is what is known as customary international law which is developed by a combination of conduct – state practice – and the conviction that this conduct is motivated by a sense of legal obligation (*opinio juris*). It can be binding universally, regionally or between particular States and is generally a slow process.

Established principles of customary law include:

- the sovereign right of states to exploit resources within their territorial boundaries, but subject to:
- the responsibility of states 'to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or to areas beyond the limits of national jurisdiction', ie common property such as the high seas and airspace, and most of the living resources of these areas. (Principle 21 of the 1972 Stockholm Declaration on the Human Environment.)

These principles were reiterated in the 1992 Rio Declaration as well as in Article 3 of the Convention on Biological Diversity.

2 Ratifying a Treaty

In Australia we have a dual system. Not all countries have this, but it means that the executive council, that is, the Federal Cabinet, decide whether we are going to ratify a Treaty, but ratification does not mean that it has come into force in Australia. Unless we have domestic legislation which 'incorporates' the Treaty, it is not legally binding within Australia. While unincorporated treaty provisions cannot operate as a direct source of individual rights and obligations under municipal law, they may influence the common law (the law developed by decisions in courts rather than statute law which is developed by parliament). The High Court has emphasised the relevance of international law:

(a) to help resolve uncertainty or ambiguity in the common law

(b) to shed light upon the contemporary values of the Australian people

The common law does not necessarily conform with international law, but international law is a legitimate and important influence on the development of the common law, especially when international law declares the existence of universal human rights.

Treaties may rely on the governments of each state/territory carrying out legislation, but it is overseen by the Commonwealth Government. It is possible to put a federal clause into a Treaty, stating that the Commonwealth Government agrees to attempt to put the treaty agreement into effect, but the implementation will be through the various jurisdictions of its constituent states, which may limit the treaty's effectiveness. Australia has done this once in relation to a Human Rights Treaty, the Convention of Elimination of Discrimination Against Women. The international community tends to regard a federal clause with contempt, viewing it as an attempt to avoid obligations by hiding behind its constituent jurisdictions. The Commonwealth Government says it will rely on state/territory legislation where the Treaty affects areas of their concern, however, it has stated that it 'does not favour including federal clauses in treaties and does not intend to instruct Australian delegations to seek to include them'.

3 Ramsar Convention

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat was signed in 1971. It now has more than one hundred member States, known as Contracting Parties. Parties must designate at least one suitable site for inclusion in the List of Wetlands of International Importance for the Convention to come into force in that country. Unlike World Heritage Listing, the wetland site doesn't need to be checked to ensure that it is of outstanding cultural or natural significance, so occasionally a site is not quite up to scratch, or the boundaries are completely wrong, which has led to listings being modified at a later date to better reflect the significant area.

The first Ramsar site in the world was Cobourg Peninsula in the Northern Territory of Australia, inscribed in May 1974. There are now 49 designated Ramsar sites in Australia, including Kakadu National Park.

3.1 Selection criteria

A wetland should be considered internationally important if it meets one or more of these criteria:

1. *Criteria for representative or unique wetlands*

- it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region;

- it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region;
- it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position;
- it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.

2. *General criteria based on plants or animals*

- it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species;
- it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna;
- it is of special value as the habitat of plants or animals at a critical stage of their biological cycle;
- it is of special value for one or more endemic plant or animal species or communities.

3. *Specific criteria based on waterfowl*

- it regularly supports 20 000 waterfowl;
- it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity;
- where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

4. *Specific criteria based on fish*

- it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity;
- it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

This selection criteria can be applied to natural and artificial wetlands.

3.2 Obligations

The obligations of the Contracting Parties are as follows:

- listing and conservation of internationally significant wetlands as Ramsar sites
- commitment to conservation of listed wetlands and to manage all wetlands according to the principles of wise use
- the Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory.

The Ramsar Contracting Parties must conserve their listed wetlands as ‘flagship’ wetlands, but they are also supposed to use wise use principles for all their wetlands. This is obviously not adhered to as there are many examples of poor use of wetlands. The underlying issue here is the very nature of international law and treaties. In order to get many different people to agree, the law or treaty must be fairly general, and often will allow significant discretion. For example, Article 3(1) of the Convention provides:

The Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and *as far as possible* the wise use of wetlands in their territory. (Emphasis supplied.)

(A striking example of discretion in an international environmental treaty can be found in the Convention on Biological Diversity. Articles 5–20 inclusive require action by the Contracting States. Of those, ten Articles allow significant discretion in the interpretation of the obligations by inclusion of the term 'as far as possible and as appropriate'.)

By picking out wetlands for special attention, as distinct from the broader landscape in which they are located, the initial focus of Ramsar was a segmented one. That was exacerbated by the emphasis on listing 'flagship' wetlands. At the first meeting of the Contracting Parties, Recommendation 1.3 was adopted which stated that, in order to achieve the aims of the Convention, 'Contracting Parties should designate as many as possible of their wetlands of international importance for the List'. Increasingly, however, a broader catchment perspective has been developed, in recognition of the many external threats posed to Ramsar wetlands.

The concept of 'wise use' has been developed during the six Conferences of the Contracting Parties and is to be utilised as guidance in the multiple use of wetlands. *Guidelines for Implementation of the Wise Use Concept of the Convention*, developed by the Working Group on Criteria and Wise Use, were recommended for adoption by Parties by the Fourth Meeting of the Parties at Montreux:

> The wise use provisions apply to all wetlands *and their support systems* within the territory of a Contracting Party, both those wetlands designated for the list, and all other wetlands. (Recommendation C.4.10 and Annex. Emphasis supplied.)

This was then further developed and, at the fifth meeting of the Parties, resolution 5.6 – *Additional Guidance for the Implementation of the Wise Use Concept* – was accepted in recognition of the complexity of applying the wise use provisions.

> In the early years of the Convention, the wise use provision proved to be difficult to apply. Most attention was focused upon the designation of sites onto the Ramsar List in line with global priorities to secure the conservation of internationally important areas. Over time, as the essential need to integrate conservation and development has become recognised throughout the world, the Contracting Parties to the Ramsar Convention have made wise use a central theme for the functioning of the Convention. (Resolution C.5.6 (Annex))

The resolution also noted a number of conclusions by the Wise Use Working Group including, at paragraph 5:

> Where wetlands form an integral part of a wider coastal zone or catchment, wise use must also take into account the problems of the surrounding zone or catchment.

3.3 Montreux Record

As with World Heritage Listing, a wetland site can be taken off the Ramsar List or the site may be placed on the 'Montreux Record'. Article 3(2) of the Convention provides:

> Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.

The Article goes on to provide that the information on such changes is to be passed without delay to the secretariat, the Ramsar Bureau. The resulting list has become known as the Montreux Record.

Contracting parties meet every three years, to make new recommendations and resolutions and re-examine listed sites. They are required to arrange to be informed at the earliest possible time if the ecological character of any wetland in their territory has changed. As wetlands constantly undergo a process of natural change, it is important to define technological developments, human interference and the threshold of acceptable/non-acceptable change. Often there is not enough known about a wetland site to determine whether an adverse impact is natural or otherwise.

In the lead up to the Brisbane Conference of the Parties in 1996, a number of the Australian sites were nominated by non-governmental organisations for Montreux listing: the Macquarie Marshes and Towra Point in NSW; Lake Toolibin in WA; and Lake Corangamite in Victoria. Both of the NSW sites are widely recognised as suffering considerable degradation and continuing threats to their ecological character. Environment Australia wrote to the three State Governments seeking comments but State Ministers effectively vetoed the proposal in each case.

Whether listing on the Montreux Record would have gone ahead even if the States concerned had agreed is doubtful. Australia has never used the Montreux Record. The 1996 Australian Report to the Convention on implementation states that no sites have been listed and adds:

> It is the current policy of Australia to solve such problems domestically rather than seek listing on the Montreux Record.

Unfortunately, the Montreux Record is often viewed as a 'Hall of Shame'. In fact the idea behind Montreux listing is not only to attract external scrutiny, but to obtain funding assistance for developing countries and to encourage efforts to rehabilitate the wetland site. However, even this view of the Montreux Record has been misconstrued within Australia to mean that the Record is only for developing countries that need to attract external funding to address such problems. There are about 60 sites currently on the Montreux Record, including the Florida Everglades in the United States and several sites in Britain.

4 Implementation of Ramsar in Australia

4.1 Legislation

Australia's 49 sites are situated within a wide range of tenure and protection status. The Ramsar Convention itself is not incorporated by any specific legislation. Implementation is through a range of Commonwealth, State and Territory instruments which directly or indirectly have an impact on wetland management.

Implementation is under the auspices of the Australian and New Zealand Environment and Conservation Council (ANZECC). A working group of ANZECC, comprising officers from each Australian State and Territory ANZECC agency, advises on the implementation of the Ramsar Convention in Australia.

Coordination of implementation at a national level is conducted by the Federal Government's Environment Australia Biodiversity Group. Its Wetlands, Waterways and Waterbirds Unit administers the National Wetlands Program which provides funding to both government and non-government organisations to promote the Ramsar Convention guidelines.

So far as Commonwealth legal initiatives are concerned, regulations can be made under s 69 of the *National Parks and Wildlife Conservation Act* 1975 (NPWCA), 'for and in relation to giving effect to an agreement specified in the Schedule'. The schedule lists a number of international agreements, including the Ramsar Convention. A similar power under s 175(1) of the *Endangered Species Protection Act 1992* is more restricted in that it only allows regulations giving effect to specified international agreements, including Ramsar, insofar as they relate to the recovery or conservation of *listed* native species or *listed* ecological communities.

The only Commonwealth designation with any claim to national status is listing on the Register of the National Estate under the Commonwealth's *Australian Heritage Commission Act 1975*. Under s 30 of the Act, Federal Ministers must ensure that their departments and authorities do not act in a manner which adversely affects sites on the Register but only about half of the Ramsar wetlands are listed in whole or in part under these provisions. Moreover, listing on the Register of the National Estate only has implications for Commonwealth activity or activities by the private sector requiring Commonwealth approval. It has no implications for day to day management.

Planning and development decisions which may have an impact on wetlands are addressed by environment impact assessment legislation in each jurisdiction, however, there is considerable variation between each jurisdiction and no specific 'triggers' of impact assessment for proposals which could affect Ramsar wetlands.

All State and Territory jurisdictions in Australia have legislation on the creation and management of nature conservation areas in which wetlands may be protected. Queensland's *Nature Conservation Act 1992* cites international significance as a factor in protecting areas. The *Nature Conservation Act* includes sections dedicated to the management of areas considered to have 'internationally significant natural values' (s57(1)) which can then be declared an international agreement area (s59) and must be managed in a way to maintain its importance (s26).

There is a commitment to cooperation and implementation between the States, Territories and Commonwealth contained in the non-binding Intergovernmental Agreement on the Environment (IGAE) which outlines the responsibilities and interests of the different jurisdictions and the accommodation of those interests by the parties.

Management of Ramsar wetlands may also be subject to wetlands policies. The policies in Australia to date are:

- Commonwealth Wetlands Policy (1997)
- New South Wales Wetlands Policy (1996)
- Western Australian Wetlands Policy (1997)

The Commonwealth wetlands policy only applies to wetlands on Commonwealth land. It is 'hoped that the Policy will provide a model' for other levels of government to follow.

4.2 Political constraints

It is the Commonwealth's responsibility under international law to ensure Australia meets its obligations under international environmental agreements to which it is a party. The multitude of jurisdictions and the consequent conflicting interests and procedures may complicate and hinder implementation but, as noted above, federal systems are not acknowledged as mitigating international responsibility of countries for actions in breach of treaties by its constituent states.

Within Australia, the States have traditionally taken responsibility for much of Ramsar's implementation in the field. The Commonwealth exercises immediate responsibility for sites only in territory within its jurisdiction. The devolution of most environmental responsibility to the States hampers effective and coordinated implementation of Ramsar. This means the Convention is implemented in an uneven manner with Environment Australia overseeing disparate approaches and initiatives.

The State and Territory borders also cut across natural boundaries, raising issues of multiple jurisdictions applying to discrete systems such as catchments. For example, the area contained within South Australia's Coongie Lakes wetland is part of Cooper Creek which originates in Queensland on the Great Divide and flows into the Lake Eyre. However, this has been addressed in Australia to some extent via the IGAE and statutory authorities such as the Murray-Darling Basin Commission.

4.2.1 Role of the Commonwealth

The Commonwealth has authority for exercising an environmental role beyond its existing position and arguably has an international duty to do so in its ratification of international environmental law. Domestically, the IGAE recognises that the Commonwealth's responsibilities and interests include:

> (i)... negotiating and entering into international agreements relating to the environment and *ensuring* that international obligations relating to the environment are met by Australia; (emphasis supplied)

Under the agreement the States 'continue to have responsibility for the development and implementation of policy in relation to environmental matters which have no significant effects on matters which are the responsibility of the Commonwealth or any other State'. The agreement thus reinforces the delineation of duty; the implementation of international environmental law is a Commonwealth responsibility as it is to ensure international obligations are met while the residual environmental matters are left to the States. Further, in Schedule 9 to the IGAE regarding Nature Conservation, clause 10 states:

> The parties agree to cooperate in fulfilling Australia's commitments under international nature conservation treaties and recognise the Commonwealth's responsibilities in ensuring those commitments are met.

It would therefore be open to the Commonwealth to intervene in a State's exercise of environmental policy if international environmental obligations were not met or were contravened. The Commonwealth can legislate with respect to environmental matters and its constitutional authority to legislate to implement an international environmental convention is now well accepted.

However, while there appears to be the capacity for intervention on the part of the Commonwealth, political reality dictates a cautious approach with State Governments anxious to defend their turf from the potential effect of treaties on the federal-state balance of power.

For example, the authority for the Commonwealth to intervene in State environmental matters by way of regulations under the *National Parks and Wildlife Conservation Act 1975* has been exercised only once: to prevent Tasmania's Hydro-Electric Commission constructing a dam on the Gordon River which was within a World Heritage area. However, there remains a clear reluctance on the part of the Commonwealth to use its constitutional powers other than in a coordinating role in cooperation with the States.

It would be infinitely preferable to have a coherent, coordinated approach to environmental management in Australia. It would avoid bureaucratic duplication, and 'jurisdictional shopping' by developers, while providing greater efficiency, a firm jurisdictional stance and enhanced communication between Commonwealth and state/territory governments. At the same time, it is vital to develop relationships with local stakeholders and to maintain a localised approach.

The reality is that there are different jurisdictions, under which people have different rights and responsibilities. The environment is subject to different legislation and managed by various agencies, which may be resource-based or conservation-based, yet all are dealing with the same issues.

4.3 Management issues

The Ramsar Convention provides for 'wise use' of all wetlands, but implementation of the Convention has tended to focus on setting aside icon areas. What is actually needed is cross-jurisdictional and landscape management of the entire wetland, including the surrounds of each Ramsar site.

Issues relating to the management of the Macquarie Marshes, a Ramsar-listed site in NSW, serve as an excellent illustration of the need for planning to be carried out in the context of the whole catchment, rather than determined by the limits of Crown land. This wetland in the north west of the State covers more than 150 000 hectares and comprises a complex of swamps, channels and floodplain. The area designated as a Ramsar site in 1986 is, however, restricted to the existing nature reserve which is only 18 143 hectares, or 14 per cent of the marshes. Many of the bird breeding colonies are located outside the reserve on privately owned areas of the wetland.

The main land use here is cattle grazing, but there is one cotton farm which relies on irrigation water. Upstream from the Marshes, there is extensive cultivation of irrigated cotton. This has led to a sometimes bitter struggle for water between upstream cotton irrigators, on the one hand, and an uneasy alliance of cattle graziers and conservation interests, on the other.

While there are a number of Ramsar-listed wetlands on private land (such as in Tasmania where of its ten sites one is entirely on freehold land and three are partly freehold) the great majority are on Crown land. There have been no conservation measures taken with regard to Tasmania's privately-held sites, all of which were listed in 1982 without prior consultation with the affected landholders. The challenge for management agencies is to ensure that the Convention's principles can be applied to listed sites, no matter what their tenure. The Convention does require wise use of *all* wetlands but for the management personnel trying to deal with a range of tenure on listed sites and a range of responses to international law, from acceptance to suspicion to hostility, then any degree of influence over land use if only on the Ramsar wetlands may be considered a relative blessing. Attempts to negotiate management guidelines with the landholders for the Tasmanian wetlands are 'ongoing'.

In NSW all six Ramsar sites are wetlands which were already protected within national parks or nature reserves.

4.4 Private land management

While Ramsar listed sites have tended to be on Crown land, there is greater acceptance now of the need to confront the issue of private land management. After all, 500 million hectares of the Australian territory is managed by private landholders, compared to 40 million hectares within the terrestrial reserve system. A broader focus is envisaged by the Convention and a total catchment approach is required. This approach will be more complex and resource intensive, and politically difficult due to the need to overcome an entrenched private land ideology and the complex issue of water rights and water allocation. The possibility of compensation has been raised, but will be complex and very expensive. It has been suggested that a far more positive approach is to develop stewardship practices where people are paid on an ongoing basis to look after their land. It is a forward-looking system based on the extent of management activity required and carried out, rather than loss of market value of the land. Stewardship could be more equitable than compensation because it is based on work performed rather than on what may be chance factors. This is a very localised approach and we hope that International Law here, the Ramsar Convention in particular, could help persuade the Commonwealth Government to recognise its obligations to wetlands, and the need to include private land to maintain catchments and to conserve our wetlands.

5 Questions

<u>Question</u>: *With those wetlands in Tasmania, what are the chances of success for some of them remaining at a high conservation value if you take the sort of approach in which you include private land?*

Tasmania did eventually realise that it probably wasn't the greatest approach. I mean it was quite a brave approach, but of course they could have got right up the noses of the farmers who would perhaps have just drained the wetland and filled it, or whatever, just because they were so irritated. Now there is a process of negotiation. New South Wales has been very 'softly-softly' about this and as a result there is no privately-held Ramsar site in that state. Tasmania probably went a little too far the other way and, yes, you should have negotiation. It's a general problem; international law doesn't get very good press generally, especially with the ongoing sensitivity with regard to 'States Rights'; the Commonwealth is seen as making a power grab. There are issues of sovereignty at a number of levels: international bodies to nation states, nation states to constituent states, governments to private landholders. You are going to have that same issue all the time, and it is the issue of defending one's sovereignty: 'This is my land, bugger off, don't tell me what to do'. It's a major constraint in the effective application of International Environmental Law.

<u>Question</u>: *I've got an example to back-up one of your points. A couple of years ago I was invited over to Maningrida to explain Ramsar to them and they had never heard of Ramsar. We were there for three days, and at the end of it they said 'well, it's got nothing to offer us, it doesn't do anything we don't already have so far as security is concerned'. The only answer I came up with was that we can offer them greater money opportunities.*

Yes, the funding provides people with some sort of incentive to see a value in it, so perhaps it is a good thing that it provides that connection which may lead to other elements of the Convention being embraced. Another positive aspect to the funding is with regard to the role of the Commonwealth which usually doesn't seem willing to exert a strong hand regarding wetland management in the other jurisdictions. But if they are giving money out then they are a little more touchy about what's happening to their funds, with expenditure at least ostensibly constrained by the National Wetlands Program guidelines which in turn comply with the Convention's objectives.

Question: With the stewardship process, can you elaborate and give a practical example of where it has worked?

Under Queensland's *Wet Tropics World Heritage Protection and Management Act* 1993, the Wet Tropics Management Authority (WTMA) can enter into cooperative management agreements under which the landholder might, in return for payments, agree to land use restrictions beyond those ordinarily applicable under the Wet Tropics Management Plan, and would actively manage the land.

Cooperative management agreements have been negotiated with a number of landholders. The agreements so far signed off have included a number of trade-offs. For example, one landholder who wished to convert two leaseholdings to freehold title agreed to a number of stewardship obligations in return for which the Authority would offer no objection to the freeholding. The conditions agreed to by the landholder included:

- conserving the biological diversity and ecological integrity of the land;
- not destroying native vegetation on the land without the prior written approval of the Authority (approval only to be given if the vegetation is a threat to public safety or to property);
- not allowing any species listed as undesirable plants to grow on the land;
- ensuring that no cat is kept on the land;
- allowing pedestrian access across the land to members of the public wishing to use the walking track to a waterfall on the property.

The landholder can also nominate areas to be revegetated back to their natural state. The Authority will provide advice and, at its discretion, material assistance.

Another example of a cooperative management agreement involved landholders who wished to re-establish native rainforest on part of their land that had been cleared. They and the WTMA agreed to enter into an agreement to allow the revegetation work to proceed. The Authority agreed to fund the revegetation and three years' subsequent maintenance of the land, including fencing of the area. In return the landholders agreed to similar conditions as outlined above as well as providing ongoing maintenance of the revegetated area.

Question: Who establishes the criteria used to determine the definition of 'wise use'?

It is generally quite abstract, where you say 'wise use' is going to be 'sustainable use of the wetland', and that decision is made by policy and/or management personnel in each area. Because a lot of these sites are on reserved land, it may simply be how the site would be managed anyway, and each jurisdiction will decide that for themselves.

6 Further reading

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Wetland management: Sectoral divides and underlying issues

A case study based on the invasion of wetlands by weeds

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Abstract

The causes of wetland loss and degradation are not independent. Management planning and monitoring to address these causes need to bear this in mind. The main apparent reasons for wetland loss and degradation are changes in wetland area, changes in the water regime, changes in the water quality, unsustainable exploitation of wetland products, and the introduction of alien species. Invariably, these causes are addressed on a sectoral basis with few examples of constructive and long running cooperative management approaches. If the rate of wetland degradation in northern Australia is to be halted we will need to urgently address the social, economic and political underlying reasons and not just the apparent expressions of the reasons for such degradation. At an international level the underlying reasons include population pressure, lack of public and political awareness of wetland values, lack of political will for wetland conservation, over-centralised planning procedures, financial policies and irregularities. A formal assessment of the relative importance of these underlying reasons in northern Australia has not occurred. The more immediate causes of wetland loss and degradation relate to weak conservation institutions, sectoral organisation of decision making, deficiencies in the application of environmental impact and cost-benefit analysis, the passing of good legislation without subsequent enforcement, a lack of trained personnel, limited international pressure, and alliances which promote studies rather than action.

1 Introduction

Comprehensive information on the extent of wetland loss and degradation in northern Australia is not available. Further, most of that which is available addresses the apparent reasons for wetland loss and degradation (such as weed invasion, drainage) and not the underlying socio-economic and political reasons (Finlayson et al 1998a). The apparent causes of wetland loss and degradation include activities that directly affect the ecological character of the wetland. These are, in fact, manifestations of the underlying causes of wetland loss and are generally inseparable from the pressures of population growth and further economic development. Major causes of wetland loss and degradation in northern Australia are given in Bunn et al (1997). To prevent further ecological change, the underlying and often invisible factors, the immediate policy and institutional elements, and the more apparent and almost always highly visible causes of adverse ecological change in wetlands must both be addressed (Hollis 1992).

General information on the underlying reasons for wetland loss and degradation can be found in Hollis (1992), Finlayson (1994), Hollis and Finlayson (1996), but there is little information specific to northern Australia. Thus, in addressing current management issues for wetlands in northern Australia little mention is made of the underlying socio-economic and political factors that greatly affect management processes and decisions (Storrs & Finlayson 1997).

Current uses of wetlands in northern Australia include: pastoralism, grazing, horticulture and commercial fishing; tourism and recreation, especially amateur fishing; conservation and nature reservation; and traditional subsistence. These land uses are most intensive in the seasonally inundated and very productive wetlands near Darwin in the northern coastal region.

The utilisation of wetlands and wetland products raises a number of specific and general concerns for conservation and land/water management agencies. Access to and maintenance of the ecological character of the wetland habitats have received a great deal of attention and been subject to land use planning and zoning. However, often this has been done on a sectoral basis with little regard for other sectors or groups within society. Within this scenario, however, sectoral divides and associated underlying socio-economic and political issues that affect land use are being seen more and more as the prime reasons for ineffective wetland management (Hollis 1992, Finlayson 1994, Hollis & Finlayson 1996). An overview of these issues is presented below along with the specific example of weed invasion of wetlands.

2 Sectoral management

Sectoral management of wetlands is neither new nor the prerogative of any one group or country. It is widespread (see Hollis 1992, Finlayson et al 1992, Kvet 1992, Jonauskas 1996). In talking about wetlands of the Mediterranean basin Hollis (1992) made the following statements:

> a solution to the problem of wetland loss and degradation … will not be found by tackling only the apparent causes of the problem.
>
> all of the problems need to be tackled simultaneously and immediately, at all levels…
>
> There has to be an offensive on the social, economic and political causes of wetland loss and degradation…

Recent assessments of the extent of wetland degradation in northern Australian wetlands (Finlayson et al 1998, Finlayson & Storrs 1997) provide evidence that these statements are readily transferable. Thus, if the extent of wetland degradation in northern Australia is to be halted we will need to urgently address the social, economic and political underlying reasons and not just the apparent expressions of these reasons (ie the impact of the weed, feral animal, pollutant or land use).

The major reasons for degradation of wetlands have increasingly been grouped along the following lines (Dugan 1990, Hollis & Finlayson 1996, Bunn et al 1997)

- changes in wetland area
- changes in the water regime
- changes in the water quality
- unsustainable exploitation of wetland products
- introduction of alien species

Management of these problems has often been assigned to individual and separate agencies with relevant expertise, but with little incentive or aptitude to cooperate openly with other agencies, landholders or users. This problem is not peculiar to northern Australia. Attempts to develop multi-functional agencies have been made, but it is still widely recognised that poor communication and sectoral attitudes still persist. Attempts have been made to overcome such problems with joint and/or interagency advisory committees and technical panels and at a governmental level some success has been achieved. The attempts to address the severe environmental problems on the Lower Mary River in the Northern Territory exemplify one such approach (Jonauskas 1996), but it is no secret that inter-sector problems still exist.

A similar conclusion was made by Bayliss et al (1998) in an assessment of the vulnerability of the wetlands of Kakadu National Park to climate change and sea level rise. The wetlands of Kakadu have recognised conservation values. However, they are under threat and many of the problems can not be managed without a high level of cooperation between the park authority, local traditional owners and users of the park, plus representative groups and agencies from around van Diemen Gulf. The wetlands are interconnected (Storrs & Finlayson 1997) and can not be managed in isolation (Bayliss et al 1998, Storrs & Finlayson 1997). In response to this situation the Environmental Research Institute of the Supervising Scientist has established a monitoring node for collating and assessing the information resource and monitoring change in the wetlands of Kakadu. It is anticipated that this monitoring node will have sufficient utility to be transferred to neighbouring lands. This project is overseen by a broadly based group of landholders and users and governmental agencies. However, this node has a research and monitoring function only, it is not a management structure. The issues of managing across this broad area with at least four different land jurisdictions (private and Aboriginal leasehold, Commonwealth and Territory conservation reserves) have not similarly been addressed (Finlayson et al 1998b).

A further example of the complexities of sectoral divides is shown by the utilisation of the concepts and instruments of the Ramsar Convention for Internationally Important wetlands. A recent informal assessment (L Tucker pers comm) has highlighted the low-level, if not absence in many instances, of knowledge of the listing of internationally important wetlands in the van Diemen Gulf region. Further, the obligations and instruments available to managers under this convention are not well known. This is in total contrast to Australia's input at the international level. To be truly effective the values that derive from participation in such a convention need to be relayed to all interest groups. At the same time it is also worthwhile pointing put that several Aboriginal communities in Arnhem Land have made informal inquiries about listing their wetlands as internationally important under this convention. Thus, the information is obviously available, but is not being evenly distributed or utilised. The challenge is to make the relevant information available to all parties in a manner that they can readily utilise. Current sectoral divides have hindered this process and possibly retarded the development and/or adoption of management attitudes and methods.

3 Underlying reasons

Hollis and Finlayson (1996) point out that the root cause of continuing wetland loss and degradation in the Mediterranean basin are:

- population pressure
- lack of public and political awareness of wetland values
- lack of political will for wetland conservation
- over-centralised planning procedures

- financial policies and irregularities

Further, the more immediate causes relate to:

- weak conservation institutions
- sectoral organisation of decision making
- deficiencies in the application of environmental impact and cost-benefit analysis
- the passing of good legislation without subsequent enforcement
- a lack of trained personnel
- limited international pressure
- and alliances which promote studies rather than action.

A similar analysis has not been undertaken in northern Australia, but many of the above issues have been highlighted in recent reviews (Bunn et al 1997, Storrs & Finlayson 1997, Finlayson et al 1998a).

The processes that result in wetland loss and degradation are, in fact, manifestations of the underlying causes and are generally inseparable from the pressures of population growth and further economic development. The major processes causing wetland loss and degradation on a global basis are:

- agricultural (including irrigation) intensification
- urbanisation and industrialisation
- tourism and recreation
- expanding fisheries and aquaculture
- hunting activities

Again, without having a formal analysis these processes have been recognised as important in northern Australia (Storrs & Finlayson 1997, Finlayson et al 1998).

Whilst these processes are listed separately they are not totally independent. For example, water pollution can be caused by industrial and agricultural practices as well as tourism and aquaculture developments. Increased tourism can also lead to the conversion of wetlands to resorts. The intensification of agriculture through irrigation, booming tourist resorts and burgeoning cities and rising demand for electricity can combine to create dams and water supply schemes which have a radical effect on downstream wetlands. This interdependence must be borne in mind when drawing up management plans and monitoring programs to address the causes of wetland loss and degradation.

4 Underlying socio-economic and political reasons for weed invasion

As previously discussed (see Storrs weed management paper this volume) there are ecological reasons that mean that NT wetlands are susceptible to invasion by weeds. They seem to be intrinsically susceptible to invasion through ‘natural’ disturbance and they have also been disturbed through anthropogenic activities, eg invasion by feral animals (Rea & Storrs 1999).

NT wetlands have received relatively few weed species but weeds are spreading through Australia faster than they can be controlled and it is expected that new weeds will enter Australia and the NT over the coming years (Humphries et al 1991). The underlying reasons for this are often socio-economic or political (Rea & Storrs 1999). Some of these reasons are addressed below.

4.1 Bureaucratic frameworks and responsibilities

4.1.1 Development

The NT economy is in a development phase, based firmly on using natural resources. Wetlands in the Northern Territory are managed under a multiple land use policy that seeks to 'maintain biological diversity and other natural resources, plus promote ecologically sustainable development' (Fleming 1993, Fulton 1995). Thus wetlands are recognised for both their conservation and economic values. The policy attempts to encourage different land uses and to provide a balance with conservation objectives.

With accelerating rates of economic development in the Top End, wetland use and conservation issues are being brought into conflict (Whitehead et al 1990, Jonauskas 1996). One of the prime examples is the introduction of ponded pasture species. To support pastoralism, the NT government has been encouraging the planting of introduced ponded pasture plants (Lemcke 1996).

The introduction of these grasses ignores advice that these plants may become major environmental weeds (Clarkson 1995). The introduction of these exotic grasses is also questionable from a needs basis. Native grasses can be very nutritious (Calder 1981) and, prior to BTEC, native pastures were able to sustain vast herds of buffalo – up to 7 animals per ha (Bayliss & Yeomans 1989). The total NT buffalo herd of approximately 341 000, was about the same as the domestic cattle herd (Bayliss & Yeomans 1989). The introduction of ponded pasture species is proceeding without ecological risk assessment or environmental cost-benefit analysis.

Wildlife values and their contribution to commercial activity (eg tourism) should be explicitly incorporated in any cost benefit analysis (NT Government 1995). For the policy of multiple use to be sustainable, authorities and stakeholders need to be aware of the effect of their actions on wetlands and other land users (Rea & Storrs 1999). As multiple use of NT wetlands is in its early development, now is the time to gain a commitment from all stakeholders to accept some constraints on the achievement of their narrower goals whilst community wide stakeholder consultation is increased (Rea & Storrs 1999).

4.1.2 Planning

Tackling weeds in the expansive natural areas of the sparsely populated NT necessitates a strategic approach (Storrs & Lonsdale 1995, Storrs et al 1996). Case studies have shown that carefully planned ongoing management of introduced species is more likely to succeed than short-term, intensive control (Usher 1988). An NT Weeds Management Strategy (NT Government 1996) has been developed which calls for government to work with land holders and land managers to plan and implement weed management on a catchment basis over the long term.

Apart from regional strategies (eg Storrs 1996), individual holdings need weed control integrated into Property Management Plans, which set out realistic frame-works for the future (Rea & Storrs 1999). Property Management Plans have been strongly adopted in southern Australia and are intended to overcome ad hoc weed management: that is, controlling weeds when money allows, when situations become critical or on a seasonal basis. The draft NT Weeds Management Bill proposes that the requirement for Weed Management Plans could be enforceable by Government authorities.

Although Aboriginal people own much of the floodplain country in the northern part of the NT, learning from indigenous land use and experience has not featured in their utilisation. One of the most exciting things happening at the moment is the Environment Australia-funded project to produce management plans for 10 important wetlands on Aboriginal land – *The Top End Indigenous Peoples Wetlands Program* (see Storrs community wetland management paper this volume). It is a great example of cooperation between individuals and agencies. The program commenced in early 1996 and adopts a strategy of 'total catchment management' coordinated between regions. At the local level the community has control of, and participates in, the planning process and implementation phase of wetlands management.

4.1.3 Sectoral responsibility

In the northern part of the NT, weed control is largely dictated by land tenure and the commitment, financial capability, and management preferences of responsible agencies (Rea & Storrs 1999). Apart from private (freehold or leasehold) and Crown land, there is significant Aboriginal ownership (~85% of the NT coastline), as well as Commonwealth and Territory administered land. These boundaries are transgressed by weeds.

The multisectoral problem is well illustrated by mimosa control in the NT. A litany of problems, ranging from experimental biological control plots being sprayed with herbicide, to non-strategic management of large-scale infestations, is the result of different management objectives and poor cooperation. A Territory-wide strategy is needed to bring together different land-owners and land-managers, and to make knowledge on control freely available and unrestricted by agency protocol (Rea & Storrs 1999).

The draft NT Weeds Management Bill proposes that as well as an NT Weed Management Committee being appointed, regional (or catchment based) or specific purpose weed management committees be established.

4.1.4 Accountability

Those utilising wetland resources need to be responsible for their impacts in the same way that mining companies are required to conduct environmental impact studies, operate within a set of guidelines, treat waste and rehabilitate their mine-sites (Finlayson 1991). Until government, industries and managers are held accountable for the impacts of their decisions and activities, then weed problems can be expected to increase. Accountability would lead to more effective weed management and control (Rea & Storrs 1999).

When problems are truly incurable, short-term control can also make situations worse. For example, one-off chemical treatments or continuous ad hoc attempts to control mimosa mechanically and with fire, appear to actually increase its growth and reproduction.

In addition, the consequences of control measures such as excessive herbicide use can lead to new and more serious problems (eg excessive herbicide use, toxicity and resistance), which can override the initial weed problem. The argument for doing something, is only warranted if real benefits accrue. Being seen to be doing something should never be a reason for undertaking weed control (Rea & Storrs 1999).

4.1.5 Resources and funding

Weed research is often undertaken with funds allocated under a short-term contract framework, with continuation contingent on outcomes (ie improved weed control). However, outcomes to environmental problems are usually achieved over the long term (Rea & Storrs 1999).

Mimosa is seen to be one of the most important weed threats to Australia. However, the CSIRO/DPIF biological control program workers in Darwin and Brisbane are continuously under funding constraints and threats of closure. Research staff have spent a lot of time obtaining support and writing proposals as well as fighting political battles. In that situation how can effective research be undertaken? Only with substantial and secure funding can researchers be truly effective.

The nature of government spending is another reason behind continued degradation of wetlands in the NT (Rea & Storrs 1999). Present expenditure is heavily weighted toward chemical control and, to a lesser extent, biological control. Where chemical control is expensive and unsustainable in the long term, biological control is a long-term solution that is environmentally sensitive and cost-effective. As well, mechanical and ecological control are often practised by 'trial and error' and not supported by substantive research investigations (Rea & Storrs 1999).

The $8 million Oenpelli spraying campaign was largely designed to attract government funds (Rea & Storrs 1999). Addressing weed issues with large one-off control programs may appease community concern, satisfy industry stake-holders, fit in with the 'commercial' cycle of government spending and have spin-offs for local economies, but it is not conducive to the successful management of environmental problems.

If improved weed management is the ultimate objective, new ways of funding environmental issues are needed. Self-regulation of funds as investments in long-term trusts, would provide continuous finance and in theory lead to more efficient and effective weed control (Rea & Storrs 1999).

Government funding of weed research and management can never be sufficient to resolve problems on behalf of industry. The industries which utilise wetlands (ie pastoralism, tourism, fisheries, wildlife harvest) are yet to contribute funds to mimosa or salvinia research and management. Yet, all stand to benefit from Territory and Federal government funds.

Ultimately, it is taxpayers money that is footing the bill for weed problems that industry practices may have contributed to in the first place. Stakeholders should be encouraged to invest in Research and Development of environmental problems, rather than expecting others to pay (Rea & Storrs 1999). Accountability and mandatory sustainable land management should be strong incentives.

4.2 The generation and application of information

4.2.1 Awareness

It is critical that the whole community is aware of the significance of wetlands and the detrimental effects of weeds. As discussed, in general, most economic development proceeds without consideration of the potential ecological impacts. Only after visible and detrimental impact to people, does research on impact assessment and measures to ameliorate change usually begin.

Ownership of weed problems are often limited to people whose livelihood depends on wetlands or live in their vicinity. For others, the inaccessibility of wetlands lends an 'out of sight out of mind' attitude, such that their value is easily misunderstood. The small population in the NT and extensive natural areas may sustain the attitude that we can still afford to sacrifice some country (Rea & Storrs 1999).

However, wetland protection is needed on large scales because of the ecological interactions that occur within and between the extensive wetlands that cover large areas and provide food, shelter and nest sites for many animals (Whitehead et al 1990). As weeds threaten the high diversity and richness of animal species, which are the principal foci for tourism in the Top End, they can have significant economic impact. Wider appreciation of these links would provide support for ecologically sensitive land use.

DPIF has for some time been producing a series of posters and calenders for distribution amongst land owners and users especially Aboriginal communities. But much more is needed – there is a need to seek relevant professional advice on the most appropriate means of transferring information (eg role of regional or local newspapers, community radio and television etc (Storrs & Finlayson 1997). Once various media have been identified the nature of the message and the target audience needs analysis. This might fall into the realm of publicity and public relations experts.

4.2.2 Research

Overall wetlands in the NT are poorly understood with little information on processes and functions in the wider landscape (Storrs & Finlayson 1997). Many studies have been of short duration and there are no multi-disciplinary long-term programs. In some cases, valuable ecological information has not been placed in the public domain by government and private sectors. This lack of theoretical frameworks and insufficient ecological information for wetland management may indirectly allow weeds to persist and spread (Rea & Storrs 1999).

Wetland specialists and managers are being asked to quickly find solutions to weed invasions and provide advice about sustainable ecological management. However, there are limited data from which to draw; the closest coming from the control of agricultural weeds in different regions. This is why herbicides are often used at the outset. Translating agricultural experience to the management of ecological problems may result in new problems (herbicide resistance, toxicity, reduction in biodiversity), which land-owners and managers need to be aware of before operations proceed.

Calls for assessment of the ecological impacts of weeds and environmental impact assessment of control operations have been around for a long time (eg Mitchell 1978). In the northern most part of the NT, few weeds have had their ecological impact assessed at any level, despite such information being essential before control operations begin.

Control programs for mimosa and salvinia have proceeded without any risk analysis, environmental impact assessment, or cost benefit analysis (Rea & Storrs 1999). While the costs, efficacy and impacts of integrated or individual methods are unknown, resources are expended without a full knowledge of the outcomes.

4.2.3 Communication

The majority of weeds require persistent, long-term, low-key control. The widespread use of the term ‘eradication’ undermines control strategies by promoting cynicism and misunderstanding (Rea & Storrs 1999). Although the Kakadu National Park Plan of Management (ANPWS 1991) states the aim of eradicating all weeds from the Park, the basic message for salvinia, after a three year ecological study, is ‘learn to live with the weed’ (Storrs & Julien 1996). Essentially, short-term control often has little real effect, and runs the risk of causing environmental degradation. Realistic integrated management plans with an emphasis on any positive result as a bonus, will avoid confusion over expectations of eradication.

4.2.4 Prevention

In Australia it is often the case that weeds are ‘allowed’ to invade. Plants that became weedy were, on most occasions, introduced intentionally for other purposes (Lonsdale 1994). As previously stated mimosa, salvinia and ponded pasture grasses were all deliberate introductions. Ecological risk assessment should be mandatory for all exotic plants (eg pastoral, nursery, cut flower, aquarium), with those qualifying as potential weeds being refused entry into Australia or distribution between biogeographic regions (Rea & Storrs 1999). Ways to predict weediness from plant traits are assisting in the development of strict guidelines and preventative strategies at the national and international level with regard to trade, transport and quarantine (Panetta 1993, Pheloung 1995).

Prevention also covers intrinsic measures that address the cause of weed problems such as reducing grazing pressure, reinstating natural water regimes, reducing nutrient run-off, ‘no go’ areas, and providing stock and vehicle wash down facilities. These measures are sometimes made to look unfeasible and impractical, despite advice to the contrary. In contrast to quick and flashy aerial spraying from helicopters, they are more time-consuming, requiring thorough and committed management (Rea & Storrs 1999).

Awareness and education programs would assist in the establishment of these changes to management practices. When the logistics are overcome, there are significant long-term advantages.

4.2.5 Integrated control

Weed management should ‘ideally consist of different control techniques integrated into a flexible program that is suited to local conditions’. There is much scope for developing ‘Integrated Weed Management’ (Rea & Storrs 1999). Integrated control is where one or more methods are used to make the plant more susceptible to another method. For example, it is hypothesised that mechanical control and fire both predispose mimosa to more damaging attack from biological control agents. Investigating the impact of, and interaction between, control methods will lead to better weed management.

Information about the ecological and biological responses of weeds to the environmental characteristics of the habitats they invade, should enable targeting of control methods for better effect. Although frequently touted as the best approach, integrated control is little adopted in the NT, due to lack of information and commitment. The proposal for the integrated control of salvinia in Kakadu National Park (Storrs & Julien 1996) is a rare example of an integrated weed strategy in the world.

4.2.6 Rehabilitation

Degraded wetlands can be made more resilient to weed invasion through the planting of competitive species. However as there are broad differences in the reasons for managing weeds there are also different ideas about post control rehabilitation. The objective on NT and Commonwealth Reserves is to reclaim native vegetation and wildlife for conservation, tourism and fisheries while the pastoral industry aims to replace weeds with productive grazing pasture. For example, in the Mary River system, 1200 kg of replacement vegetation seed was aerially distributed at the same time as herbicides in 1995/96. Most of it was non-native species such as commercial rice and ponded pasture species (G Schulz pers comm).

Objectives need clarification and rigorous assessment to confirm they are realistic, and in the case of pastoralism, that one weed is not replacing another (Rea & Storrs 1999). There is also a need to complement control and rehabilitation with an effective monitoring program, which can help prevent further seed germination and plant invasion.

5 Conclusion

Introduced flora and weeds are just starting to get the attention they deserve. The overriding goal of wetland weed management should be to prevent further loss and degradation of wetlands. There needs to be concerted discussion at the national level about what sort of country we want Australia to be in the future.

Australia has the luxury of having natural wetlands and other ecosystems to protect. We remain optimistic that if some of the obstacles and opportunities outlined in this paper are removed or taken up, respectively, then weed management and wetland protection can vastly improve.

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Ecological risk assessment and management

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Abstract

The degradation and loss of wetlands is a global issue, and in many cases can be attributed to anthropogenically-related factors such as altered water regimes, physical modifications, the invasion of exotic species, and pollutants. With the increase in recognition of such problems, the last two decades have seen a growing emphasis towards sustainable management of the environment, whereby both ecosystem health and the quality of human life can be maintained. Towards achieving this, an understanding of the type and magnitude of stressors an environment can or cannot tolerate is required. One way of determining or estimating this is by a process known as ecological risk assessment (ERA), which involves the estimation of the likelihood of adverse environmental effects occurring as a result of exposure to a stress, usually through human activity. Ecological risk assessment is a series of steps: *problem formulation*, *effects characterisation*, *exposure characterisation*, *risk characterisation*, *risk management*, and *monitoring*. The first step involves the collation of information on the nature of the problem and developing a plan for the remainder of the risk assessment based on this information. Effects and exposure characterisation represent the analysis phase of the risk assessment, where data concerning the responses of the environment to the stressor, and the likely level of exposure to the stressor are gathered. Risk characterisation involves the comparison of effects and exposure data, to estimate the likelihood of adverse ecological effects. Risk management is the process of decision-making based on the results of the risk assessment, which attempts to minimise the risks without compromising other societal or community benefits. Finally, monitoring must be implemented in order to assess the effectiveness of the risk management decisions. This discussion deals with the specific details of each of the above steps of ecological risk assessment, particularly with regard to the potential impacts of pollutants on aquatic ecosystems. Following this, it provides some guidance on how ecological risk assessment can be applied to wetland ecosystems.

1 Introduction

Aquatic environments are under ever-increasing pressure from human activities. Many aquatic ecosystems, including wetlands, have already been degraded through urban and industrial development of coastal areas and inland waterways. Such degradation is due to a multitude of anthropogenically-related factors. Physical alterations and habitat modification, such as the draining of wetland areas for urban development, or the damming of rivers for water supplies and agricultural purposes have impacted significantly on Australian aquatic ecosystems (Bunn et al 1997). In addition, the introduction of exotic species has had a dramatic effect on both marine and freshwater ecosystems throughout Australia (Bunn et al 1997). Several examples of animal introductions include the European carp, *Cyprinus carpio*, and the mosquito fish, *Gambusia affinis*, into temperate freshwater habitats, the water buffalo, *Bubalus bubalis*, into tropical wetland habitats, and an array of exotic species into marine habitats via the release of ballast water from ocean-going ships. Exotic plants have also caused widespread degradation of waterways and wetlands, particularly *Mimosa pigra* and *Salvinia molesta* in northern Australia (Miller & Wilson 1995). In addition to the above causes of environmental degradation, pollutant inputs into aquatic ecosystems have also been a significant contributing factor in Australia (Bunn et al 1997), although probably not to the extent of that in more industrialised countries in Europe, Asia and North America. Nevertheless, pollutants are still of major concern in Australia for several reasons: the unique faunal groups represented and the lack of knowledge regarding their tolerance to xenobiotics; the seasonal/environmental extremes exhibited within and between regions; and also the fact that along with changes in habitat and water regime, future industrial and urban development will also bring with them the threat of further pollutant impacts (van Dam et al 1998).

With the pressure of anthropogenically-related stressors on the environment currently at its greatest, and likely to intensify in the future, the last two decades have seen a growing emphasis towards proper, or sustainable management of the environment, whereby both ecosystem health and the quality of human life are maintained (Cairns & van der Schalie 1980, Stortelder & van de Guchte 1995). Short term gains in the quality of human life can and have been made at the expense of ecosystem health, but ultimately such a situation cannot be sustained. For effective environmental management, an understanding of the type and magnitude of stressors that an environment can or cannot tolerate is required. In addition, potential effects of anthropogenically-related stressors on the environment need to be characterised, and weighted against economical and/or societal benefits. A process which serves to achieve this is known as risk assessment or, more specifically, ecological risk assessment.

The remainder of this discussion presents an overview of the process of risk assessment, with an emphasis on ecological risk assessment and its application to wetland research and management.

2 Defining risk assessment

The concept of risk assessment originated from the insurance industry, estimating probabilities and magnitudes of undesired events, such as human mortality, morbidity or even property loss (Suter 1993). However, it has since spread into a variety of other fields including engineering, toxicology, epidemiology and economics (Suter 1993).

Risk assessment can be defined as a structured process involving the estimation (qualitative or quantitative) of the likelihood of clearly defined adverse effects occurring as a result of exposure to a stress, usually through human activity (Suter 1993). It estimates the likelihood of harm to humans or the environment (van Leeuwen 1995a) and allows managers to make decisons based on that likelihood.

In brief terms, the process of risk assessment involves: 1) identification of the nature of stressor; 2) determination of the likelihood of adverse effects due to the stressor; 3) determination of the consequences of such an event; 4) estimation of the risk and its acceptability; and 5) management of the risk. Risk assessment need not be directed exclusively at chemical contamination, and thus can be used to assess risks associated with other forms of human activity such as physical disturbances (eg deforestation; van Leeuwen 1995a) or even natural occurrences (eg climate change, fire). However, the majority of this discussion refers to the risk assessment of chemical contaminants.

2.1.1 Human health risk assessment (HRA)

Historically, risk assessments have emphasised the risks of hazards to human health (Suter 1993, Vermeire & van der Zandt 1995). Human health risk assessment (HRA) has usually been associated with the effects of chemicals on humans. Chemicals which are assessed include drugs for use in medicine, general workplace chemicals such as solvents and pesticides, and industrial pollutants.

The major characteristic of HRA, and the one that separates it most from ecological risk assessment, is that it focuses on the protection of only one species, *Homo sapiens*. Although, most toxicity data for HRA are derived from standard laboratory test species (eg rodents), and then extrapolated to potential human health effects, the ultimate interest in the health of only one species eliminates much uncertainty in the results. Extrapolation of animal data to humans is usually done by extrapolation of the dose of a no-observed-adverse-effect level (NOAEL), based on body weight, and the use of a safety factor, usually 100 (Kroes 1995). This apparently accounts for the uncertainty in the extrapolation procedure (Kroes 1995). Therefore, uncertainty is mostly limited to variations in exposure routes (ie dermal, inhalation, ingestion) and intra-specific variation (van Leeuwen 1995a,b).

2.1.2 Ecological risk assessment

With man's bias towards assessing the risks of hazards to human health, effects on the natural environment have largely been ignored. Previously, there has been a common but mistaken belief that protection of human health automatically protected non-human health (Suter 1993). This has since been shown not to be the case, particularly for certain chemicals known to be particularly non-toxic to humans, but found to be very toxic to aquatic life (eg chlorine, aluminium; Suter 1993). In addition, stressors such as physical disturbances (eg deforestation, river flow regulation), not associated with chemical contaminants, will have severe effects on the natural environment, but not necessarily on human health.

The US EPA (1992) defined ecological risk assessment as:

> a structured process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors

While a number of different frameworks exist for ecological risk assessment, they generally follow a similar series of steps, as summarised below. However, there are some variations within the literature as to exactly how the process of risk assessment is structured. For example, Suter (1993) incorporated both the assessment process and the process of decision making based on the results of the assessment, termed risk management, in the overall risk assessment process. In contrast, van Leeuwen (1995a) attempted to separate the processes of risk assessment and risk management, although still recognised the inter-relatedness of the two. The US Environmental Protection Agency offers another modification of the risk assessment paradigm (US EPA 1998). For the purposes of this discussion, a slightly modified risk assessment framework is described, incorporating information from Suter (1993), van Leeuwen (1995a) and US EPA (1998).

The process of ecological risk assessment can be divided into the following steps:

1 Problem formulation

2 Effects characterisation

3 Exposure characterisation

4 Risk characterisation

5 Risk management and reduction

6 Monitoring

The above steps are represented as a flow diagram in figure 1, while table 1 gives the definitions of some of the terms commonly used in risk assessment, including those of the above steps. Further details regarding the steps of ecological risk assessment are discussed below in section 3.

Although highly structured, ecological risk assessment is a flexible process for collecting, organising and analysing data, information, assumptions and uncertainties in order to estimate the likelihood of adverse ecological effects (US EPA 1998). As such, it provides a framework that allows effective analysis and decision making based on the analysis, while also providing an adequate mechanism of feedback if and when required. Ecological risk assessment can incorporate the assessment of both natural or human-induced stressors, and need not focus exclusively on the effects of chemical contamination, although this area has dominated the research, and is the focus of this discussion. ERA is also sometimes referred to as *environmental* risk assessment (van Leeuwen 1995b), however, this is generally a term given to the broader assessment of hazards to both humans and non-human biota (Suter 1993).

In ecological risk assessment, the biological level to be protected is usually the ecosystem. Essentially, one wants to assess the risks of a particular stressor, for example the potential adverse effects of petroleum hydrocarbons from an oil spill, to the ecosystem of interest, in this case coastal mangrove swamps and estuarine ecosystems. However, it will be impossible to assess the effects on every species as there will most likely be hundreds present. The solution to this, which is discussed in greater detail below, is to select several indicators or endpoints, that best represent the ecosystem of interest. However, the cost is that uncertainty is exacerbated by the fact that many more indicators/endpoints will not have been assessed. Thus uncertainty is increased due to interspecies variation (van Leeuwen 1995a), in addition to that already existing due to stochasticity (random variation), a lack of knowledge about the stressor, the endpoints being assessed, the ecosystem of interest, and human error (Suter 1993). Thus, it is important to recognise and understand the uncertainties surrounding the scientific information on which the decision will be based (Suter 1993). While past environmental assessment techniques have often incorporated aspects of risk assessment, they have generally lacked a formalised structure and, importantly, have failed to recognise uncertainty. The following section describes, in detail, the process of ecological risk assessment, based on the six steps outlined above.

3 The process of ecological risk assessment

3.1 Problem formulation

Problem formulation is the process of identifying the nature of the stressor and the receptor (ie the environment of interest), and developing a plan for the remainder of the risk assessment based on this information. It defines the objectives and scope of, and provides the foundation for, the entire risk assessment (Pascoe 1993, US EPA 1998). In the case of a chemical stressor, problem formulation would include obtaining and integrating information on the chemical's characteristics (eg properties, known toxicity) and source, what is likely to be affected and how is it likely to be affected and, importantly, what is to be protected. Such information is then used to determine the structure and complexity of the remaining steps of the risk assessment. Problem formulation includes selection of *assessment* and *measurement* endpoints; assessment endpoints are explicit expressions of the actual environmental value(s) to be protected (eg invertebrate community diversity), while measurement endpoints are measurable responses to a stressor that can be correlated with or used to predict changes in the assessment endpoints (eg invertebrate reproduction, macroinvertebrate monitoring) (Solomon et al 1996). It is the measurement endpoints that are directly assessed during the risk assessment (section 3.2). Thus, the selection and use of *ecologically relevant* measurement endpoints are highly important, and are discussed in further detail below (section 3.2).

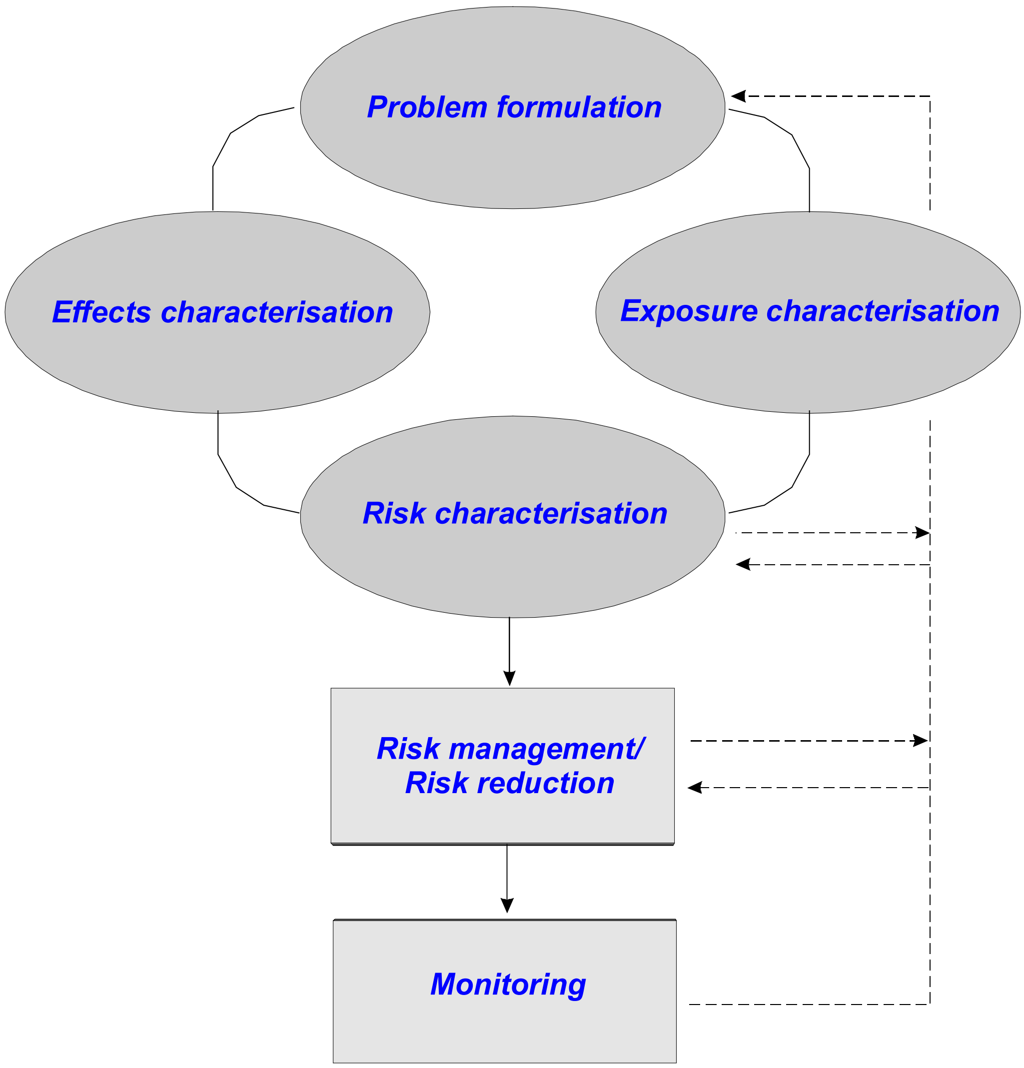

Figure 1 Ecological risk assessment paradigm (modified from van Leeuwen 1995)

Table 1 Definitions of terms commonly used in risk assessment (from van Leeuwen 1995a & US EPA 1998)

Term	**Definition**
Stressor	Any physical, chemical, or biological entity that can induce an adverse response.
Hazard	The potential, or capacity of a stressor to cause adverse effects on man or the environment, under the conditions of exposure.
Risk	The probability of occurrence of an adverse effect on man or the environment resulting from a given exposure to a stressor.
Risk assessment	A process which involves some or all of the following elements: problem formulation/hazard identification, effects characterisation, exposure characterisation, risk characterisation, risk management and monitoring.
Problem formulation	The identification of the nature of the stressor and the receptor (ie the environment of interest), and the development of a plan for the remainder of the risk assessment based on this information.
Hazard identification	The identification of the adverse effects a stressor has the potential, or capacity to cause (another term for, or confined within, *problem formulation*).
Effects characterisation	The estimation of the relationship between dose, concentration, or level of exposure to a stressor, and the incidence and severity of an effect.
Exposure characterisation	The determination of the emissions, pathways and rates of movement of a stressor and its transformation or degradation in order to estimate the concentration/dose/level to which humans or environmental compartments are, or may be, exposed.
Risk characterisation	The estimation of the incidence and severity of the adverse effects likely to occur in humans or environmental compartments due to actual or predicted exposure to a stressor.
Risk management	A decision-making process that involves considerations of political, social, economic, and engineering information with risk-related information to develop, analyse and compare regulatory options and to select the appropriate regulatory response to a potential health or environmental stressor.
Risk reduction	Implementing measures to protect humans and/or the environment from the risks identified.
Monitoring	The process of repetitive observation for defined purposes of one or more chemical or biological elements according to a pre-arranged schedule over space and time, using comparable and standard methods.

Once the relevant information has been gathered and the objectives/goals defined, a conceptual model of the problem is developed. This involves defining possible exposure and effect scenarios based on the information. Conceptual models may be represented in the form of flow diagrams describing the possible routes of exposure and potential effects of concern (US EPA 1998). Such diagrams can then be used to develop a series of working hypotheses regarding how the stressor might affect exposed ecosystems and their components (Solomon et al 1996, US EPA 1998). Hypotheses might read as follows: 'Atrazine will cause damage to the community structure of macrophytes and reduce the ability of the aquatic habitat to sustain populations of other organisms such as invertebrates and fish' (Solomon et al 1996). The conceptual model is then used to construct an analysis plan (ie the plan for the remainder of the risk assessment). Those hypotheses considered more likely to contribute to risk are targeted (US EPA 1998), and a plan of how to best assess them, using both available and new data, is developed. As with the conceptual model, the analysis plan is often presented as a flow diagram.

The nature of the stressor must be clearly defined (eg the use of a herbicide and its potential toxicity to non-target aquatic organisms and plants in tropical floodplain environments) so as to gain a better understanding of the potential effects, and to assist in the determination of appropriate assessment and measurement endpoints (NLC & ***eriss*** 1997). A poorly defined stressor may result in the selection of inappropriate assessment endpoints (and thus measurement endpoints), due to a lack of understanding about the environmental components and processes that will be exposed and potentially affected.

At this point, a distinction between *stressor*, *hazard* and *risk* is useful. To distinguish between the latter two, van Leeuwen (1995a) used the following example: a toxic chemical that is a *hazard* to human health does not constitute a *risk* unless humans are exposed to it. The hazard is the potential adverse effect, while the risk is the probability that it will occur. The stressor, then, is the entity possessing the hazardous properties, ie the toxic chemical in the above example.

Potential shortcomings in problem formulation that could lead to inappropriate risk assessments include (1) absence of clearly defined goals, (2) endpoints that are ambiguous and difficult to define and measure, and (3) failure to identify important risks (US EPA 1998).

3.2 Effects characterisation

Effects characterisation evaluates the effects of the stressor on the measurement endpoints selected during problem formulation (van Leeuwen 1995, US EPA 1998). As stated above, a good understanding of the stressor will assist in selection of appropriate measurement endpoints on which to assess effects. Therefore, there is a degree of overlap between problem formulation and the initial stages of effects characterisation. Depending on the stressor, effects characterisation can take a variety of forms. In the case of chemical stressors (ie pollutants), ecotoxicological bioassays are usually used to derive concentration-response data for a range of species (see Appendix A for further details on ecotoxicological testing). The results of these bioassays are used to derive an estimate of effect, or 'no effect', and this can be done in a variety of ways. In its simplest form, data from bioassays are used to determine a *predicted no-effect concentration* (PNEC) of a chemical to species of concern (ie relevant aquatic organisms) (van Leeuwen 1995a). The PNEC can be defined as the maximum concentration of a chemical which, on the basis of available knowledge is likely to be tolerated by an organism without producing an adverse effect (Tas & van Leeuwen 1995).

Other more comprehensive, and hence complicated, approaches exist, where all the effects data are used to construct a cumulative distribution of known sensitivities (US EPA 1998).

A major attribute of measurement endpoints used for effects characterisation are that they be *ecologically relevant*. Ecological relevance can be described as the ability to directly link the observed response to effects at the population, community and/or ecosystem level (Finlayson et al 1998). This equates to being able to relate the measurement endpoints to the assessment endpoints. For chemical stressors, effects on whole-body responses of individuals (eg growth, reproduction, survival), or on populations or communities are generally considered to possess ecological relevance, while effects below the whole-body level of biological organisation (eg biochemical and physiological biomarkers) are not (Pascoe 1993, Solomon et al 1996).

As stated above, there are a variety of methods that can be employed for effects characterisation. These range from laboratory studies to field surveys, and quantitative assessments to qualitative observations. Laboratory studies allow strict control of all variables bar the one(s) of interest, but they may not reflect responses in the environment. Alternatively, field studies measure biological changes in the actual environment of interest, integrating all the environmental conditions, but as the conditions are not controlled, natural variability may make it difficult to detect the changes. Thus, the choice of method is specific for the type of risk assessment being carried out and its objectives (note that decisions on this are made during problem formulation, well before effects characterisation has commenced).

3.3 Exposure characterisation

Data on the effects of a stressor to an organism, plant, or ecosystem provide little useful information without knowledge on the actual level of exposure. Exposure characterisation estimates the exposure of a stressor to the receptor, by utilising information gathered about its behaviour and extent of occurrence. Such information is usually acquired by the use of historical records, laboratory and/or field experiments, field monitoring, and also modelling.

In the case of a chemical stressor, exposure characterisation requires knowledge about the quantities of, and the means by which a chemical can enter, and subsequently move about within the environment of interest. Processes such as transport, dilution, partitioning, degradation, and transformation (Suter 1993, NLC & ***eriss*** 1997), in addition to general chemical properties, and data on rates of chemical input into the environment, need to be considered. In its simplest form, the objective of exposure characterisation of a chemical stressor is to derive a *predicted environmental concentration* (PEC) of the chemical in the environment of interest. This can be obtained in a variety of ways, ranging from estimates based on chemical properties such as water solubility, vapour pressure, fugacity, rate of hydrolysis, photodegradation and microbial degradation, and data on environmental input rates (Macek 1986), to actual measured concentrations in the environment of interest (US EPA 1998). Concentrations can be measured in water, soil, sediment, suspended solids, air, and/or biota, depending on the complexity and objectives of the risk assessment. As with effects characterisation, more complex methods exist for estimating exposure, including cumulative distributions of measured environmental concentrations.

Laboratory experimentation of the fate of a chemical is especially useful when the assessment is predictive (ie the chemical is new, and the environment yet to be exposed). However, such laboratory assessments have the same limitation as laboratory toxicity bioassays, in that the data are not always easy to extrapolate to the situation in the environment. Computer modelling is also used for predicting exposure to chemical stressors (Suter 1993, Nendza & Hermens 1995). The type of modelling that needs to be carried out depends on the type of chemical being assessed, and the environment of interest. This information is first used to form a qualitative or semi-quantitative model, which provides the basis for quantitative mathematical models (van de Meent et al 1995). For ecological risk assessments of aquatic environments, water models, some of which incorporate sediment phases, and multi-media models are used (see Appendix B for examples of some environmental fate models).

For a biological stressor, such as an invasive weed species, exposure characterisation might involve integrating information on the source of the weed, the potential route of entry into the ecosystem of interest, rate of spread, habitat preferences, and reproductive biology.

Effects and exposure characterisation form the overall *analysis* phase of an ecological risk assessment. They are generally inter-related, and thus, usually carried out con-currently and in an iterative fashion: simple assessments are often performed initially, followed by more comprehensive assessments if considered necessary.

3.4 Risk characterisation

Risk characterisation involves comparison of the results of effects characterisation with the results of exposure characterisation, in order to estimate the likely level of adverse ecological effects resulting from the exposure to the stressor (Pascoe 1993, US EPA 1998). There exist a range of techniques for estimating risks, often depending on the type and quality of effects and exposure data. Two of these are described below, regarding the estimation of risks of chemical stressors.

i) PEC/PNEC ratio: The risk quotient

One of the simplest forms of risk characterisation is the calculation of the risk quotient, simply being the ratio of the PEC to the PNEC. It is an indication of the extent to which the predicted concentration in the environment (PEC) exceeds (or doesn't exceed) the highest concentration predicted to cause no effects (PNEC). It is a simple, inexpensive and easily understood means of identifying high or low risk situations that can allow risk management decisions to be made without the need for further assessment (US EPA 1998). Essentially, as the risk quotient increases, the likelihood of adverse effects increases. Above a ratio of 1, environmental concentrations are estimated to exceed effect concentrations, and a risk is deemed to exist. The risk quotient method is often used as the initial component of risk estimation. If there is clearly no risk, and the risk assessor is satisfied with the quality and quantity of data, no further assessment is required. If a risk is perceived to exist, more comprehensive risk estimations can be performed. However, the quotient is not an absolute measure of risk, and thus, may not be of use to a manager who needs to make a decision based on quantified risks (US EPA 1998).

ii) Comparison of cumulative exposure and effects distributions

Exposure distributions, based on measured environmental concentrations, can be compared with effects distributions derived from toxicity values for a range of different species (Solomon et al 1996, US EPA 1998). The degree of overlap of the curves along the x axis (ie the concentration of the chemical in question) indicates the likelihood that a certain percentage of species may be affected. This provides the risk manager with quantified risks for decision-making. In addition, by comparing different exposure scenarios it is possible to predict the likelihood of effects of different risk management options (US EPA 1998). However, some limitations of this method include the increased data requirements compared with the risk quotient and other methods, and the possibility that the full range of exposure and effects data is not fully covered (Solomon et al 1996, US EPA 1998).

It is important to emphasise that the output of risk characterisation need not be a quantitative estimate of risk. However, sufficient information should, at the very least, be available for appropriate experts to make judgements based on a weight of evidence approach. In the event of insufficient information being available, or uncertainty being judged to be too great, it is possible to proceed with another iteration of one or more phases of the risk assessment process in order to obtain more information and decrease uncertainty (US EPA 1998). Therefore, the whole assessment process is based on a tiered, or iterative process of testing and subsequent assessment, whereby more information is generated based on the previous assessment, in order to decrease the uncertainty surrounding the estimates (fig 2) (Macek 1986, Suter 1993). Regardless of the approach, uncertainty associated with the risk assessment must always be described, while interpretation of the ecological significance of the conclusions must also be carried out (Pascoe 1993, US EPA 1993). In addition, the risks must be sufficiently well defined to support a risk management decision, as discussed below.

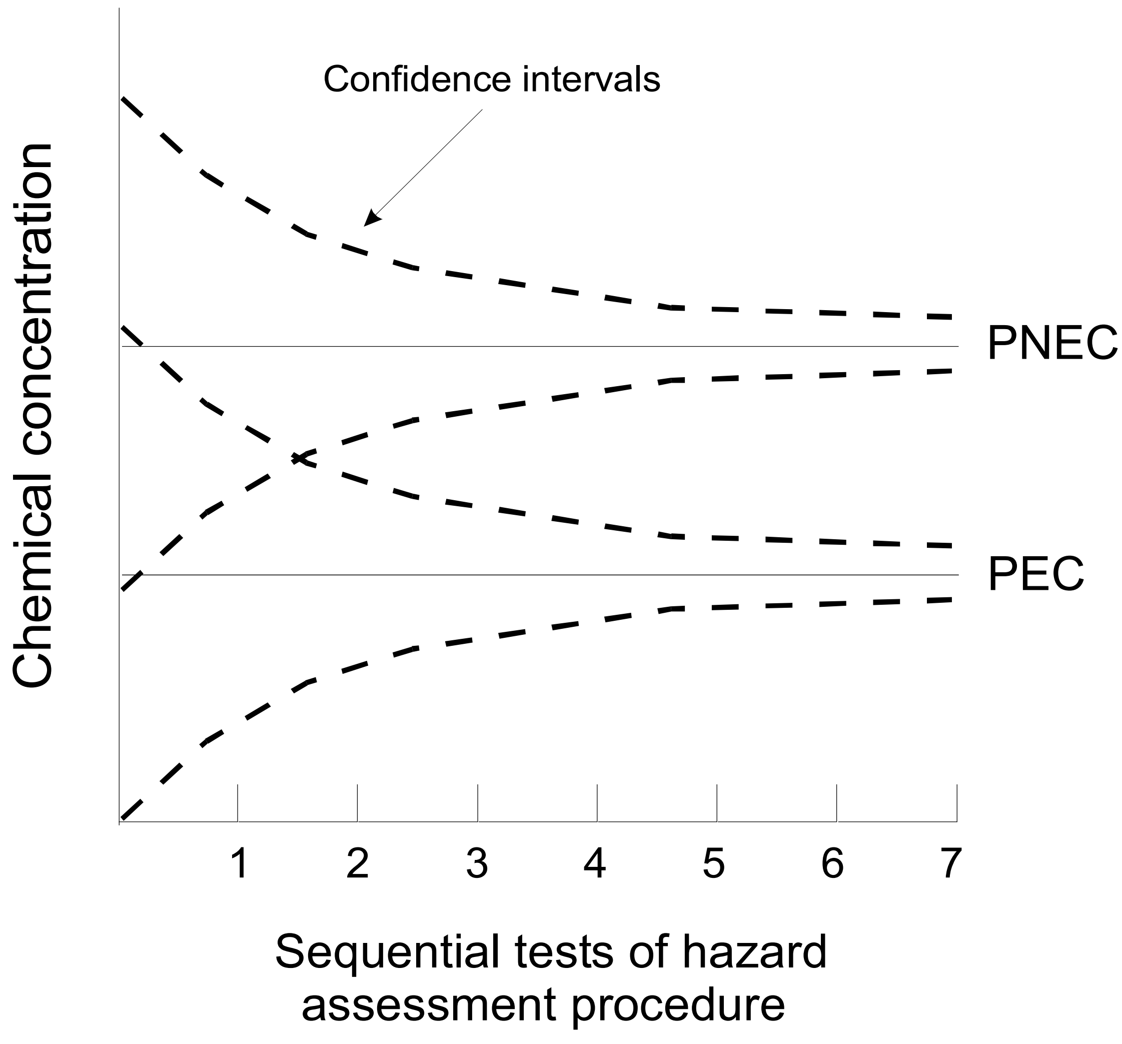

Figure 2 Tiered testing and assessment approach to risk assessment/characterisation (modified from Suter 1993)

3.5 Risk management

Risk management is the final decision-making process that utilises the information obtained from the risk assessment (the processes described above), and attempts to minimise the risks without compromising other societal or community values. According to Vermeire and van der Zandt (1995), the first process of risk management is that of risk evaluation, whereby a decision is made about whether the effects and exposure estimates can be improved by new data (ie the iterative approach to ecological risk assessment), or whether risk management, and subsequently risk reduction, should be implemented. This emphasises the importance of fully describing all uncertainties associated with the risk assessment, during risk characterisation.

It may be that the risks associated with a chemical are minimal, and no risk reduction is required, in which case risk management need go no further. However, it may be that the risks are considered significant, and risk reduction is required. In such a scenario, the results of the risk assessment are not the only factors that risk management considers. It also takes into account political, social, economic and engineering/technical factors, and considers the respective benefits and limitations of each risk-reducing action (van Leeuwen 1995a). It is a multidisciplinary task requiring communication between risk manager, the risk assessor(s), and experts in the other relevant disciplines (US EPA 1998).

Risk reduction involves the implementation of the selected measures to protect the environment from the risks identified. For example, it may be required that a particular industry discharging process effluent into a receiving water install a secondary or tertiary treatment facility. Alternatively, it may simply involve the manufacturer of a chemical to properly label the chemical's hazardous properties and handling requirements, to minimise improper handling/disposal, and therefore, potential adverse effects. Depending on the situation, risk reduction can take a multitude of forms.

Managers must be aware of, and clearly describe in their final risk assessment reports, the sources and causes of risks, the degree of confidence in the risk assessment, the rationale for the risk management decisions(s), and the options for reducing risk.

3.6 Monitoring

Monitoring is the last step in the risk assessment process, and one that has largely been ignored as a formal one. The process of monitoring has been explained in detail previously in this course, and is only briefly considered here, in the overall context of risk assessment. Monitoring should be undertaken to verify the effectiveness of the risk management decisions. It should be able to function as a reliable early warning system, detecting the failure or poor performance of risk management decisions prior to serious environmental harm occurring. Therefore, the risk assessment will be of little value if effective monitoring is not undertaken, as its effectiveness will not be evaluated. As with effects characterisation, the choice of endpoints in the monitoring process (ie what will be monitored?) is critical, and should be determined from information gathered throughout the risk assessment. Depending on the nature of the risk assessment and available resources, endpoints may or may not be the same as those used for effects characterisation. However, as 'early warning' may be a key criterion for indicators selected for these monitoring purposes, biochemical and physiological responses (ie biomarkers) may also be applicable.

4 Application to wetlands: Wetland risk assessment

Wetland risk assessment is not a new term or process. The US Environmental Protection Agency (US EPA) defined wetland ecological risk assessment as a quantitative or qualitative evaluation of the actual or potential adverse effects of stresses on a wetland ecosystem (US EPA 1989). In addition, Pascoe (1993) discussed the concept of wetland risk assessment, outlining two case studies to demonstrate its use, while the US EPA (1998) are currently developing *Watershed ecological risk assessment* frameworks similar to that required for wetland risk assessment. Further, the US EPA's recently revised guidelines for *ecological risk assessment* incorporate detailed information on the prediction and assessment of physical and biological stressors as well as chemical stressors (US EPA 1998). They are very broad, and generally embody the concepts of wetland risk assessment that are briefly discussed below.

The general ecological risk assessment paradigm in figure 1 can be applied to the prediction and assessment of risks to wetlands. However, in order for this to be realised, the details within the general structure must be appropriate for assessing the types of change experienced in wetlands. This not only includes recognising the inter-relatedness of the types of ecological change (eg chemical, biological and physical), but the spatial and temporal scales over which they occur. Some examples of methods/procedures that are relevant for risk assessment of wetlands, are described below.

In considering the nature of the stressor and the wetland habitat of interest (ie during problem formulation), it is important to recognise the interactions that occur between habitats and their catchments, in addition to the nature of, and processes occurring within, the habitat of interest. Thus, careful site-specific considerations will be required when defining the objectives of the risk assessment, selecting assessment and measurement endpoints, and developing conceptual models.

Data for effects characterisation should preferably be derived from field studies. Field data are more appropriate for assessments of multiple stressors, a common situation in wetland environments. Depending on the stressor and available resources, such studies can range from quantitative field experiments to qualititative observational studies (Pascoe 1993, US EPA 1998). For chemical stressors, *in situ*, or on-site ecotoxicological bioassays represent a useful approach. However, this does not exclude the use of laboratory experiments if considered useful (eg for single chemicals or when particular environmental conditions need to be controlled). Biological monitoring will most likely also represent a useful method for characterising effects, not only of chemical stressors, but also biological and physical stressors. Sites for assessment can be chosen based on existing information, or from data obtained from exposure characterisation (see below).

For multiple chemical contamination of a wetland, measurement of particular chemical residues throughout the site (perhaps in water, sediment and/or biota, depending on the chemical), based on knowledge of the pollutant source(s) (obtained during problem formulation) would represent an important component of exposure characterisation. Such measurements could be incorporated into a GIS framework, to develop a spatial picture of exposure.

A potentially useful technique for characterising risks in wetlands is via a GIS-based framework, whereby results of exposure and effects characterisation are compared spatially. Relative (semi-quantitative) risks can be determined based on corresponding areas of significant effects and exposure. Additionally, potential problem areas could be identified for further scrutiny. Risk management should be concerned with making decisions on managing inputs into a wetland and/or altering practices associated with the wetland. Again, due to the inter-relatedness of wetland habitats/ecosystems care should be taken that decisions made for one habitat do not have adverse consequences on another linked habitat. Thus, a holistic approach is required. This holistic approach should be carried through the entire wetland risk assessment process, including the monitoring phase, where any adverse on-site and off-site (indirect) effects of the management decisions should be detected prior to further and potentially serious effects occurring.

5 Conclusion

Ecological risk assessment has been used successfully to assess the risks of stressors, particularly chemical contaminants, to aquatic ecosystems for a number of years. Upon identification of a stressor, the objectives, scope, and structure of the risk assessment are determined during an initial step known as problem formulation. Then, by comparing estimates of effects and exposure to a stressor, an indication of the likelihood of adverse effects occurring can be obtained. Such estimates of risk provide another tool for managers to make decisions about the input and potential effects of stressors in the aquatic environment. Part of this process involves the weighting of the estimated risks of the stressor against political, societal and economic factors, to determine their acceptability. If the risk is considered to be unacceptable, risk reduction measures are implemented. The success and effectiveness of the risk assessment and management process is then evaluated by monitoring the environment of concern following implementation of risk reduction. While the process of ecological risk assessment can be applied to wetland threats and issues, it is essential that the large spatial and temporal variability exhibited between wetland habitats be recognised and addressed.

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Appendix A Ecotoxicological testing for effects characterisation

Ecotoxicology, or specifically, toxicity testing, plays a major role in effects characterisation of chemicals and industrial effluents, and thus is a major component of ecological risk assessment for chemicals. For example, to derive a predicted no-effect concentration (PNEC), one typically measures such properties as acute toxicity to a standard species (for comparative purposes), the relationship between acute and chronic toxicity to a given species, the variability in sensitivity between representative species, and the potential of the chemical to bioconcentrate (Macek 1986). This discussion focuses on the use of ecotoxicology for effects characterisation in aquatic ecosystems.

Ecotoxicology can be simply described as the study of toxic effects on non-human organisms, populations and communties (Suter 1993). The majority of ecotoxicological testing has dealt with effects on the individual organism. This is probably due to mammalian toxicology's prime interest in the individual, as well as the fact that organismal responses are more easily observed and interpreted than those of lower (eg biochemical, cellular) or higher (eg communties, ecosystems) levels (Suter 1993). Some advances have been made in this area, as are described later, but overall, organism-level effects have dominated effects characterisation. Standard single species toxicity tests are generally recommended for use in ecological risk assessment (Suter 1993), however, there is often a need for broader site-specific assessments, based on effects on resident species and local environmental conditions.

A number of decisions need to be made regarding the type of toxicity testing to be carried out, including test species selection, test endpoint selection, and test statistics selection.

Test species selection

When selecting appropriate test species for effects characterisation, several criteria should be considered. The first is whether standard, or local species should be used. The purpose, or objective of the risk assessment should enable a decision on this. Standard species are often used for risk assessments of new chemicals, while local, or regionally relevant species are often used for specific assessments of particular chemicals known or proposed to be released into a particular aquatic ecosystem. For a species to be regionally relevant, it should be an important component of the receiving system of interest. However, a species that has economic relevance (eg fisheries, tourism) may also be a useful test species. Test species should also exhibit relative sensitivity to the pollutant being assessed, and the use of sensitive life stages of a species (usually early life stages) is often employed. Successful and efficient laboratory culturing must also be considered when selecting an appropriate test species. Unfortunately, amenability to laboratory culture often conflicts with the criterion of species sensitivity.

It is essential that organisms representing different trophic levels be utilised. As effects of a chemical on single species will ultimately be extrapolated to estimate risks to communities or ecosystems, testing more organisms will reduce the uncertainty in the estimates. However, as time and resources will often be limited, the general consensus is that an absolute minimum of three organisms from different trophic levels should be tested. For example, a primary producer (eg aquatic macrophyte or alga), an invertebrate (eg cladoceran or copepod), and a vertebrate (eg fish) would represent an adequate range of trophic levels. In addition to the representation of different trophic levels, different environmental compartments should also be represented, depending on the chemical in question. Until recently, most test species have been pelagic, and very little attention has been paid to sediment-dwelling organisms, regardless of the knowledge that many chemicals are known to rapidly adsorb to sediments upon entering the aquatic environment (van Leeuwen 1995b). This point relates back to knowledge of the properties of the chemical, and the environment into which it is, or will potentially be released.

Test endpoints

Having selected appropriate test species, appropriate biological or test endpoints need to be considered. Endpoint selection is based on proper identification of the stressor and its potential effects, and ecological relevance, as discussed in section 3.1 and 3.2 of the main text, respectively.

The choice of endpoint will often also determine the test duration. The majority of acute toxicity tests use lethality as the test endpoint, and generally last for 2 to 4 days. Such an endpoint, although generally less sensitive than most sub-lethal endpoints, clearly indicates an adverse effect at the individual level, and most likely represents an effect at the population level, which is ultimately the extrapolation being drawn from such studies. As such, it can be considered to be ecologically relevant. However, identification of more sensitive, sub-lethal effects on individuals, which can predict, with confidence, effects at the population level, provide a more comprehensive and realistic assessment of risks to aquatic life. Growth, maturation and reproduction are commonly assessed sub-lethal endpoints, with the latter often, but not always being the most reliable indicator of adverse effects in the environment. For particular organisms, chronic toxicity tests can be carried out in relatively short time periods. For example, algal bioassays can generally assess pollutant effects on ecologically relevant endpoints such as population growth over approximately 72 h (3 days), while similar endpoints can be assessed using *Hydra*, over 96 h (4 days).

Recently, more subtle endpoints have been investigated for potential use in ecotoxicology. These include the use of biomarkers such as the mixed function oxidases (MFOs), or cytochrome *P*-450s, and immunotoxicological endpoints. MFOs have the disadvantage that while they may be suitable indicators of pollutant exposure, they are difficult to relate to adverse effects, or toxicity. As a result, they cannot be considered ecologically relevant, and hence should not be used as endpoints for effects characterisation.

Test statistics

There are two major approaches to statistics for ecotoxicological testing: 1) hypothesis testing, and 2) point estimation, and there is currently considerable debate over which is more appropriate.

Hypothesis testing is primarily concerned with comparing a series of two or more concentrations, typically serial dilutions, with control conditions (ie absence of the pollutant). Generally, such tests identify the highest concentration of a dilution series that does not differ significantly from the control condition, known as the no-observed-effect concentration (NOEC) (Chapman et al 1996). It should be noted that hypothesis testing need not be restricted to the estimation of the NOEC alone, but it is generally the most common statistical estimate (Chapman et al 1996), and the one that is used to estimate the PNEC. The major advantages of hypothesis testing for effects assessment are that it is a well suited technique for comparing a control treatment with a particular concentration of pollutant, and the statistical computations involved are well known and generally straight-forward. In addition, the past reliance on hypothesis testing makes it easier to directly compare present studies with previous research if hypothesis testing is utilised. The major disadvantage of hypothesis testing, is that the calculation of the major statistical estimates, the NOEC and LOEC (lowest-observed-effect concentration) can only be concentrations used in the experiment. As experiments are often conducted using serial dilutions (eg 0.1, 1, 10 and 100 mg/L), there are significant concentration gaps for which the effects are unknown, although they will generally not be greater than an order of magnitude in size.

Point estimation estimates the concentration associated with a specified level of change from that observed under control conditions, generally known as the effective concentration (EC) (Chapman et al 1996). It allows the estimation of concentrations that would cause different magnitudes of responses, such as a 50% reduction in growth (EC50), or a 10% reduction in reproduction (EC10). The effective concentration can also be referred to as the lethal concentration (LC) when lethality is the endpoint. The major advantage of point estimation for interpreting ecotoxicological data stems from the above-mentioned disadvantage of hypothesis testing. Point estimation uses regression techniques to quantify the response of organisms at every concentration by determining a concentration-response relationship and estimating where effects of a particular magnitude will occur. As a result, ECs are not restricted to being one of the test concentrations, as they are estimated from the concentration-response curve that is fitted to the data (Chapman et al 1996). In addition, different levels of effect can be estimated (eg EC1, or EC50) depending on the objective of the assessment, or what is considered biologically or ecologically significant. For example, the concentration of a pollutant in a water body could be considered to pose no risk if it does not exceed the estimated concentration that has an adverse effect on 1% of the tested organisms (ie EC1). For point estimation, the EC1 could be considered the PNEC, although other regression techniques have been developed to derive statistical estimates analagous to the NOEC (eg BEC10; Hoekstra & van Ewijk 1993).

While hypothesis testing has dominated statistics in ecotoxicology, there is a strengthening viewpoint that point estimation techniques are more suitable for use in ecological risk assessment. This is mostly due to the advantages described above.

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Appendix B Examples of environmental fate models for exposure characterisation

Some examples of environmental fate models used for exposure characterisation are described below. For further details the reader is directed to the review of van de Meent et al (1995).

Water models

Dilution models

Dilution models divide the concentration of a chemical in a pollutant mixture by a specific stream dilution factor (DF). The DF is usually based on measured volumes and flows of both the chemical discharge and the river/stream. Obviously, this is only the first step in understanding exposure, but it does provide an estimate of the concentration of the chemical in the aquatic environment prior to processes other than dilution acting upon it. In addition, such models can apparently give satisfactory predictions of exposure within a few kilometres from the discharge point, as dilution will be the major factor acting upon a chemical within this zone (van de Meent et al 1995).

Dispersion models

Dispersion models are used to describe the concentration profiles of chemicals throughout the water column, taking into account natural factors such as turbulence and even tidal movements. They are often used to model the extent of chemical dispersion following a spill, or even to monitor pollutant plumes such as produced formation waters or drilling muds from oil platform. They are only of real benefit where a point source of a chemical or discharge exists.

Compartment models

Compartment models describe the transfer and transformation of chemicals through a surface water system. Most water-based compartment models contain a water and a sediment layer. These models are somewhat more complex than the previous two, and therefore require the input of more informtation (eg on biodegradation, photolysis, volatilisation, sorption).

Multimedia models

Multimedia models incorporate several compartments (eg water, aquatic biota, sediment, suspended solids, soil and air) and are utilised in situations where chemicals are known to be released into several compartments simultaneously, or when a chemical is thought or known to move between several compartments, and those compartments are of interest to the risk assessment. As they are more complex than the models described previously, more information is required. Information on the chemical includes molecular weight, solubility, LogK_{ow}, vapour pressure, and its biodegradability, while half lives in the various compartments is also useful, but not a necessity.

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Community involvement in wetland management: Lower Mary River Landcare Group

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Clair O'Brien was President of the Lower Mary River Landcare Group from early 1994 until mid-1999, and coordinator of the Group since 1996. Her family own and operate 'Carmor Plains', a Brahman stud property on coastal wetlands between the Wildman River and Mary River in the Northern Territory.[*]

1 Introduction

I've been in the Northern Territory for four years and I have a background in primary production. Our livelihood depends on the land and what we do with it.

We came here to the NT after we had several properties in Queensland. I was born and bred on cane farms, then moved onto cattle properties after I was married. We had 10 years of drought in Queensland before we moved over here. Everyone said 'Why did you move?' We'd spent 30 years building the property up from nothing, right up to the point where my husband said there was nothing left to do but build me a house so we'd better go!

As a family, coming out of 10 years of drought in Queensland, we've now been through the process of a Property Business Plan. Our Mission Statement is 'We want quality cattle, depth of purity, and quality country'. We'd put our Queensland property on the market in 1990 in order to come to Katherine, but no one made a bid. Later when we saw Carmor Plains and wanted it, we got a buyer almost immediately. We still had grass on our Queensland property after 10 years of drought.

So we moved 2500 head of stud Brahman cattle and a family of three generations to the Northern Territory, which was quite a move. When we started at Carmor Plains we were thrown in the deep end, as working on and with the wetlands was a new experience. The Wet is our drought, our worst time of year. Carmor Plains has 100 000 acres (41 000 ha), 60 000 acres of which is floodplain adjacent to the Mary River catchment area (fig 1). We share a boundary with Kakadu National Park and the Wildman River. We are fortunate to have very little *Mimosa pigra* weed on Carmor Plains, but it's a constant job to monitor Mimosa and make sure it doesn't become a monoculture.

With the wetlands, we're learning all the time. In the 4 years we've been at Carmor, we've really noticed how the country is coming back. We've lightly stocked the property and the improvement has been phenomenal. As 60 000 acres are under water for 3–4 months a year, we can't have cattle out there, so we leave them on the high country. When they do go back out on the floodplains, it's prime feed. So we're really only using half of the property and I guess that's where we're fortunate with an equal break-up of the country.

[*] Adapted from transcript, July 1997

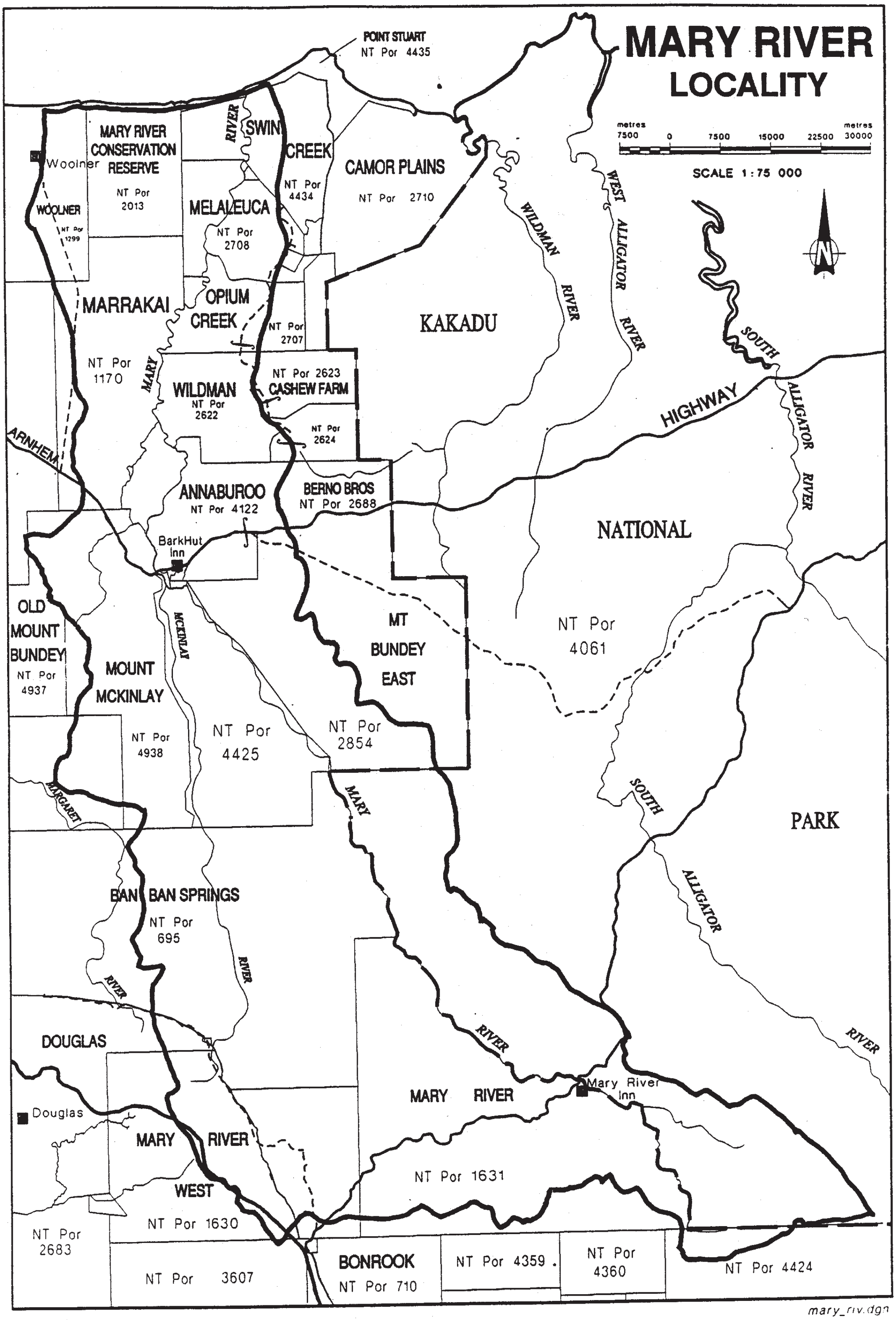


Figure 1 Mary River locality

Some of the other Mary River catchment properties don't have the ability to hold cattle on their high country. Some properties only heavily stock during the Dry, then sell for the export market.

We were also surprised to find out about the proposed Mary River National Park when we came here. All the documents said 'the Park' but 'the Park' included all the privately owned areas around. We had just bought into it. We said 'we're not the Park!' and started finding out more about it.

2 Lower Mary River Landcare Group

While trying to find out what was really going on, I became involved in the Lower Mary River Landcare Group (LMRLG) and took over its presidency. My involvement has grown and grown since. Trying to find out what government departments are doing is quite difficult at times from a layperson's point of view. Having the time to do it is also a problem. We only manage it because of our family structure on the property. My husband, his bachelor brother, our eldest son and our youngest daughter live at home, and Carmor Plains is a totally family-run operation. The Landcare Group got us involved in the community.

The LMRLG brings the whole community in that area together to address land management issues. 99% of the landowners of the area are members of our Group, apart from a few members in the upper catchment who are waiting to come on board. The diversity of members in the Mary River catchment area is quite unique. There are graziers of buffalo and cattle, tourist operators (eg boat tour operators and wilderness lodges), gold and sand mining companies. The area also includes the Wildman Ranger station which manages ten reserves they hope eventually to amalgamate into the proposed Mary River National Park. There is a cashew farm with a proposed horticultural area and the Mount Bundey Defence training area. It's a very diverse group, and to have them all in one room talking about Landcare and management ethics is an experience! It certainly leads to an appreciation of other people's perspectives and you learn to make compromises. Landcare has made people in our area much more aware of their actions. They still might go ahead and do something, but they begin to think about its effects on other people.

Members currently pay an annual fee each year. To be a full member of the Landcare Group you must own land or a concession in the area. Full members have full voting rights and hold positions on the committee. Associate members are just interested people, able to have their say but without a vote. The Group's constitution ensures that landholders will run the committee.

There hasn't been a lot of Aboriginal involvement in the LMRLG to date, as there are very few Aboriginal people living in the catchment. However, now the Group has expanded to include the entire catchment, Jawoyn land owners may be involved. The rangers based at South Alligator in Kakadu National Park have always been associate members of the LMRLG, and may come on as full members now that the LMRLG area has been extended to include the total Mary River catchment.

3 Funding for the Group

The funding that our Landcare Group receives is very minor and includes membership fees and landholder contributions. As part of landholders' own land management they do saltwater intrusion works, wildfire and erosion controls on an ongoing basis, putting money into it all the time. Other groups like the Centralian Land Management Association get a lot of funding eg to employ people for rabbit control. Our own area consists of individual landholders doing individual property management. Their yearly budget for Landcare works would include:

- $20 000 (very conservative figure) for salt water intrusion
- $50 000 for wildfire control
- $15 000 for erosion works
- $10 000 for feral animals control
- $20 000 for conservation
- $40 000 for water quality monitoring
- $250 000 for weed control, with government subsidies for aerial control and poisons on big infestations of *Mimosa pigra*.

These are the baseline figures for landholder contributions to funding, based on an average of 10 properties.

The only government funding the Group receives is for the coordinator, to produce the newsletter and keep abreast of what's going on. The coordinator position is important because it helps keep everyone informed. There have been suggestions that landholders and other users of the Mary River area, including tourists, could be charged a levy to contribute to the LMRLG coordinator costs, allowing the group to do even more while not just relying upon government funding.

4 Group coordinator

For the past 12 months I have been a paid Landcare coordinator for the LMRLG, which has made life more hectic but a little easier financially. I've kept on doing the work I was doing but I'm getting paid for it and have a vehicle to use. I produce a newsletter every 2 months for the group with the assistance of my family at home. The newsletter has got better and better! We've come a long way since the first edition, with a broader scope of articles.

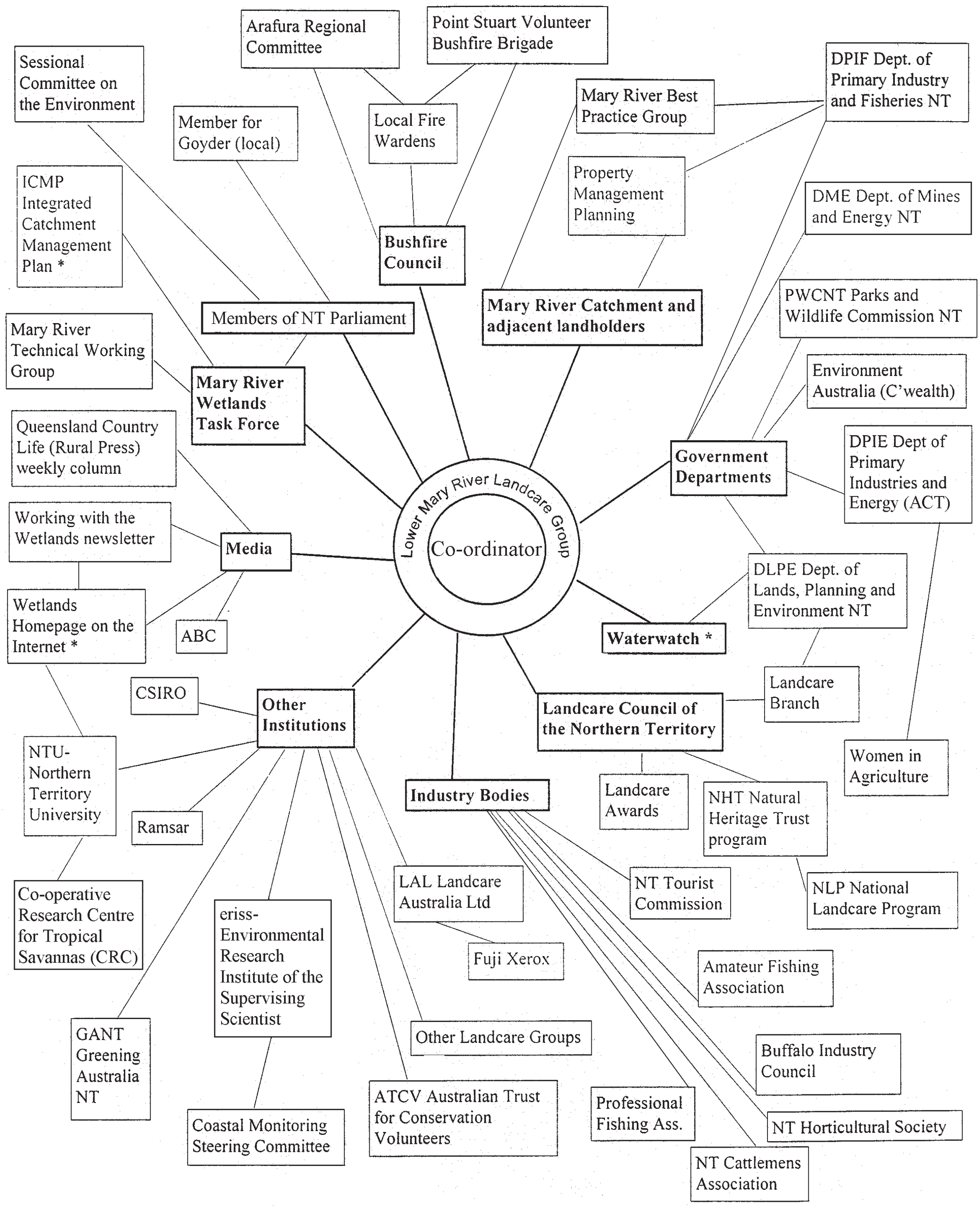
As coordinator, I also set up a communication network. The coordinator is the centre point, surrounded by Landcare members, then an inner circle of institutions and government/businesses eg the media, NT Bushfires Council, Parks Australia North and ***eriss*** (fig 2). I have a contact name and number for them all. It is quite involved but it's all about keeping the Landcare Group informed. We hope funding for the Landcare coordinator position will continue next year.

5 Coordinating major issues

There is a coordinated approach within the Landcare Group to major issues. For example, the Group has agreed to clearing guidelines and accepted them. We don't then go around reinforcing those guidelines, we just hope the landholders follow them. We find that in a lot of cases they do. They take on those issues, weigh them up and then you find that they may still go ahead, but they have probably made a compromise somewhere.

The issues that united the Group when it began in 1989 were saltwater intrusion, land degradation (including *Mimosa pigra* and other woody weeds), feral animals, wildfire and the value of natural flora and fauna resources. These issues become very complex at times with such a diverse group, but we work through them. The Landcare meetings are a forum through which you can just thrash those issues out.

Communication Network Plan for the Co-ordinator of the Lower Mary River Landcare Group



*In process but yet to be implemented.

Figure 2 Communication Network Plan for the Coordinator of the Lower Mary River Landcare Group

At one meeting we had, the Parks and Wildlife Commission of the Northern Territory had written to the LMRLG asking us to comment upon a recent proposal by two boat operators who were also LMRLG members. The members currently operate two 25 passenger capacity boats at the Rockhole on the Mary River. One of them proposed to use a larger boat, carrying 50 passengers. The second operator had offered to take the smaller boat, which would result in two small boats operating in one area while the big boat went somewhere else because it couldn't access places the smaller boats could. It actually took pressure off the areas visited, with the added advantage that tourists didn't see other boats nearby, thereby helping to keep the Mary as a more 'isolated' experience.

When we talked about it as a Landcare Group, we said that we didn't want to be the ones to make a decision on that, but we wanted assurance that no bank erosion would result from the larger boat's wake or damage to the bank by people's feet. We used this issue as a lever, saying that we hoped this sort of issue would be dealt with through a management committee for the proposed Mary River National Park, which would include a LMRLG representative.

As the Mary River is so close to Darwin we got a lot of pressure from government departments, with government officers coming out to have a look around, telling us this version or that version and then going away. We got many conflicting reports from the Department of Primary Industry and Fisheries, conservationists and others. The graziers are lay people; they don't know who to believe. Their lease documents say they're allowed to graze cows, so why are they told they should run their property like a national park? It is conflicting, putting members in quite a quandary.

So the LMRLG said there should be a coordinated approach, and the Minister set up the Mary River Technical Working Group to coordinate all the government bodies that come out to work in the Mary River area. The big wetlands conference that met in Darwin in 1995 resulted in the formation of a Wetlands Taskforce which is supplied information by the Technical Working Group. The Wetlands Taskforce has been developing the first integrated catchment management plan for the NT (1998). I am the LMRLG representative on the Taskforce, along with others representing the amateur fishermen, the tourism industry and the graziers. An independent chairman is flown up from Victoria for every meeting. We've worked on the plan for 18 months now, overcoming little problems along the way. At grassroots level we want the integrated catchment management plan to be a working document and not gathering dust on shelves. The plan has received ministerial approval and initial implementation steps are underway.

6 Involving landholders in research

Funding agencies are placing more emphasis on communication between the researcher and landholders. Researchers should involve local landholders in the development of the program, the research and the outcomes. As a landholder, my advice is that you talk to us!

I sit on a lot of research assessment panels and we go through the documents and they say they've consulted with the LMRLG and yet we've never seen them!

A good way to contact landholders in the Mary River area is to contact the LMRLG first. We welcome people to visit, with prior consent, because we don't know what we've got or what you're looking for. We are lay people and know things from the practical level, but from the research, technical or scientific side we don't know how to mesh in with you.

However, we do live out there and see things that could be researched, so we can offer ideas for research priorities. For example, at Carmor Plains we don't burn the vegetation. Visitors can see the difference along our boundary with Kakadu National Park, which is burnt annually. There is a marked difference and it should be researched. We want to show the world that we can run an ecologically sustainable property, with people and cattle, yet maintaining the biodiversity of animals and birdlife. How do we document that, to justify what we are doing? We think there should be something done but we'd need some help on how to start.

Another issue is the planting of introduced grasses as improved pasture species. There's been a lot of talk about growing para grass eg taking out Mimosa by chaining and then planting para grass in its place. Although this is not common practice, it is happening because there's no alternative. Para grass chokes out the young Mimosa coming back up, giving the desired result with less chemicals and expense. This way the landholder can generate income from previously unproductive land, recovering that dollar that they're spending in weed control. To do control works to make the country viable, you must get the dollar out of those animals and improved pasture is the way to do it. The best option from an environmental perspective would be to plant native grass species instead of para grass, but seed is difficult to get and has very low germination. Marrakai Station are harvesting native grasses, but viability and quantity of seed is still a problem. More research is needed.

I appreciate the opportunity to be involved in this course. As landholders within the LMRLG we are there at all times to be contacted, and we hope to be of further assistance to researchers. We look forward to strengthening communication links with regular sessions like this one.

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Community involvement in the management of our waterways: NT Waterwatch

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Abstract

State and federal governments in Australia have recognised the need to involve the community in management of waterways, as it helps to build community awareness of water quality issues, and fosters a sense of 'ownership' of local waterways and catchment management initiatives. Waterwatch is an Australia-wide, community-based program that fosters cooperation between government agencies and communities. Volunteers carry out water quality monitoring and other on-ground activities in their local catchment, assisted by coordinators. In the Northern Territory, Waterwatch activities are coordinated by the NT Waterwatch facilitator. Volunteers from both urban and remote areas enthusiastically participate in water quality monitoring, while taking into consideration special factors arising from the remoteness and tropical climate of much of the Northern Territory.

1 Introduction

Waterwatch is an Australia-wide program that involves volunteer water quality monitoring and on ground activities that focus on the ecological sustainable management of our waterways. An important component of Waterwatch is facilitating communication between waterway stakeholders (government departments, researchers and landholders) to address issues of water resource management. In particular, Waterwatch recognises that the community is a vital contributor to waterway management and, by providing the necessary training and management tools, makes this possible. Even ten years ago, much of this communication and information exchange did not occur. If it did, it was often in the form of government directives to the community, with community consultation and involvement at a minimum. This is where community-based catchment management programs like Waterwatch and Landcare have made an important contribution to integrated catchment management. In many instances, the Waterwatch program has helped to bridge this communication gap between the community groups and scientists. Through community-based water quality monitoring activities, Waterwatch has leveled the water resource management 'playing field' by giving the community the tools to access and contribute to waterway management decision making.

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[*] Adapted from transcript, July 1997

2 Waterwatch: A national network

Waterwatch is a national volunteer monitoring and environmental education program aimed at raising awareness of water quality issues and involving the community in action for healthy, sustainable waterways. The Waterwatch program was announced in 1992 as an Australian Federal Government initiative in response to a growing number of community groups requesting involvement in assessing and managing water quality issues in their local creeks, rivers and wetlands. Interestingly, the announcement coincided with a range of federal and state government initiatives which heralded the recognition by government bureaucrats that ecological sustainability could only be achieved through raised community awareness and involvement in natural resource management decision making (Phillips 1997).

Today, the Waterwatch program is a network of more than 50 000 people, regularly monitoring close to 4000 sites around Australia. For those involved in Waterwatch, the value of the network is that it operates as a conduit for information exchange, sharing of resources and allows for the development of a consistent approach. However, there are still many bureaucrats and academics who have a tokenistic approach to community involvement in natural resource management, or who see it as a threat rather than an opportunity. These people soon discover that trying to undermine the work of a Waterwatch group, which is part of such a strong national network, is not worth their while. They only need to read the range of contributions made to water resource management by the 'Waterwatchers' featured as case studies in Waterwatch Australia's *Snapshot 97* publication (Waterwatch Australia 1997) to realise that this national program has the 'runs on the board'.

A number of facilitators and coordinators are in place to maintain the strength of the network and provide necessary support to enable community groups to be involved in Waterwatch. The National Waterwatch Facilitator, a position based with Environment Australia, provides the national administrative direction for the Waterwatch network. Through a partnership agreement with the federal government, each state/territory water resource authority implements a Waterwatch program. The state/territory facilitators meet twice a year as the Waterwatch Australia Steering Committee to address issues associated with implementing the Waterwatch Australia Strategic Plan. Each state/territory Waterwatch Facilitator has a steering committee of community and government representatives to oversee the development of their strategic plan. In the Northern Territory, the NT Waterwatch Facilitator is employed by the Natural Resources Division of the Department of Lands, Planning and the Environment (DLPE). Operating funding for facilitating the implementation of the Northern Territory program has been provided to date by the federal government under Natural Heritage Trust (NHT) funding. (Since this time (1997), the Northern Territory government has also provided operational funding to the NT Waterwatch program.)

The Regional or Catchment Coordinator plays a vital support role for the Waterwatch groups who monitor waterways and conduct awareness activities for healthy waterways. These coordinators are people from the local community who are funded through the NHT initiative to coordinate Waterwatch in their local catchment area or region. Training for the Coordinators – in the aims of Waterwatch, water quality monitoring, data management and group coordination – is arranged by their state/territory facilitator. In the Northern Territory, NHT funding for these coordinators is hosted by non-government organisations such as Greening Australia, Keep Australia Beautiful Council, the Arid Lands Environment Centre and Dhimurru Land Management Corporation.

Interested community groups are inducted into the Waterwatch network and are provided with necessary support. Waterwatch participants and coordinators can exchange catchment information and share water monitoring experiences across catchments and even across state/territory boundaries (*Bush* articles January 1997; Waterwatch Australia 1997). Moreover, the Coordinators assist groups to liaise with the relevant government authorities and catchment stakeholders. Through these contacts, groups can gather catchment information to build a picture of the health of their catchment and to contribute their waterway data to natural resource management decision-making forums.

Although the Waterwatch Australia network is designed to service national needs, it does have global partnership links to similar initiatives such as the Globe program and the United States Riverwatch network. Last year, the Malaysian government liaised with the National Waterwatch Facilitator to adopt the Waterwatch Australia model for their country. The Malaysian Waterwatch program will have an emphasis on groundwater monitoring and will draw on the techniques used by South Australia Waterwatch.

3 Community involvement

3.1 Local monitoring and data management

Although Waterwatch Australia operates under a national Strategic Plan and complementary State/Territory Strategic Plans, there is scope within the national framework for Waterwatch groups to evolve within the network to meet their own needs and interests. Waterwatch Coordinators and Facilitators tailor Waterwatch to meet community needs rather than dictate a set of hard and fast rules for every participant. If, for example, a group decides that their involvement is in collecting data to produce a water quality report for the local catchment committee, then the level of confidence in the data collected would need to be high. In formulating such a monitoring program, the coordinator would advise on a rigorous monitoring program and arrange the necessary training. This would incorporate regular sampling, strategic site selection, quality assurance/control and reliable monitoring equipment. At the other end of the Waterwatch participation spectrum, a group (eg school class) may only be interested in monitoring a site with more of a focus on providing students with an understanding of monitoring equipment or an aquatic biology lesson.

Through an equipment sub-committee of the Waterwatch Australia Steering committee, a ‘clearing house’ has been established to review water quality equipment that comes onto the market. New equipment is checked for its suitability for community use by assessing characteristics such as cost effectiveness and ease of use (including calibration, time and field use). As an example of the equipment used, NT Waterwatch groups generally use a test kit for dissolved oxygen measurement that takes just 10 minutes for a volunteer to add three tablets and to do a small titration to get a mg/L measurement. Such kits are easy for community groups to use and produce reliable results. To enlist local support for Waterwatch, community groups are encouraged to seek local sponsorship to purchase their kits.

Another piece of practical Waterwatch equipment is the turbidity tube. This perspex tube with turbidity levels etched into the side requires groups to collect a water sample and put it into the tube until the white backed Waterwatch logo at the bottom of the tube can no longer be seen. By reading off the water level against the scale, Waterwatchers can record the turbidity level, using a piece of equipment that costs just $50. Besides dissolved oxygen and turbidity, groups can test for a range of biological and chemical parameters. These include pH, temperature, salinity, dissolved solids, phosphates, nitrates and faecal coliforms. Waterwatch groups also assess the health of their waterway by sampling macroinvertebrates and monitoring riparian and instream vegetation. The NT Waterwatch *Guide to* *macroinvertebrates*, produced in consultation with the scientists from the national Monitoring River Health program, allows groups to record a measure of water quality from the number and variety of macroinvertebrates found (NT Waterwatch n.d.).

Any meaningful data collection project needs to have a means of managing the data from storage to data manipulation to reporting. To assist Waterwatch groups with this, Waterwatch Australia launched a national Waterwatch database in 1997. All Regional and Catchment Waterwatch coordinators participated in a 1 day training course to equip them with the skills to coordinate data management in their area of operation. This data management tool allows groups to develop graphs and produce short reports about their data. The stand-alone Waterwatch Data Entry program allows the groups to store their data with the option of uploading it into the Database for catchment reporting.

3.2 Waterwatch events

In addition to the monitoring described above, Waterwatch Australia encourages groups to be involved in a range of international (World Wetlands Day, World Environment Day), national (Water Week) and community events to communicate information about their activities. This helps to increase local community awareness of waterway management issues and exposes Waterwatch to the broader community. In national Water Week, the Waterwatch network coordinates a national Snapshot of water quality. This involves a national macroinvertebrate or turbidity sampling event. In 1997, over 50 000 people participated and, with the considerable media coverage, celebrated community involvement in waterway management. Other groups, such as those in Darwin, organise and participate in an annual Waterwatch community drain stencilling event to label drains with a message ‘This drains to our creek’.

4 NT Waterwatch: From facilitator to community action

Waterwatch has been underway in the Northern Territory since 1994. As discussed above, the NT Waterwatch Facilitator is based in Darwin in the Natural Resources Division of DLPE. In 1996, the Facilitator, together with a Water Advisory Committee, produced the document *Strategic Plan for NT Waterwatch for 1997–2000* (DLPE & WAC 1996). The Plan identifies some of the challenges faced by NT Waterwatch and lists objectives for the program which will be reported each financial year. In 1997, the Minister for Lands, Planning and the Environment appointed the NT Waterwatch Steering Committee which has statutory reporting obligations under the NT Water Act. This committee consists of natural resource management and community representatives and will provide an advisory role to the NT Waterwatch Facilitator.

With the indigenous demographics of the NT, it is important that Waterwatch as a community involvement program be accessible for the natural resource management issues of indigenous communities. Use of ‘traditional ecological knowledge’ in monitoring the health of waterways is an avenue that needs further Waterwatch attention. For guidance on meeting indigenous communities needs, the NT Waterwatch Steering Committee has a representative from the Northern Land Council and the Central Land Council.

Due to program resource limitations, the NT Waterwatch participants have been utilising Queensland’s Waterwatch manual to date. In 1998, the Waterwatch Australia Steering Committee will release a shell for a national Waterwatch manual that will build on existing state Waterwatch manuals and will be designed to include state/territory supplements about the water resources, surface water and groundwater. For example, in the Top End of the NT, the water temperatures are usually 30–35°C with some natural hot springs reaching 40°C.

These levels are not represented in the Waterwatch manuals to date and will need to be included in the national manual, as they will service the needs of the Wet-Dry tropics as well as groups in Australia sampling in areas experiencing thermal pollution. Also NT Waterwatch, through the appointment of a Coordinator for Alice Springs, will have the opportunity to adapt South Australian groundwater Watertablewatch for use in the NT.

In the NT, Regional Waterwatch Coordinators currently provide support to groups monitoring 55 sites in:

- Darwin
- Litchfield Shire
- North East Arnhem Land
- Alice Springs
- Katherine
- Mary River

4.1 Darwin Waterwatch

In Darwin for example, groups have been monitoring 16 sites along Rapid Creek, which is 9.5 km in length and flows through Darwin city. The 16 sites are monitored monthly by a range of adult Landcare and school groups and the data entered into the Waterwatch Australia Database. In 1998, the Regional Coordinator intends to produce a water quality report, which will be provided in draft form to the DLPE water quality scientists for technical comment prior to final release.

Waterwatchers are encouraged to take local action should they find an issue. In Darwin for example, pollution spills have been reported as a result of monitoring by Waterwatch volunteers. For one spill, the Darwin regional coordinator was sampling in a creek, noticed high nitrate levels and a sewage smell and reported it to the NT government's pollution response line. Further investigations by authorities found that the source of the sewage pollution was a failing sewage pump. Similarly, spills have been reported in the Duke Street waterway in Darwin where there are numerous car yards in the catchment. This site is being monitored by Waterwatchers and a photographic record being kept of the oil and rubbish. The Waterwatchers hope to put pressure on the local government authorities to take legislative action against the offenders to help clean the area up.

4.2 Nhulunbuy Waterwatch

In Nhulunbuy, the Regional Coordinator has had the task of developing a local Waterwatch program in partnership with Nabalco mine, the local Aboriginal people (Yolngu) and other residents. The Coordinator has received considerable sponsorship from Nabalco mine that has enabled her to purchase a Horiba multi-probe monitoring kit that she regularly calibrates. The Nabalco laboratory staff and DLPE water quality scientists have provided training in calibration procedures. In recognition of the importance of embracing the local Yolngu people, the Coordinator asked for a Yolngu name for their Waterwatch group. They have been given the name Gapuwu Mel'ngu Mala which translates to 'Water for Surveillance People'. Raymattja, a leading Aboriginal woman, has put an indigenous perspective on the value of caring for the riparian vegetation around the local lagoon by conducting bush tucker walks with local school children.

With assistance from Department of Primary Industries Weeds Education Officer, the Coordinator has implemented an education program to train local people in identifying and reporting the aquatic weed *Salvinia molesta*. In addition, the Coordinator is working with the Yirrkala school to develop a local Waterwatch logo that features a Yolngu drawing of a water monitor in a traditional Aboriginal artwork design. For the Gapuwu Mel'ngu Mala group, monitoring takes on an additional safety concern not experienced by our southern colleagues. This hazard is crocodiles and is a major hindrance to regular sampling. As a safety precaution, the local Parks and Wildlife staff are invited to talk to Waterwatch groups about crocodile awareness and safety techniques. The Nhulunbuy coordinator has also written a crocodile safety pamphlet for the Waterwatchers.

4.3 Litchfield Waterwatch

In the Litchfield Shire, the Coordinator has focused on raising awareness about wetland issues associated with the many lagoons in the Shire. Landcare field days have included macroinvertebrate and habitat monitoring to raise awareness about the unique wetland habitats the rural residents have in their backyards. The Litchfield Waterwatch Coordinator and the DLPE Landcare officer have cooperated to produce community newsletters that raise awareness of local lagoon land and water management issues. With the data results having revealed no problems with the water quality in the Litchfield Shire, the emphasis is on a preventative approach.

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Community wetland management: The Northern Land Council's Top End Indigenous People's Wetlands Program

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Abstract

Aboriginal people own 85% of the Northern Territory coastline and many of the vast and important sub-coastal wetlands. The Northern Land Council-facilitated *Top End Indigenous People's Wetlands Program* (TEIPWP) was conceived to assist Aboriginal land owners prepare management plans for some of these wetlands. Land owners have control over the pace and process of the program in their areas. The TEIPWP is developing into a good example of cooperation between individuals and agencies.

This paper describes the TEIPWP and, in particular, work undertaken in two major wetland sites, the Blyth-Liverpool system near Maningrida and the Arafura Swamp in central Arnhem Land.

1 Introduction

The Northern Land Council (NLC) is a statutory body set up under the *Aboriginal Land Rights (Northern Territory) Act* (1976). The NLC has a legal obligation to consult with land owners and to help them manage their land. To achieve this the NLC has set up a small group called the Caring for Country Unit. Caring for Country is concerned with helping Aboriginal people manage their country – and this is everything, sandstone, savannas, wetlands and seas – and to foster developmental enterprises (Taylor 1995). To achieve this, both Aboriginal (or traditional ecological) knowledge and non-Aboriginal (or contemporary/ scientific) knowledge is used.

Aboriginal people have capably managed their land for thousands of years and there would be no great need for external advice or assistance if it were not for new pressures and faster rates of changes. These are pressures from unfamiliar sources, such as weeds and feral animals, infrastructure development and also Aboriginal people's desire to pursue economic independence. Traditional Aboriginal management practices often do not effectively address these issues – bridging the divide between traditional practices and contemporary problems is where the Caring for Country Unit can be of assistance.

Aboriginal people own 85% of the 'Top End' coastline and therefore most of the vast and important sub-coastal wetlands in the Northern Territory (NT). Top End wetlands are in a relatively pristine condition (Storrs & Finlayson 1997). They are recognised as having high national and international conservation value (Whitehead et al 1990) and are also recognised for their cultural significance because of a long and unbroken tradition of indigenous management. However, wetlands in the NT are under threat from various sources such as introduced species, both animal and plant (Storrs et al 1996), changed fire regimes and possible overuse of resources due to commercial harvesting activities (Storrs & Finlayson

1997). Such threats have significance for Aboriginal people because they can cause damage to food resources or sacred places.

2 The Top End Indigenous People's Wetlands Program

The NLC-facilitated *Top End Indigenous People's Wetlands Program* (TEIPWP) was conceived to assist Aboriginal people prepare management plans for their wetlands. The TEIPWP employs a Wetlands Officer who operates within the NLC Caring for Country Unit. The strategy adopted is 'total catchment management' coordinated amongst the NLC regions. At the local level Aboriginal land owners have control of, and participate in, the planning process and implementation of wetlands management. Ten important wetlands have been initially identified for the program:

1. The Arafura Swamp
2. Blyth-Liverpool Floodplains and Boucaut Bay System
3. Daly-Reynolds Floodplains-Estuary System
4. Moyle Floodplain and Hyland Bay System
5. Murganella-Cooper Floodplain System
6. Arnhem Bay System
7. Blue Mud Bay System
8. East Alligator River Middle Reaches
9. Fitzmaurice River Middle Reaches
10. Little Moyle Floodplain

More recently it has been suggested that Gulf of Carpentaria, Joseph Bonaparte Gulf and the wetlands of the Barkly Tablelands be added.

2.1 Program aims

The major aims of the program are to undertake a technical review of the major wetlands, determine what information is documented and identify gaps. Then, through consultation with traditional owners, identify what things are important (eg mimosa control) and what land owners need for 'wise' management. This information will be used to help Aboriginal communities develop and implement wetland management plans. It is envisaged that wetland management planning for 'one or two sites' will be undertaken during the initial phases of the TEIPWP.

2.2 Funding the program

The three year program, which was instituted in early 1996, is funded by Environment Australia through its National Wetlands Program. The funding is limited, covering the Wetlands Officer's wage. It does not contain money for consultation, management planning or implementation. Therefore a large part of the Wetlands Officer's job is to obtain resources and research assistance where available. Despite this limitation the program seems to be developing into a good example of how cooperation between individuals and agencies can be used to benefit Aboriginal communities who are interested in land management.

2.3 Technical Advisory Committee

A Technical Advisory Committee (TAC) was set up under an informal agreement between a number of organisations not only to provide technical advice, but also to increase access to government resources and services, expedite efficient and effective allocation of technical assistance, avoid duplication of research and increase funding opportunities. The TAC includes: Professor Marcia Langton, Director, NTU Centre for Indigenous Natural and Cultural Resource Management (CINCRM); Professor Greg Hill, Director, NTU Centre for Tropical Wetland Management (CTWM); Dr Max Finlayson, Principal Research Scientist, Wetland Ecology and Conservation Program, ***eriss***; Peter Whitehead, Principal Wildlife Research Officer, Wildlife Research, Parks and Wildlife Commission NT (PWCNT) in 1997 (eds: now Director, Key Centre for Tropical Wildlife Management – An ARC Key Centre for Teaching and Research, NTU), Rod Applegate, Director, Land Resources Branch, NT Department of Lands, Planning and Environment (DLPE); Dean Yibarbuk, Chairman, Bawinanga Aboriginal Corporation (BAC); Piers Barrow, Senior Project Officer, Natural Resource Management, Kakadu National Park; and Tom Scotney, Project Officer, National Wetlands Program, Environment Australia.

3 The importance of wetlands

Wetlands are important in that they provide a home for plants and animals (ie they support abundance and diversity), they filter pollution, they provide clean water for domestic, industrial and agricultural use and they can be used for recreation. But most importantly, in the context of this paper, wetlands support indigenous cultures in many places around the world, providing food and other resources and a traditional way of life for the people.

Research in the Kakadu area has shown that wetlands are the focus of resource utilisation by Aboriginal people (Russell-Smith et al 1997). Until quite recently Aboriginal people experienced their leanest times when wetlands were inaccessible during the Wet season. Latterly wetlands are also providing opportunities for sustainable economic development. Economic independence, self-determination and self-government are major aspirations of Aboriginal people today.

From a worldwide perspective wetlands, especially coastal wetlands, are being destroyed through development. With the loss of wetlands traditional ways of life are being lost. An international effort is required to save the remaining wetlands, and Australia is playing an important role in this. Australia has signed a number of international conventions, some states and territories have wetland policies, and through Environment Australia there is support for various programs such as the TEIPWP that promote the wise use of wetlands.

4 Wetland management planning

One of the primary tasks of the TEIPWP is to undertake an issues and needs analysis for the major wetlands on Aboriginal lands. This has broadly been addressed in a document entitled *Overview of the conservation status of wetlands of the Northern Territory* (Storrs & Finlayson 1997). Further to this the PWCNT have received a $25 000 grant from Environment Australia to develop a wetland Geographic Information System (GIS) database by collating all their inventory information on wetlands. Part of the contract agreement provides NLC with access to the databases. Remotely sensed imagery of a number of sites has been obtained by the NLC and provided to the NTU, La Trobe University and the Australian Geological Survey Organisation, all of whom are currently enhancing the data.

The TEIPWP is invited into an area by land owners, who thereby remain in control of the process. Community conservation ranger programs have been initiated at a number of sites collaboratively by communities and the Caring for Country Unit. Caring for Country Unit staff talk to the rangers about what needs to be done, who can do it, where and when to do it, and who can help. The process is then issue driven. Projects are developed for each issue and rangers assigned to projects. The challenge is to foster the use of indigenous knowledge while delivering non-indigenous management training to the rangers so they have access to both knowledge bases. The expectation is that when research is done it is a two-way learning process involving Aboriginal people.

Indigenous projects include the use of fire as a hunting tool or for managing the vegetation, protection of sacred sites, mapping of cultural boundaries, hunting and collecting of food etc. Non-indigenous projects include such things as mapping of wetlands, establishing GIS databases, animal and plant surveys, control of introduced species, and research into the commercial harvest of wildlife (a topic in which Aboriginal people are very interested). All these projects can be brought together under a management plan.

The drafting of a management plan is about establishing what people want to use the wetlands for, what work needs to be done (projects) and how people go about getting the work done. It is about planning for the future as, without effective planning, it is hard to achieve goals. As with other communities, Aboriginal people within a community have different aspirations for their wetlands, which can cause conflict. The planning process can help to clarify different priorities and in some situations offer satisfactory compromises.

4.1 Blyth/Liverpool River systems

For its first year of operation, the TEIPWP focussed on the wetlands of the Blyth/Liverpool River systems in Central Arnhem Land – an area in which the Bawinanga Aboriginal Corporation (BAC) operates near Maningrida. This area was chosen because of the excellent administrative infrastructure of the BAC and the fact that some land management planning had already occurred. The latter was associated with the formation of a community ranger program (the Djelk Community Rangers) under a previous Caring for Country training program. Through the TEIPWP government help has been organised, requests for government funding for specific projects have been made, and the community is being helped to draft a management plan for the wetlands.

Djelk Rangers are now receiving more advanced training through participation in the NTU's Certificate IV in Resource Management and a broader world view is being offered through participation in conferences and workshops. In 1997 they also undertook coxswains and small boat handling training. In September 1997 the PWCNT conducted a 10 day ranger training camp. This involved senior research staff and park rangers working alongside the Djelk Rangers and other Aboriginal community rangers to undertake vegetation and fauna surveys.

The Djelk Rangers are involved in projects to follow up treatment of *Mimosa pigra* (mimosa) infestations near Maningrida in collaboration with the DPIF Weeds Branch (the early intervention of this incursion was brought about through education, training and resourcing). The management of feral animals, particularly pigs, which are causing damage to sites of both natural and cultural significance is being furthered in collaboration with the PWCNT who are seeking research funds.

eriss has been undertaking a wetland inventory, including plant, macroinvertebrate and fish surveys. These surveys are undertaken collaboratively with Djelk Rangers and some rangers have visited ***eriss*** in Jabiru to take part in field and laboratory studies. The BAC are setting up a GIS for biological and cultural purposes with assistance from the NTU, while erosion control works are being undertaken by the DLPE.

A crocodile egg harvesting and incubation program facilitated by Wildlife Management International Pty Ltd (WMI) was successful over the 1996/97 Wet season and was very well supported by the Djelk Rangers. It is envisaged that the program will be completely controlled by the Djelk Rangers in the 1997/98 Wet season.

The BAC in collaboration with Wildlife International Pty Ltd had planned a trial harvest of 100 saltwater crocodiles in 1997 for the skin trade and for subsistence consumption of meat, the first such harvest in 20 years. After an initial harvest of six adult crocodiles in September the program has been put on hold following objections to the harvest by members of a clan for whom the saltwater crocodile is a principal totem. It is difficult to forecast an early resolution of the issue of adult harvest, however the totemically affiliated group have not taken a negative stand on egg harvesting or incubation.

Plans by the BAC to take a lead role in the revitalisation of the trepang industry are less well advanced. Since the large-scale trepang industry involving Aborigines and Macassans ended early this century there has been only desultory activity despite the fact that Australia probably holds a large portion of the global trepang resource. With funding from a variety of sources, the BAC have attracted interest in studies to determine core areas of abundance, variability and preferred habitat characteristics. In areas of known occurrence, the research will model biomass dynamics and measure the effects of harvest on selected sites (Carter & Yibarbuk 1996).

Research arrangements within all projects emphasise local benefit from collaboration and involve the community rangers and equipment as essential parts of the research teams. Research planning is carried out collaboratively and the community receives ongoing reports of research results.

The BAC has built a ranger station, which incorporates a field laboratory, about 20 km out of Maningrida. This will allow more technical aspects of collaborative research to be carried out on Aboriginal land and give rangers the opportunity to observe and participate in scientific studies and surveys. The vision of the Djelk Community Ranger program includes construction of a more extensive training and research centre to focus on further development of collaborative research aimed both at maintaining the near-pristine natural biota and in developing sustainable uses of wildlife. This has a dual aim of conserving biodiversity through sustainable use and creating a future economic base for the Aboriginal community.

Staff from ***eriss*** have been collating available information from the Blyth-Liverpool systems into a document (Thurtell et al 1999) that will form the technical basis of the management plan (which will then be developed through participatory planning with the community).

4.2 Arafura Swamp

Now that management planning in the Blyth-Liverpool systems is underway, the TEIPWP's focus of attention has shifted to the Arafura Swamp. The Arafura was chosen because of its proximity to the Blyth-Liverpool wetlands (ie it is the next catchment to the east) and, being on the Interim Register of the National Estate, it was hoped that management funds for conservation initiatives could be attracted. The Arafura is Australia's largest tropical freshwater swamp.

The TEIPWP is setting up a land management board made up of representative land owners for the Swamp and its surrounds. There are land management issues in the Swamp which need to be addressed urgently, for instance there have been 11 incursions of the rampant weed mimosa since the early 1990s. As well, there appears to be a lot of interest from funding agencies and researchers who want to involve themselves in the area. The challenge is to facilitate this outside interest and resources while addressing the land management issues but, most importantly, ensuring that the land owners are kept in charge of the process. It can be a delicate balancing act!

A number of meetings have been held in Ramingining with members of the Interim Arafura Swamp Land Management Board and other land owners about future directions in land management in the Swamp. There appears now to be fairly general support for the establishment of community ranger programs in the northern part of the swamp. The CFC Unit on behalf of Ramingining Resource Centre and the Council has submitted a funding application to the NHT to train four community rangers.

Existing and planned community ranger programs in the south-east part of the Swamp have very high community acceptance, but are currently suffering from extreme resourcing problems. On behalf of several communities, Dr Neville White from La Trobe University in collaboration with the NTU Centre for Indigenous Natural and Cultural Resources Management (CINCRM) is seeking support funding for community rangers for weed control and other land management in the south-eastern part of the Swamp.

In October 1997 a collaborative research team offered their services to undertake some baseline geomorphology work in the Arafura Swamp. The research team was made up of the Australian Geological Survey Organisation's (AGSO) Coastal Lands Project Group led by Dr Trevor Graham and a group from the ANU Division of Archaeology and Natural History led by Professor John Chappell (and including Professor Rhys Jones). Apart from providing baseline data for management planning, the paleo-geomorphologic work in the Swamp will give land owners information on how that area has responded to environmental perturbations over the last 100 000 years or so and how, amongst other things, it might therefore respond to anticipated sea level rise due to global warming. Land owners were fully consulted over the work program and accompanied researchers into the field. Researchers will return to the community to explain their findings.

Members of the DLPE's Water Resources Division (Ursula Zaar and Geoff Prowse) have been undertaking a Landcare-funded program to determine the underground hydrology of eastern Arnhem Land. Field work in the Arafura Swamp area is currently being undertaken. Dave Williams, a surface water hydrologist with Water Resources, has been instructed by his Division Head to undertake a hydrological modelling exercise of the Arafura Swamp. This work will be dependent on obtaining further funding and will be undertaken in collaboration with Professor Chappell and the local landowners.

A major achievement for the TEIPWP was holding a research workshop on the Arafura Swamp in Darwin on 24–25 November 1997. The TEIPWP received $30 000 from the Land and Water Resources Research & Development Corporation to consult with land owners and conduct the workshop, which was facilitated by CINCRM. The main purpose of the workshop was to conduct an audit of previous relevant research and to flag future research interests from non-local agencies. This information will be important in planning how to use research in the development of on-ground capacity for land management, such as providing support to the evolving community ranger groups in the region. This was the first occasion research results were shared in such a way among more than 50 individuals from a range of institutions. The workshop will undoubtedly result in better collaborative research in the future.

5 Future directions

Although the TEIPWP is achieving some degree of success, the broad plan of adequately addressing management planning on the most important wetland sites on Aboriginal land in the Top End of the NT is contingent on receiving adequate funding. The TEIPWP was successful in obtaining a commitment for funding from the CRC for Tropical Savannas for a half-time position to undertake a research and training needs analysis in the Arafura Swamp. More recently Environment Australia's National Wetlands Program have granted money for half a position for a wetland management coordinator for Central Arnhem Land. These monies could be used for one full time position or a number of part-time positions. Negotiations are proceeding.

Once a person(s) is engaged to carry on with wetland management in Arnhem Land it is envisaged the existing NLC Wetlands Officer position will shift the focus of activities to wetlands on the western side of the NT (eg Wagait, Daly/Port Keats etc) to 'kick start' awareness and initiate wetland management planning in that area.

Further to this there is a need to adequately resource the partner organisations of the TEIPWP (fig 1). For instance the AGSO/ANU team will need some funding over and above their own to complete the Arafura Swamp geomorphology (and extend the work to other areas), DLPE Water Resources will need some funding to undertake hydrologic modelling, PWCNT will need funds to undertake biological surveys, while ***eriss*** will require funds to undertake the collation of information for the TEIPWP. Depending on the availability of funding, and continued consultation and collaboration with traditional owners, the TEIPWP could develop into a truly world class program.

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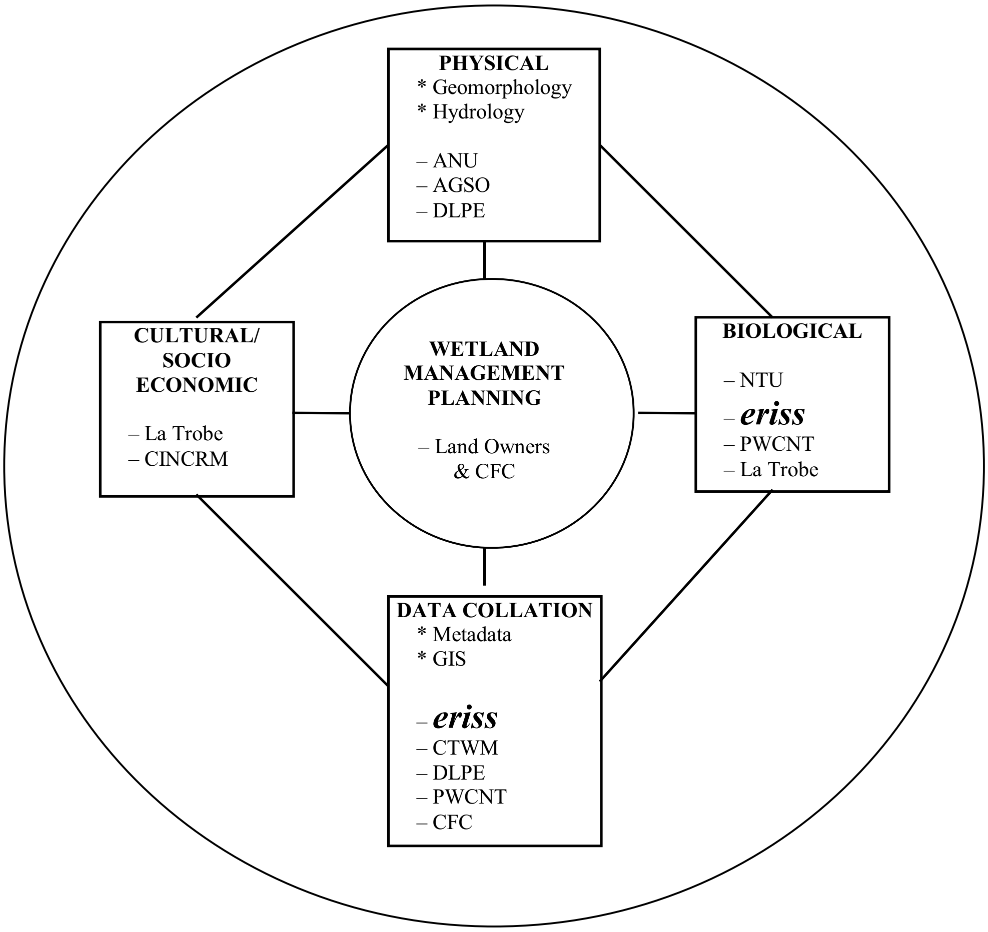

ORGANISATION ACRONYMS

AGSO	–	Australian Geological Survey Organisation – Geohazards, Land and Water Resources Program
ANU	–	Australian National University – Division of Archaeology and Natural History
CINCRM	–	Northern Territory University – Centre for Indigenous Natural and Cultural Resource Management
CTWM	–	Northern Territory University – Centre for Tropical Wetland Management
CFC	–	Northern Land Council (NLC) – Caring for Country Unit
DLPE	–	NT Department of Lands Planning and Environment – Water Resources Division
eriss	–	Environmental Research Institute of the Supervising Scientist – Wetland Ecology and Conservation Program
La Trobe	–	La Trobe University – School of Genetics and Human Variation
PWCNT	–	Parks and Wildlife Commission of the NT– Wildlife Research Division

Figure 1 The Top End Indigenous People's Wetlands Program

Aboriginal management of wetlands and the Dead Sea Scrolls

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1 Introduction

I teach the Lands, Parks and Wildlife Management course at the Jabiru Regional Centre for the Northern Territory University, and I come from a national parks background. I spent 15 years working as a ranger for the South Australian National Parks and Wildlife Service before coming here, and when I arrived, people said to me 'Can you help our Aboriginal ranger trainees here in Kakadu with their literacy?' So I started as a part-time tutor in 1986 and soon became a full-time lecturer for various subjects.

This morning I was asked to replace a lecturer who was unable to turn up, so with less than a few hours notice I decided to talk about the importance of the Dead Sea Scrolls in wetland management in the Top End. I feel this is relevant because it brings together the temporal cultural and scientific elements of wetland management in the Top End.

2 Time, tradition and the Law

The Dead Sea Scrolls are about 2100 years old. The wetlands here in Kakadu are about that old too. They're not very old at all. That's an interesting point, because I've just come from the Bushfires '97 Conference in Darwin, where experts on fire gathered from all over Australia to present their opinions on fire management. At the conference, several speakers got up and said things like 'Aboriginal people have been managing this country adequately for the last 40 000 years and there's got to be a lot of knowledge there that we can use'. Well that's partly true and it's partly false. Nobody here is 40 000 years old for a start. Whether balanda (non-Aboriginal) or Aboriginal, we have all learned what we've learnt from our fathers and mothers, depending upon who we listen to the most. In traditional Aboriginal society people learn most from their uncle, who is himself usually not more than 30 or 40 years old. The wetlands themselves are not very old either. They're not 40 000 years old, they are only 2000 years old, if that.

If we read the Dead Sea Scrolls, we can read the thoughts, intentions, aspirations, problems and the Law of a people who lived on the earth 2000 years ago. We can read it in detail, draw observations from the scrolls and know the people quite intimately. We can't do that with Aboriginal people, because Aboriginal people had an oral tradition, not a written tradition. That is something we must remember, because it changes every generation and so the

[*] Adapted from transcript, July 1997

tradition we have here to draw on, in that sense, is only one or perhaps two generations old. Tradition is formed in a very short time. Anyone who has been in land or parks management will know that! For example, when you go to a remote campsite and there's a man there and you ask him for his camping permit, he says 'But I've been coming here for years'. If you happen to have been the ranger there for the past 10 years, you know he only arrived last year for the first time. Traditions are often of that nature.

If you read the Dead Sea Scrolls today, those people may as well have come from Mars, because of the irrelevance of much of what they write to the modern technical society and the scientific culture. They would not know how to cope if you put them into a spot here and now. They come from an academic tradition, but it is an academic tradition of the Law. Aboriginal people similarly come from an academic tradition with regard to the Law – it is an oral tradition, but academic nevertheless. And the Law does funny things. People do funny things with the Law. Some of those things are long-standing in human society. One might say that the Law expressed in the Dead Sea Scrolls is in essence the same as the Law that's expressed in Aboriginal society; it is non-materialistic to the same degree, it puts the sacred above the material and people somewhere in between. (Modern Australian society puts the material above people and the sacred somewhere at the bottom, attaching no sanctions to it whatsoever!) There are some, perhaps many, aspects in the laws of Middle Eastern society which are identical to Australasian society's traditional law.

2.1 What is relevant today?

Something from the Dead Sea Scrolls which I thought might be relevant today is an old law, going right back to the Law of Moses and probably about 4000 years old, that 'you shouldn't lead a blind man into a ditch'. That was the Law. So you mustn't believe a word I say today, and don't believe too much of what you've heard in the whole time you've been here! It is better that you don't. It is better that you check up on everything. That is what I tell all my students, especially Aboriginal students, because I want them to check up. I don't want them to sit back and believe everything I tell them, because I might be wrong. Science, as you probably well know, is a house of cards. It is people's deductions built on other people's assumptions. If something that somebody assumed at the bottom of the stack is later proved incorrect, then what are you left with? You have to remove the card from the bottom of the stack. Some people believe that the house of cards will still stand up even though the whole bottom row is missing! So I say, be careful, especially when thinking about the relevance of traditional Aboriginal land management in the modern world.

3 Myths and misconceptions

I agree with the statement that Aboriginal people were quite adequately managing this country for thousands of years – perhaps not the wetlands for all that long but certainly the dry country – but recent influences have upset the whole process and that is where our role comes in as scientific land managers, especially in terms of wetlands.

Here we have to remember something else. We have come to assume, over the last two decades (and it's a balanda myth, not an Aboriginal myth, although Aboriginal people have come to believe it and to promulgate it) that Aborigines, as hunter-gatherers in Australia, actually knew what they were doing. Now when you read the Dead Sea Scrolls, you read about people with a very high level of intellectualism. Those people were managing the Middle East 2000 years ago in a time when the Middle East was more fertile, had a higher rainfall than it has now etc – and yet we can see what has happened to the Middle East as a result of several hundred years of management. Our western scientific land management culture has developed out of that civilisation, and we know for a fact that we haven't known what we've been doing for thousands of years!

3.1 Could we destroy the earth?

There's a very interesting set of books in the Dead Sea Scrolls called the Apocalyptic books. The Jews at that time had quite a number of Apocalyptic books available to them. One of these books, written at about the time when the very last Dead Sea Scrolls were being stowed away in caves, is the Book of Revelation which we now have in the New Testament. There is an interesting verse in there which says 'God will destroy those who destroy the earth'. For hundreds of years this verse was translated as 'God will destroy those who *corrupt* the earth', because at the time it was written and in subsequent centuries (up until this century) it was impossible to conceive that man could destroy the earth.

In the mid-1800s people began to think that perhaps we could manage the earth better than we are, and there is quite a lot of writing about that, even in Australia amongst the colonists. There is one famous quote from about the 1860s that 'surely God meant Australia to be used for a purpose higher than to be tottered over by the squatters' scabby sheep?' which I think is a marvellous quote. I think what he meant was that the sheep should have been moved off and they should grow wheat, but the point was that they were thinking about management back then.

By the 1950s people were sounding a note of caution: 'hey, it's still out there to be exploited, but perhaps we'd better be careful how we do it because we've just about discovered everything by now'. By the 1960s, Rachel Carson was saying 'hang on a minute, it's all come unstuck and if we don't do something about it soon we'll have an environmental disaster'. By the 1970s people were saying 'it's not only possible that man might be able to destroy the earth, but we think it's inevitable'. And of course now in 1997 we are in a critical period.

3.2 Aboriginal people and conservation

Where does my role with Aboriginal people come into this? The idea of a big national park in this area was first mooted in the 1960s by conservationists. Then they discovered uranium and that put the cat among the pigeons. Eventually Kakadu was established as a bit of a tradeoff; the Aboriginal people could have their land if they allowed mining to go ahead, and the conservationists could have their national park if they supported the Aborigines' claim to land, and so followed a domino effect by which the federal government managed to get its uranium mine with the least possible political damage.

Of course we all know what kind of social damage has occurred since, and the environmental damage which perhaps could occur, but I won't go into that. The point is that Aboriginal people were invited to play a role in the management of Kakadu very early in the piece, on the basis that they would be managing the Park within the first 10 years. Now that was a promise made to them, a genuine belief of the bureaucrats in Canberra and of conservationists generally.

You see, conservationists thought that Aboriginal people were also conservationists. That was the first myth. Hunter-gatherers are not conservationists. Hunter-gatherers are exploitative, just like agriculturalists or pastoralists etc. They are producing food and they are interested in the largest amount of food for the least amount of effort. That is their first priority. Hence, what Aboriginal people see as an excellent or perfect landscape might not be what conservationists think is an excellent or perfect landscape, from a biodiversity or other point of view. They are managing towards quite a different goal.

3.3 Aboriginal ranger training program

3.3.1 Misunderstandings

So very shortly after the first Aboriginal ranger training program started, problems began to arise in terms of joint management. There were obvious discrepancies between the aims of the Aboriginal people – even the Aboriginal rangers – and the balanda rangers, the balanda administration and conservationists who were supporting areas like Kakadu. However, generally only the balanda rangers actually knew about that. The Aboriginal rangers didn't know there was a conflict either, because they didn't know enough about what balanda rangers did. They didn't think the balanda rangers did anything! The Aboriginal rangers had done a crash course (6 months) on the public service, among other things, and then were put into ranger positions. They didn't know how the public service worked after just 6 months, they didn't know anything about what we would call conservation land management, and they didn't even know what they were expected to do each day in their work, in terms of what they were being paid for.

For example, one man said to me 'I've got a couple of extra children now, do my wages go up?' I asked 'Why do you think your wages should go up?' He replied, 'Well, everybody else's do'. If you are living on welfare payments and you have more children, your benefits go up, so he thought his wages did that too. He didn't understand that his wages were based on the fact that he was supposed to turn up to work every day. There were a lot of such things that Aboriginal people did not understand.

3.3.2 Communication problems

Communication difficulties also arose. One senior ranger was invited to District Supervisors' meetings because he was considered very astute and articulate, and the supervisors said to me 'We don't understand where this guy is coming from, because we know he has opinions on particular issues, and we'd like him to express them in our meetings, but when we invite him to the meetings he sits there and says nothing while we discuss the subject!' They were becoming quite frustrated with the fact that they couldn't seem to get any dialogue between the Aboriginal people and the supervisors, even on issues upon which they knew Aboriginal people had well-founded opinions.

So I went along to a literacy course I was teaching, and, as I do with all my students, I asked this senior ranger 'Why are you doing this course? What can we give you?' He said 'I'd really like to be able to read and understand what the District Supervisors read and understand'. I asked 'In what way do you feel you're falling short?' 'Well,' he said, 'I go along to the District Supervisors' meetings and I don't understand a word they say!' So he wasn't saying anything because he didn't know they were discussing the topic he was interested in. Nobody had realised that.

3.3.3 Solutions

The Kakadu National Park Board of Management, which was established as an advisory board, recognised this problem, as some of the members were Aboriginal rangers who knew the shortcomings of the system. The Board decided to have a better ranger training program. They got it started and abolished what was by then an 18 month limit, leaving it open-ended with the requirement that the trainees must get to certificate level.

We held an Open Day at NTU Jabiru (then the NT Open College) so they could look at relevant courses that were available, including courses at Batchelor College, which is an Aboriginal College. The Board of Management decided on the NT Open College course, now the NTU course. I was surprised, as I thought they'd prefer their people to be trained as rangers at the Aboriginal College. Their reason for this decision was that they wanted their Aboriginal rangers sitting in the classroom with balanda rangers, so the Aboriginal people would understand that their certificate was not just an Aboriginal qualification, but a broadly-based, mainstream qualification for everybody. I thought that was a good decision, and the training has been underway since.

It is rather interesting because we now have Aboriginal rangers who, of their own volition, ask for their own classes (without balanda students) to enable them to work at their own pace. They feel that if other Aboriginal people in the community who'd like to be rangers see them in the course and succeeding, they may think they can do it too. At NTU Jabiru we try to be flexible wherever possible and encourage more Aboriginal people to come and study.

3.3.4 Training today

So training has progressed from a '6 month crash course, then throw them to the wolves' (from which the attrition rate has been huge over the years) to today's scenario, in which there are a number of Aboriginal rangers undertaking study in a range of subjects.

4 Common sense versus science

The reason why Aboriginal people are undertaking study (and they're particularly interested in scientific subjects) is because they don't have that knowledge. They only know certain things. When you're a hunter-gatherer you live on common sense. Common sense is different from science. Common sense tells you that the sea is higher than the land because the waves fall onto the land. Common sense tells you that the sun comes up on one side of the earth and goes down on the other side, and that there's probably another sun the next day because otherwise where did that one go? Common sense tells you that the earth is flat. But common sense is absolutely indispensable for survival. However, in order to understand things at the level we now need to know for survival, we have to look at things in a scientific way, and many Aboriginal rangers are learning this as well.

Aboriginal people need to know more than they did before. They know lots about barramundi and other fish that they catch to eat, but they know very little about the small fish the barramundi eat. They don't know the complexities of the food chain; they didn't need to know while there were plenty of barramundi there. Now, when animals are likely to be threatened by influences elsewhere, Aboriginal people need to know scientific management. In a recent successful, ongoing initiative in Kakadu, Aboriginal rangers tag turtles to find out what the turtles are doing. In fact this turtle survey program was first proposed in about 1987 by an Aboriginal ranger. He was opposed at the time by scientific staff who felt that rangers shouldn't be involved in scientific work, especially Aboriginal rangers; they thought it was better to bring in consultants from elsewhere. Yet Aboriginal rangers have since proved to be keen participants in research projects.

So, to put it in a nutshell, we are in a new era. We are all having to learn rapidly, and Aboriginal people are being swept along by the same wave. We are finding out things for the first time and so are they. The idea that Aboriginal people have to come up to speed because these jobs must be done, is a very valid point. There are Aboriginal people who acknowledge this. It is very important that we do not ride roughshod over their rights as land owners, but the clue to proper management of wetlands in the future, here in the Top End in particular, is education – for everyone. The more Aboriginal people get involved with education, and the more they are helped along with information, the better.

eriss has had a very bad reputation in this area for non-communication. It is very easy for academics to keep their heads down at their work because they are often very specialised people and can forget about the rest of the outside world! Many Aboriginal people don't know what ***eriss*** does. They think that scientists know nothing. They quite genuinely believe that balanda rangers with university qualifications, recruited from other states, know nothing. This is because balandas have been busy telling Aboriginal people that they know everything, which is also wrong. The more we tell them that, the greater the disservice we do them. There is a lot of work yet to be done to redress this problem.

5 Conclusion

Well, I am going to finish with this poem about indicator species. A canary in a cage was once a good indicator species – miners would take a canary into the mine and if the canary fell off its perch they got out of the mine rapidly! But the indicator species studied here in Kakadu are macroinvertebrates, considered to be good species for monitoring environmental change. Macroinvertebrates are at the very bottom of the food chain. As we are at the top, there may be a bit of a paradox in watching them for indications that we might be in trouble!

Indicator Species

Sunk in substrate Macroinvertebrates
Wiggle their tails and claws
Beckoning enticing friends and relatives to
Macroinvertebrate jaws
Macroinvertebrates love their mud
Safe beneath both fire and flood
Steadfast resolute they shrink not from their
Macroinvertebrate cause

Casebound cryptic Macroinvertebrates
Scrabble their river beds
Gathering and shaping tiles to decorate their
Macroinvertebrate sheds
Macroinvertebrate grope and graze
Safe from predatory gaze
Blissful oblivious they fear not for their
Macroinvertebrate heads

Thrice transvestite Macroinvertebrates
Struggle to find a mate
Fluttering and searching moonlit billabongs for
Macroinvertebrate bait
Macroinvertebrates nymphs may be
Even so some may fly free
Lusty purposeful they set seal to their
Macroinvertebrate fate

All unwary Macroinvertebrates
Dazzle in Man's bright light
Pickling and probing Man must study their
Macroinvertebrate plight
Macroinvertebrates know their place
Not quite so the Human Race
Poisoning polluting Man can't last but
Macroinvertebrates might

(AG Spiers © 1992)

<u>Question</u>: *In terms of providing Aboriginal people with the science, is there any risk that we might be diluting their culture even further, losing their cultural values or characteristics? What is your interpretation of that?*

That is a very good question. Aboriginal people are always trying to say 'Look, don't you understand that culture changes? Don't you understand that Aboriginal culture is not the same from one side of Australia to the other? We're different.' And we never listen to them. We like to believe that they have the oldest continuous culture in the world, and that Aboriginal culture is the same all over Australia. I suppose some Aboriginal people have picked up on this popular belief and now say 'Ours is the longest continuous culture in the world'. Well, that's just another balanda myth.

The oldest continuous culture in the world is human culture. Aboriginal people brought a fully-fledged culture with them when they came across to Australia, and what they brought with them came from thousands and thousands of years in their place of origin. It comes from the same source the Dead Sea Scrolls came from. Human culture is the same all over the world in terms of its source (unless you believe in convergent evolution of *Homo sapiens* in different parts of the world at different times – I don't). Like all other human beings, Aboriginal people are very keen to adapt their culture if they find something that is worthwhile. They only discard those bits of their culture that they don't want or don't consider worthwhile. Now in terms of answering that question, I'd be making a value judgement. I'd be saying 'Yes, well, it's a pity they've lost that bit because it was really important'. Well it's no longer important to them if they choose to discard it.

(*Tape ends*)

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Coastal management in the Alligator Rivers region

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Abstract

The Alligator Rivers Region is of great cultural and conservation value. The coastal zone wetlands, in particular those contained within Kakadu National Park, have been the centre of much research. This research base has been used to assess the vulnerability of the coastal wetlands to climate change and sea level rise. Estimates of change were based on a climate change scenario developed by IPCC and CSIRO. Environmental responses were estimated from the wealth of biophysical data available. However, no actual measurements were made to confirm the predictions. In order to develop a better model and management strategies an integrated monitoring node has been established. The initial components of this node include further coordination and collation of existing data and information, and the development of a framework for monitoring of large-scale change processes on the floodplain wetlands.

1 Introduction

In 1994 the Commonwealth Government of Australia, through the Department of Environment Sport and Territories, commissioned eight Australian studies to establish regional differences in methodology required to assess the vulnerability of coastal land to potential change in climate and rise in sea level. The objectives of the projects were to establish data requirements for vulnerability assessment, determine the adequacy of existing information, ascertain the capacity of existing management structures to cope with potential issues devolving from predicted climate change and rise in sea level, and to establish the preparedness of management agencies to confront the issues.

Two case studies were conducted in the Northern Territory, at Darwin and Kakadu. The case study of the Alligator Rivers Region, and Kakadu National Park in particular, included the extensive tracts of wetland on floodplains bordering the principal rivers of the Region (Bayliss et al 1998). The Alligator Rivers Region (ARR) is a highly dynamic environment. It is subject to extreme rates of change due to seasonal and interannual variation in climate, storm incidence, sea-level fluctuation, and river discharge. Since management has had to take account of this variability its principles and policies may differ from those applied to management of the less variable, temperate environments of the southern coasts. Management of coastal and wetland areas on the western flank of the ARR, is vested in the departments of the Northern Territory Government, whereas Kakadu National Park is the responsibility of the Commonwealth Government. Day-to-day management of the Park is the responsibility of Parks Australia North (PAN) acting on behalf of, and in consultation with the Kakadu National Park Board of Management.

As a consequence of the vulnerability study a coastal monitoring node was established at the Environmental Research Institute of the Supervising Scientist in Jabiru, Northern Territory. The process being adopted to develop this node is described along with an assessment of the scenario of climate change and management responses (see Bayliss et al 1998, Finlayson et al 1998).

2 Regional setting

The ARR encompasses the catchments of rivers draining into van Diemen Gulf between Point Stuart and the eastern bank of the mouth of the East Alligator River, including Love Creek (Bijibiju) and the Wildman, West Alligator (Marangayu), South Alligator and East Alligator Rivers (fig 1). The region is part of a broader, biophysical region encompassing all of the coastal wetlands from Cape Hotham to the Ilamaryi River on the western flank of Coburg Peninsula. The region lies to the east of Darwin (fig 1) and includes all of Kakadu National Park.

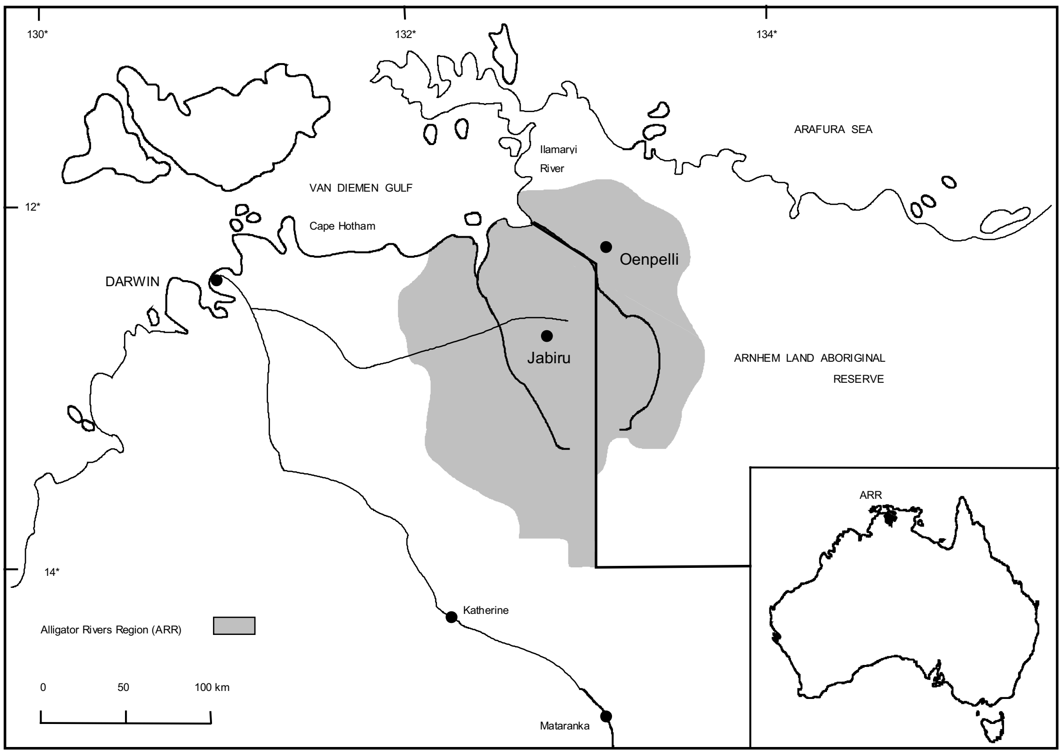

Figure 1 The Biophysical Region

The major part of Kakadu National Park is drained by the South Alligator and East Alligator Rivers, with the smaller West Alligator and Wildman Rivers draining the north-western portion of the region. The Mary and Katherine Rivers drain a minor portion of the south-westerly part of the region and they are not considered further. The rivers are fed by a network of ephemeral creeks and drain into van Diemen Gulf, in the north. The combined catchment area of the four major rivers is approximately 28 000 km^2, about 8000 km^2 greater than the size of Kakadu National Park

Coastal lands of the region are low in elevation, which makes them susceptible to sea level fluctuation. Floodplains generally lie between 3 and 4 m above Australian Height Datum (Williams 1969, Woodroffe et al 1986), below the more elevated Koolpinyah Surface, which is characterised by a laterised profile and above 5 metres in elevation (Wasson 1992). This makes them only 0.2 to 1.2 m above mean high water level. Arguably, a change in climate would substantively affect the physical and biological conditions of the coastal wetlands that constitute the greater part of the coastal plains, especially if significant rise in sea level occurs. In turn, changes to the physical and biological conditions are likely to have cultural, social and economic ramifications. Ultimately, any changes in the environmental conditions will affect the way in which the natural resources of the Region are managed. The challenge is to ensure that management recognises and can cope with such change.

3 Management structure

Kakadu National Park is the most important natural, cultural, recreational and tourist resource in the region. The importance of its natural and cultural heritage values are recognised internationally, and it is listed as a UNESCO World Heritage Area. The park is largely owned by the Aboriginal people of the area, the Bininj. It is leased by the Commonwealth of Australia and managed by Parks Australia North (PAN).

Uranium is mined within the catchment of Magela Creek, a tributary of the East Alligator River. The mining lease areas and nearby townsite of Jabiru have been excised from Kakadu National Park. Mining operations and provision of residential and urban services at Jabiru, together with recreational and tourist activities, have direct and indirect effects on the environmental values of the Park. However, management of mining, urban and tourist activities is intended to minimise any adverse impacts and maximise the opportunities to conserve the physical, biological and cultural heritage values. This has been pursued through a comprehensive research and monitoring program along the channel and floodplains of Magela Creek downstream of the Ranger uranium mine site at Jabiru East (Finlayson et al 1990, Humphrey et al 1995). The Environmental Research Institute of the Supervising Scientist independently, and in collaboration with other agencies, undertakes and promotes research relevant to the environmental effects of mining operations in the ARR and minimisation of these effects after decommissioning and rehabilitation. Although the coastal component of the research has focused on downstream effects of mining, much of the information gathered is applicable as a baseline to assess the effects of climatic and other changes on the catchment environment. It also provides a sound basis for comparison with other parts of the region.

Scientific research in the ARR commenced in the early 1970s with an Environmental Fact Finding Study (Christian & Aldrick 1977). Results of the study were used in assessment of the impact of mining and milling uranium ore, and by the Fox Inquiry (Fox et al 1977). Research has continued in the region to gain information for the management of the National Park. As a consequence of the history of research, information available for the wider region matches the breadth and detail of that for many coastal areas in Australia with a large urban population. However, important questions for management of the Region are

- is effective use being made of the information?
- is the information being converted to intelligence that supports effective and efficient management?

For coastal management to be most effective it is increasingly necessary to ensure dialogue and cooperation between the technical, scientific and management bodies, as well as between various government agencies and community groups that share responsibility for management. In this respect, the ways in which the Aboriginal people from the ARR are involved in the environmental management process for the region, through management of the National Park, may provide a working model for integrated coastal management elsewhere in the remote Wet-Dry tropics of Australia.

4 The climate change scenario

Climate is an abstract concept. It represents the summation of all interacting atmospheric processes and weather conditions affecting a locality. The climate changes under consideration in this context commonly refer to trends in climatic factors, such as CO_2 content of the atmosphere, temperature and rainfall. These changes occur at time scales up to 100 years and may be irreversible. Changes predicted to occur as a result of the 'greenhouse effect' provide examples of the type of variability to be considered in vulnerability assessment, although other fluctuations in climate may be equally important at this scale. Hence the natural variability of local climatic conditions should be examined as part of the vulnerability assessment process. McQuade et al (1996) have pointed out that the masking effects of natural climate variability make it unlikely that changes of the order suggested by global climate models will be confirmed for decades. The natural trends, oscillations and more random perturbations in climate need to be identified and distinguished from the 'exotic' changes caused by human populations.

The major source of information for the prediction of potential climate change in the Northern Territory, and current scientific advice on the regional implications of that change, has been provided by Wasson (1992) and CSIRO (1994). The generalised best estimates and ranges, mainly for the year 2030 AD have been provided by CSIRO (1994). Unless greenhouse gas emissions are substantially reduced, the cumulative effect of increases in all greenhouse gases is expected to be equivalent to a doubling of pre-industrial concentrations of atmospheric CO_2 (Halpert & Ropelewski 1992, CSIRO 1994). Climatic change is likely to be a continuing process from now until well beyond 2030, with superimposed interannual variations due to other natural effects such as solar activity and volcanic eruptions. Estimates are based on the Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment and ongoing CSIRO research. Surprises, including rapid changes, are possible according to these sources. Potential future changes outlined by the CSIRO (1994) are summarised in table 1.

5 Predicted sea level rises

Sea level changes are related to global climate change (Warwick 1995); interannual variation in weather conditions, such as those related to ENSO events (Komar & Enfield 1987); as well as to hydro-isostatic (Chappell et al 1982) and tectonic (Woodroffe et al 1987) effects within van Diemen Gulf. Two scenarios for global sea level rise have been published. Initially, the IPCC scenarios (Houghton et al 1990) were the main source of information for Australia. However, these are currently under revision and are due to be updated. More recently the IPCC scenarios have been replaced by the work of Wigley and Raper (1992). This has been adopted by the CSIRO (1994) and provides the basis for vulnerability assessment in the ARR. Global predictions of sea level rise range from 25 to 80 cm by the year 2100, with a best estimate of 50 cm. By the year 2030 sea level will have risen between 8 and 30 cm. The estimates are plus or minus 25% lower than the best estimate presented by the IPCC in 1990 (Warwick & Oerlemans 1990). They require further adjustment to allow for regional and site specific conditions to determine the relative sea level change at that place. Such predictions are not currently available for the ARR.

Table 1 Predictions of climate change (CSIRO 1994)

Temperature Global average warming to increase by 0.2–0.5°C per decade. Australia in 2030, relative to 1990, will be 1–2°C warmer in northern coastal areas 1–3°C warmer in southern coastal areas 2–4°C warmer inland Even warmer in drier areas, and possibly less so in wetter areas
Rainfall Rainfall in Australia in 2030, relative to 1990 Large area average increase of 0–20% in summer in the summer rainfall region monsoon more intense but monsoon trough not extending further south less certain overall decrease of 0–20% in winter in the winter rainfall region local changes could be two or three times larger due to topographic effects general increase in rainfall intensities possible marked increase in heavy rain events longer dry spells in mid-latitudes
Extreme events Will change in magnitude and frequency more rapidly than the averages eg more very hot days, fewer frosts, more floods and dry spells.
Clouds Preliminary indication of an increase of 0–10% in total cloud cover in tropical Australia and a 0–15% decrease in the south of the continent.
Tropical cyclones Cyclones could travel further south and their preferred paths may alter but effects on intensity are uncertain. ENSO could affect both the location and frequency.
ENSO Future behaviour of the El Nino – Southern Oscillation events is uncertain. Probably El Ninos and anti-El Ninos will continue to occur, to produce drought and flood years.
Winds Stronger monsoon westerlies are expected in northern Australia and stronger winds will accompany severe weather. Mid-latitude westerlies are expected further south over Australia but changes in the trade winds of the north are not yet clear.
Evaporation It is anticipated that there will be a 5–15% increase in potential evaporation by 2030.
Sea level Predicted changes in global sea level include a global average rise of 3–10 cm per decade a best estimate for Australia by 2030 AD is about 20 $\pm$ 10 cm above 1990 levels local variations due to changes in weather and currents, affecting magnitude and frequency of extreme events such as storm surges, waves and estuarine flooding
Direct CO_2 effects CO_2 concentrations increase from 350 ppm in 1990 to 460 ppm with increased growth rates of C_3 plants (eg wheat and temperate grasses), but have less effect on C_4 plants (eg sorghum)

Long-term variations in climate and sea level, those occurring over hundreds of years to millennia, in the ARR have been established in geomorphologic and stratigraphic investigations for the Mary (Woodroffe & Mulrennan 1993) and South Alligator River systems (Hope et al 1985, Woodroffe et al 1985, 1986), the Magela Creek and coastal plains (Nanson et al 1990, Wasson 1992), and the Point Stuart chenier sequence (Clarke et al 1979, Lees 1987). General descriptions of landform evolution in the region have been provided by Storey et al 1969, Christian and Aldrick (1977) and Duggan (1985). These investigations provide a context for environmental changes currently occurring in the ARR and for the higher frequency changes that have occurred in the past 100 years and which may recur in the near future.

More recently, short-term fluctuations in sea level, those occurring within the historical period, have been examined by the National Tide Facility. The record is short, dating from 1959 to 1992, and based on tide gauge records from Darwin Harbour. It indicates that there may have been a slight variation in sea level in the region over the period of record, at rates between approximately 0.10 mm and 0.17 mm per year. However, there is a need for caution in interpreting the short record because the trend is very low. It may be biased by interannual variations in climate, such as those due to ENSO events, and it is located outside the ARR.

The record of annual mean sea levels for Darwin displays an interannual variability rising from approximately 3875 mm to 4125 mm over the 4 years from 1972 to 1975, and a relative fall to 1992 levels. The variation reasonably could be anticipated to affect coastal processes and tidal activity within the estuarine reaches of the rivers. However, the response rate of coastal and estuarine processes to such change is largely unknown. Responses of a sandy beach to sea level fluctuation are of the order of 1.0 m of shoreline retreat for each 1.0 cm of sea level rise (Bruun 1962, 1983) with the beach response lagging the peak sea level. Similar changes may be anticipated to occur on muddy coasts.

6 Environmental responses

Environmental responses to climate and sea level changes are manifested through hydrological, hydrodynamic, geomorphological and ecological processes. Development of the coastal plains also rests on a balance between these processes such that the coast progrades when sea levels are lowering, rainfall is high and fluvial forces prevail. Conversely, the shoreline retreats and tidal creeks extend landwards when sea level is rising, rainfall is low and coastal processes prevail. There is a wide range of interactions and responses between these extreme conditions. Hence an understanding of the coastal hydrodynamics, and particularly the hydrology of streams and wetlands, is a fundamental requirement for understanding the biological and chemical processes that characterise stream and wetland ecosystems. The complexities of the hydrological cycle for the ARR are not thoroughly understood, especially in relation to groundwater interactions with the aquatic and wetland ecosystems. Effective management practices for such aquatic ecosystems are often limited by an inadequate understanding of the underlying hydrological processes. Although the Kakadu wetlands have undergone major ecological change over the past few decades (Finlayson 1990, Finlayson et al 1988) and controversy has surrounded plans by mining companies in the region to release excess runoff water to the aquatic ecosystem (Johnston 1991) this has not provided sufficient impetus to thoroughly investigate the complex hydrology of the region.

Adjacent to the ARR pastoralists have registered concerns over increasing encroachment of saline waters into freshwater wetlands that are used for seasonal pastures (Knighton et al 1991, 1992, Woodroffe & Mulrennan 1993). Remedial measures to deal with this problem have included emplacement of open mesh rubble mattresses and earth bunds to impede tide water penetration. The porosity of the mattresses and inherent instability of the bund walls brings these mitigation measures into question. More successful approaches to the problem will require an increased understanding of coastal and floodplain hydrodynamics and geomorphology that is based on rigorous, scientific research (Sessional Committee on the Environment Northern Territory 1995.)

Ecological process affected by environmental change include the expansion and contraction of plant communities with consequent effects on animal habitats. Again, insufficient knowledge of the interaction between wetland plant communities and changes in hydrological and depositional conditions makes prediction of the long-term effects difficult. Wetland plant communities are viewed as being widespread in the region and highly dynamic in terms of variability in species composition, structure of the community and geographic spatial extent. The plant species are widespread at pan-regional and regional scales and no communities or individual species of rare or endangered species have been recorded. Similarly, animal species are widespread and no rare and endangered species are known from areas that could be affected by environmental change.

Environmental change is continuous. All physical, cultural, social and economic systems are changing. A key factor to be considered is whether change can be perceived as having adverse effects on natural and human systems. In this context, perception is important because it dictates the type of response taken to change. Heightened perception of change can result in increased activity to record and identify changes, and implement measures to deal with them. On the other hand, diminished perception of change can result in relaxation of measures previously used to address the negative effects of change. For instance, this latter situation is seen over successive years following extreme climatic events, such as tropical cyclones, wherein there are gradual cuts in budgets and reductions in resources to deal with potential but very real hazards. It is accompanied by a lowering of awareness of the implications that the events or changes can have in terms of hazards, risks and lifestyles of humans.

7 Management strategies and research

Bayliss et al (1998) pointed out that the floodplains of Kakadu National Park cannot be managed in isolation from the remainder of the region or, indeed, lands bordering on van Diemen Gulf. Environmental information from across the larger region is required in order to implement integrated coastal zone management. The wetlands of the region are already undergoing major ecological change and can be expected to change even further, especially in consideration of globally predicted climate change and sea level rise. Long-term monitoring of key biophysical parameters in the wetlands and adjacent seas are required for change to be assessed and appropriate management strategies implemented. This will require a spatial and temporal database that itself must be contained within an effective information management system. In many instances the management strategies will be aimed at rehabilitating degraded habitat, whether it includes control of weeds or alteration of the water regime or physical features of the wetlands. Management objectives can be targeted at specific problems, but they are unlikely to be effective in the long term if carried out in isolation of adjacent linked areas.

In the context of wetland management throughout the region it is stressed, as argued above, that a holistic approach should be developed as it is not possible to manage the wetland systems in isolation. This point is made by Bayliss et al (1998) and Storrs and Finlayson (1997) who assessed the extent of biophysical interaction between wetland ecosystems. The adjacent areas of the East Alligator floodplain are not covered by a similar plan even though they share many of the same problems, as listed above. Further, Bayliss et al (1998) present a case for the integration of management effort for all lands bordering van Diemen Gulf (ie involving all tiers of government, land-holders and representative associations).

Effective management, including rehabilitation, of wetlands is, at least in part, dependent on access to an adequate information base. The necessity of both establishing and curating this information resource has been expounded by Bayliss et al (1998). Information and database systems that could be of value within the ARR could include: a meta-database to record basic information on the projects undertaken; a relational database to provide linkages between data sets and data types; and a spatial database for maps and imagery (Finlayson 1997). As with the management tasks themselves it is doubted that these databases will be truly effective if they are confined to jurisdictional boundaries. Given the ecological linkages that exist between the wetlands the information base can not be confined by lines on maps. Management processes that involve cooperation across these lines are occurring and are strongly encouraged.

In addition to utilising effective integrated decision making processes and information systems there is a need to implement well designed monitoring programs. The steps required for designing monitoring programs have been presented by Finlayson (1996). These are not repeated here except to emphasise the necessity of framing realistic objectives and linking these to hypotheses that can be tested with well chosen sampling regimes and analytical procedures.

8 Coastal monitoring node

The aim of the ARR vulnerability assessment project was to facilitate ongoing assessment of the coast, in particular the wetlands, to the effects of short-term changes in climate and other environmental factors that occur within planning horizons of approximately 100 years (Bayliss et al 1998). While the project focused on Kakadu National Park, and the floodplains of Magela Creek, its outcomes have wider application to the management of the ARR in general, as well as for floodplain environments elsewhere in the Wet-Dry tropics. Thus, the proposed monitoring node is being established with the purpose of establishing a monitoring approach with sufficient utility to be extended across the wetlands of the Wet-Dry tropics.

The aims of the coastal monitoring node are to:

- Develop a regional capacity to measure and assess change on the floodplains and coast of Kakadu National Park, its catchment area, the wider ARR, and in the Wet-Dry tropics in general.
- Increase Australia's capacity in the monitoring of coastal change through establishment of a coordinated monitoring program which can function as a benchmark for monitoring in the Wet-Dry tropics and eventually in any low lying coastal areas subject to episodic flooding.
- Provide a regional and local benchmark against which to measure environmental changes in the Magela Creek system which could be attributed to mining and other human activities.

The operation of the node will meet the basic requirements of the Commonwealth Coastal Policy, namely the need to:

- Ensure that the monitoring program addresses management questions.

- Coordinate Commonwealth information collection exercises and monitoring initiatives within the Commonwealth.
- Generate understanding, cooperation and support of the key players in coastal management of the region through involvement and ownership rather than centralised control.

Furthermore, there is a need to provide benchmarks, both nationally and internationally, from which to measure changes in Wet-Dry tropical environments. The ARR provides an excellent opportunity to do this as a result of its conservation and resource significance, its sound history of research and its considerable body of material that could be collated to provide baseline descriptions of the essential characteristics and attributes of change in this type of environment. The development of further expertise that would result from this proposal will be of national and international significance.

The initial components of establishing the monitoring node are:

- Coordination and collation of existing data and information
- Development of a framework for monitoring of large scale change processes that shape the morphology of the floodplains.

These tasks are being addressed through a consultative process with other governmental agencies, research institutions and local community groups. The emphasis is on consultation and collaboration in order to address the needs of land managers and users in this highly variable and changing coastal environment.

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Major components of the coastal monitoring program in the Alligator Rivers Region

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Abstract

A Coastal Monitoring Program for assessing and monitoring environmental change in the Wet-Dry tropics is currently being established within the Environmental Research Institute of the Supervising Scientist (***eriss***). This node will develop a regional capacity to measure and assess change on the floodplains and coastline of Kakadu National Park, the wider Alligator Rivers Region, and the Wet-Dry tropics in general. The initial aim is to provide a survey and monitoring framework using a differential Global Positioning System to accurately georeference and store information, and provide baseline data.

1 Introduction

There are many important components that have been identified as integral parts of the coastal monitoring program; however the broad aim is to:

- Provide a survey framework for georeferencing and mapping of all spatial information to be gathered in the coastal monitoring program in the Alligator Rivers Region (ARR), which contains Kakadu National Park.

As it is a large-scale time-consuming project, many smaller projects and tasks have been identified as necessary parts of the program. These are listed below in the recommended sequence of investigation:

- establish a Geographic Information System (GIS) structure for data collation, analysis and management;
- establish and adopt standards for georeferencing of all information to be gathered, particularly in the field by a differential Global Positioning System (differential GPS) and other means of referencing to known coordinates;
- acquire and deploy: (a) meteorologic, (b) oceanographic, and (c) river gauging equipment for fully automated recording of core environmental information;
- from available, vertical aerial photographs estimate historical shoreline movements along the coast and in the lower estuarine reaches of the rivers;
- establish key monitoring sites and initiate regular surveys of storm washover and shoreline movement;
- from available, vertical aerial photographs, assess historical changes to the tidal creeks of floodplains on the East and South Alligator River systems;

- from available, vertical aerial photographs estimate historical change in the distribution of mangroves along the coast and in the lower estuarine reaches of the rivers;
- initiate monitoring surveys of the species distribution and community structure of mangroves along the coast and in the lower estuarine reaches of the rivers;
- from available, vertical aerial photographs, determine historical changes in the distribution of salt-affected vegetation communities on the floodplains of the East and South Alligator Rivers;
- incorporate all spatial information and temporal descriptions in the Geographic Information System; and
- acquire bibliographic materials and collate information on data sets relating to integrated coastal zone management in the Wet-Dry tropics in a centralised metadatabase.

Two additional areas where work is required have recently been identified:

- document the history of land use and environmental change; and
- review the existing work (Woodroffe & Mulrennan 1993, Wasson 1992, etc) that has been done in the region with regard to stratigraphy and sediments.

Each of these projects and/or tasks initially require commitments of time and resources to determine what is known about each area of interest before proceeding with a monitoring strategy. Initially an information-gathering exercise is taking place to establish what work has been proposed, commenced or completed. This is being undertaken in consultation with various government departments, companies and organisations that hold relevant data and information, and are perhaps working in this area.

2 Project description and status

This section will provide a brief description of each of the projects listed above, provide the aim/s or rationale, the present status of the project and expected outcomes. The broad aim of the project – to establish a survey framework for georeferencing and mapping of spatial information – will be further discussed in section 3.

2.1 Establishment of a GIS system at eriss

eriss is in the process of establishing a GIS system structure for data collation, analysis and management. The GIS will be used to store and analyse data from all ***eriss*** programs and in particular the Coastal Monitoring program. It is fundamental to have an effective strategy for data management and information storage, management and exchange for all projects undertaken in this program, and for the data management systems to be in place before projects are begun. The GIS will provide the framework and base data layers into which all new and collated information will reside.

The hardware and software is now in place and many of the base GIS layers are available for use. These include coastlines and other topographic data, administrative boundaries, vegetation and geological data and herbarium records. In the near future data will be available from the Parks Australia North GIS which includes a great deal of valuable data on firescar mapping in Kakadu National Park.

The Coastal Monitoring program is expected to make significant contributions of new data which will be combined with the existing data and analysed as required. Metadata entry into the Environmental Data Directory has commenced and through this process metadata will be available via the National Metadata Directory.

2.2 Georeferencing of spatial data using a differential GPS

The establishment of a differential GPS at ***eriss*** will provide the flexibility to establish reference sites within the ARR as they are required. It will also provide a survey framework for spatial differential GPS and develop ***eriss*** capacity to locate and map features such as saltwater intrusions, mangroves, wetland areas, cross-sections (both floodplain and channel), tidal creek extensions etc. With the location of these features accurately known, relocating these features for future research and study will be possible.

The following tasks have been identified as essential to the establishment of a georeferencing framework at ***eriss***:

- Relocate the AUSLIG (Australian Surveying and Land Information Group) GPS base station from Manton Dam to Jabiru Airport;
- Select and purchase suitable differential GPS equipment;
- Organise and administer staff training in use of the equipment, including procedures for downloading data to GIS;
- Relocate existing Benchmarks and Geodetic points;
- Establish field control points as projects are identified and implemented.

It has been agreed that the AUSLIG GPS base station should be moved from Manton Dam to Jabiru airport and the move should be completed during August 1997. ***eriss*** has also purchased an Ashtech differential GPS, which is directly compatible with the AUSLIG GPS equipment, and training in its use has commenced.

2.3 Establishing baseline information

Information is required for various environmental parameters, to determine a set of conditions that can be called baseline. This will effectively give us a starting point by which we can monitor and determine any changes that occur in the future. Examination of historical records could provide an indication where such changes have occurred and perhaps are ongoing, and point to sites where monitoring equipment could be located.

The location, costs and reliability of existing data sources and information are being investigated to determine the base line conditions for the following parameters within the ARR.

2.3.1 Meteorologic records

The aim is to establish a network of weather stations within the ARR (at a density to be determined) and surrounding regions, to collect, collate and analyse weather and climate information, enabling climatic variation within the ARR to be monitored. Climatic conditions for the ARR have been described by the Australian Bureau of Meteorology (1961), McAlpine (1969), Christian and Aldrick (1977), Woodroffe et al (1986), Nanson et al (1990), Riley (1991), Wasson (1992), Butterworth (1995) and McQuade et al (1996).

The following tasks have been identified for this project:

- Obtain locations of weather stations (operational and discontinued) and determine what instrumentation they have or had;

- Establish what data exists for each of the weather stations and its usefulness to the project;
- Determine the density of coverage required for a network of weather stations and establish where new stations should be located to complete full network coverage of the ARR.

The location of weather stations within the ARR and surrounds has been determined through consultation with Bureau of Meteorology (BOM) and the NT Power and Water Authority (PAWA), Department of Lands, Planning and Environment (DLPE) Water Resources Division. The instrumentation at these sites is presently being ascertained.

Data collation problems with remote locations mean that weather stations may be telegraphic, automatic, radar or Doppler radar, and can be set up for specific research purposes, usually in collaboration with other bodies. This substantially increases the cost of establishing weather stations.

A fully automated weather station has just been purchased by ***eriss*** ($8000) to be located at Jabiru East for use in various projects. All equipment, sensors and probes will be compatible with BOM standards.

Once this information has been gathered the existing network can be determined and additional weather stations may be established as necessary, within financial constraints.

2.3.2 Oceanographic records

The immediate aim of the oceanographic monitoring project for the ARR is to design an atmospheric and oceanographic monitoring framework for van Diemen Gulf. The oceanographic processes operating within van Diemen Gulf may have considerable influence upon the hydrology of the ARR; hence tidal data may provide insight into the hydrology and circulation within both the Gulf and the ARR. It has been suggested that offshore circulation patterns are tide and wind-driven whilst long and short wave radiation causes inshore effects (D Williams pers comm).

It is important to determine relationships between weather conditions, sea level fluctuation, water circulation and shoreline changes on the coast of the ARR, and to examine any relationships between sea level fluctuation and tidal water movement in the Wildman, South Alligator and East Alligator Rivers during low-flow conditions.

Unfortunately there are no tide gauges in van Diemen Gulf with Darwin Harbour (1/1/59 to present) and Melville Bay at Gove (9/5/80 to present) the closest, both operated by PAWA. There has been some work completed by PAWA with tide gauges, however, these are relatively short projects in the vicinity of Chambers Bay, Mary River region. Processes in van Diemen Gulf are complex, including oceanic processes and ENSO events, integrated with wind, tides, coastal and island geomorphology and bathymetry, which should all be part of the modelling process. A network of monitoring points (such as tide and weather stations) should be established around the Gulf to verify modelling. It may be possible to determine the circulation and current patterns in van Diemen Gulf using wind direction and velocity, therefore the location of weather stations that measure these parameters is also important to this project.

The following tasks have been identified:

- Investigate the oceanographic processes within van Diemen Gulf, beginning with a broad scale circulation model. More complex modelling should include wind, tidal and geomorphological influences affecting Gulf oceanography;

- Establish a network of monitoring points and tide stations around the Gulf to verify modelling;
- Investigate the worth of van Diemen Gulf as an indicator for predicting climate change in Australia.

This work is outside the scope of the present staffing at ***eriss*** and is likely to be carried out in collaboration with the University of Western Australia (UWA) and PAWA.

2.3.3 Hydrologic and river gauging records

The hydrological cycle of the ARR involves complex interactions between the atmosphere, the topography and the lithosphere. The ARR is drained by the South Alligator and East Alligator Rivers with the smaller West Alligator and Wildman Rivers draining the north-western portion of the region, all into van Diemen Gulf (fig 1). The Mary and Katherine Rivers drain a minor portion of the south-westerly part of the region. Much of the information on the hydrology of the region comes from Chartres et al (1991), Kingston (1991), Nanson et al (1990) and Roberts (1991), while McQuade et al (1996) suggests that the hydrology of the region is affected by three of the major physiographic land surface units: 1) the escarpment plateau; 2) the lowlands; and 3) the flood plains.

The tasks that have been identified are:

- Obtain locations of gauging or water level recorders (operational and discontinued), and determine the length of recorded data and its usefulness and reliability;
- Determine if the operational gauging stations are sufficient to provide the knowledge of the hydrology, rainfall and storm patterns of the ARR that is required. If they are not, determine locations where new stations might be established and investigate recommissioning gauges that have been discontinued;
- Investigate whether the use of data from surrounding regions might be satisfactory ie carry out a regional hydrologic analysis.

The locations and lengths of record for existing and discontinued gauging stations have been established, however at this stage the analysis has not been started. The aim is to understand the hydrology of the ARR and determine its regional context.

2.3.4 Shoreline movement and storm surges

Changes in shoreline characteristics and surge overwash features can be identified from vertical aerial photographs taken since 1940, gaining information which can be utilised in other projects eg status and distribution of mangrove communities. Patterns of shoreline movement occurring between 1943 and 1989, in the vicinity of Tommycut Creek and Sampan Creek on the Lower Mary River Plains, have been reported by Knighton et al (1992) and Woodroffe and Mulrennan (1993). The Lower Mary River Plains are adjacent to Kakadu National Park, both meeting van Diemen Gulf to the north.

The tasks identified are:

- Utilise aerial photography taken intermittently since 1943 (for which coastline only is available) to determine whether the shoreline of the ARR is experiencing the same trends;
- Investigate availability, usefulness and cost of Landsat and spot imagery as well as other remotely sensed information;
- Attempt to scan photographs into GIS environment and rectify from common points;
- Locate key areas by differential GPS and determine any obvious changes.

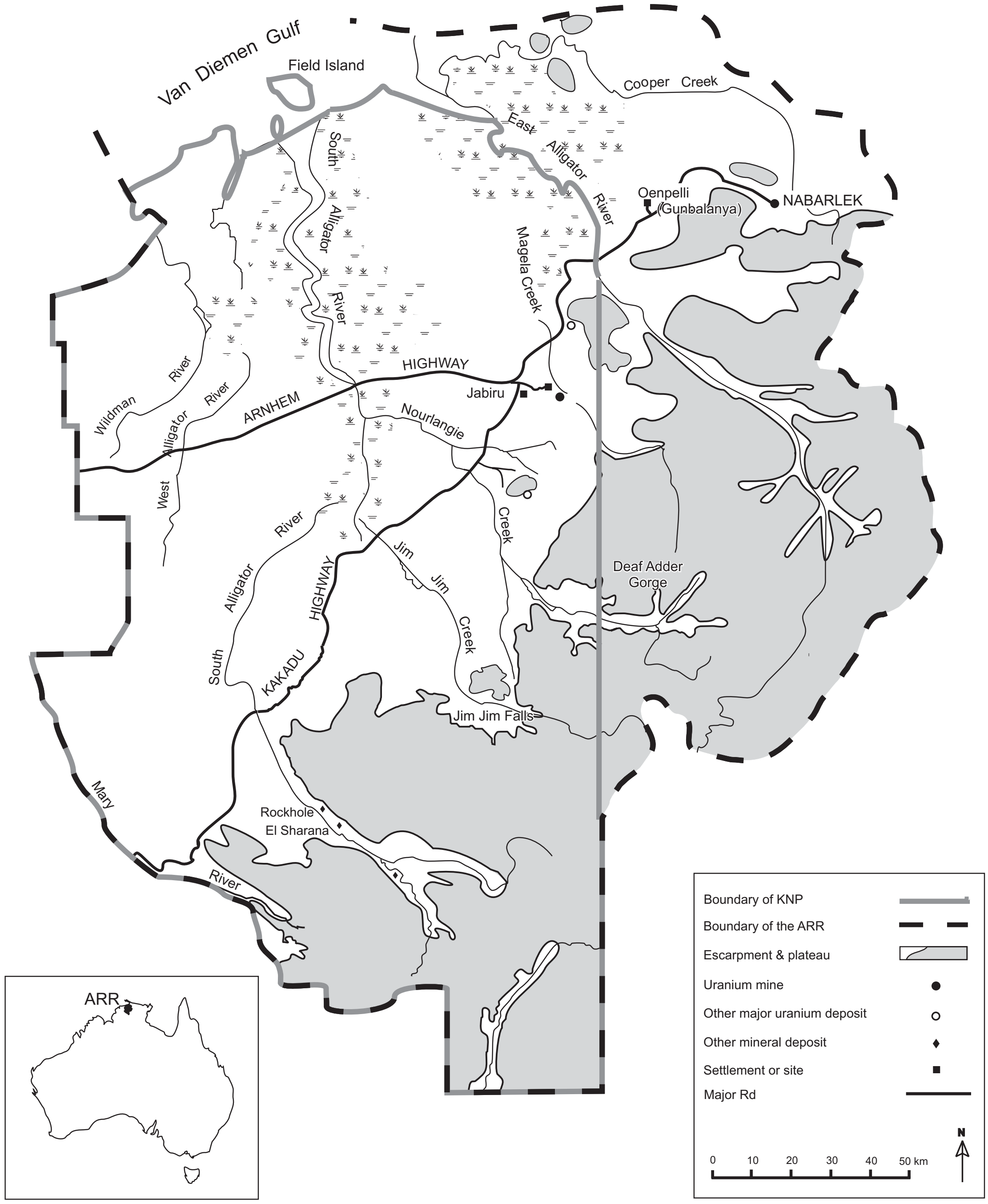

Figure 1 Drainage network of the Alligator Rivers Region

Relevant aerial photography should also be acquired to complement the existing aerial photographs that ***eriss*** has already obtained (1943, 1950, 1991). This existing and any future aerial photography will require some form of ground truthing.

A map of the existing shoreline of ARR, as well as historical changes that might have occurred, will be produced. This will serve as the baseline and provide information as to where potential monitoring sites could be established. If possible future aerial photography should be flown on a regular basis.

2.3.5 Mangrove distributions and species identification

The aim of this part of the coastal monitoring node is to determine spatial variation in the structure and productivity of mangrove communities along the coastline, including the coastal margin and lower estuarine reaches, in Kakadu National Park and the wider ARR.

In the vicinity of the ARR, Woodroffe and Mulrennan (1993) documented dramatic recent changes to the Lower Mary River floodplain, with salt water intrusion and upstream expansion of the tidal creek network. This has caused death of freshwater wetland communities with loss of 60 km^2 of Melaleuca forest, and upstream invasion of mangroves. There are a number of potential causes including shoreline retreat, salt water intrusion and sea level rise. There is therefore considerable overlap with the shoreline retreat and salt water intrusion sub-projects of the Coastal Monitoring program.

The main tasks identified are:

- Utilise aerial photography to determine present and past extent of mangroves as described in section 2.3.4; similarly utilise satellite imagery and georeferencing with the differential GPS.
- Collaborate with Darwin Harbour mangroves projects where possible, crossing jurisdictional boundaries only by invitation.

As mentioned in section 2.3.4 some of the relevant aerial photography has been purchased and it is envisaged that the project will be a collaboration with the Australian Institute of Marine Science and the Parks and Wildlife Commission of the Northern Territory. The expected outcomes are similar to those of shoreline retreat as there is considerable overlap in the methodologies.

2.3.6 Salt flats and saline intrusion

The aim of this part of the Coastal Monitoring program is to determine past and potential changes in salt flat distribution and abundance. This will involve mapping the current extent of salt flats, providing a basic description of the type of salt flats present, and determining the status of data – what historic data exists at present and what will be required in order to monitor changes in distribution and ecological character of salt flats of the ARR, including Kakadu National Park.

Changes in salt flats in the vicinity of the ARR have been suggested by Woodroffe and Mulrennan (1993), with documentation of dramatic recent changes to the lower Mary River floodplain, including salt water intrusion and upstream expansion of the tidal creek network. There are a number of possible reasons for these events, including relative sea-level rise (Woodroffe 1995). Extension of tidal creeks and mangrove development has occurred on river systems within Kakadu National Park (Woodroffe 1995). Clark and Guppy (1988) showed that sea-level rise of 0.5–1.0 m would convert the Alligator Rivers freshwater wetlands to the large mangrove swamp that existed during the mid Holocene.

The tasks required for this part of the project are very similar to those outlined in sections 2.3.4 and 2.3.5, with the addition of:

- Establishing markers to monitor rate of tree loss in combination with remotely sensed data;
- Examining techniques for measurement of soil salinity.

Several sub-projects have been identified:

- An initial survey of salt water intrusion into Melaleuca forest has been carried out by ***eriss*** and 3 sites selected.

- Kath Lynch (Northern Territory University) has completed an Honours project on salt tolerance of *Melaleuca* spp and provenances; responses in germination, growth and other physiological parameters.
- Stephanie Cobb (University of Western Australia) has completed an Honours project on channel extension and geomorphology of tidal creeks and salt flats in Kakadu National Park.

These projects have provided a greater understanding of the salt flats and associated geomorphic and biologic features in the ARR, which will serve as a base line for future monitoring.

2.3.7 History of land use and environmental change

The history of land use affects current uses and provides baseline information for monitoring.

Historical events and records can shed light upon the nature of the landscape prior to extensive non-Aboriginal land use in a region, assisting researchers and land managers to differentiate between natural and artificial change, and determine management priorities. When investigating environmental change, it is immediately a challenge to separate perceived from actual change. However, perceptions of change within the living memory of local people can serve as a guide to further investigation and research. This project gathers information on land use and environmental change from diverse sources, oral and written, with the aim of establishing a data registry of land use information. The project will also identify processes for a comprehensive historical analysis of this information. Current management issues may then be addressed with greater understanding of their history and more comprehensive baseline information available.

The tasks identified are:

- Carry out a literature review using metadata and other sources of information of land use changes in the region, including an analysis of the underlying reasons for such changes
- Identify and liaise with key contacts within agencies and/or associations and/or individuals holding unpublished information on land use changes
- Initiate a review of and document information on key organisations, including non-governmental groups and local community associations, involved in land use practices and management
- Obtain information on major changes in land use and store in an appropriately designed data registry
- Document and describe the extent of selected changes in land use, such as the presence and management of buffalo and extent of selected weed species
- Review the operations and management processes of the Lower Mary River Landcare Group.

The expected outcomes include:

- Analyses of major historical changes in land uses from both written and oral sources
- Analyses of management structures and their effectiveness in addressing changes in the coastal environment, including community involvement and inter-sectoral interaction.

2.3.8 Sediments and stratigraphy

Long-term variations in climate and sea level, those occurring over hundreds of years to millennia, in the ARR have been established in geomorphologic and stratigraphic investigations. These have been completed for the Mary (Woodroffe & Mulrennan 1993) and South Alligator River systems (Hope et al 1985, Woodroffe et al 1985a,b, 1986), the Magela Creek and coastal plains (Nanson et al 1990, Wasson 1992), and the Point Stuart chenier sequence (Clarke et al 1979, Lees 1987).

There is a need to review this work to determine whether additional work is required. For example, there is little mention in the literature of geomorphic and stratigraphic investigations undertaken and completed on the East Alligator River.

Several tasks have been identified:

- Review existing work and determine if additional work is required
- Address the apparent absence of sediment study with regard to floodplain stability and its relationship with tidal and stream sedimentation patterns.

Work is yet to begin on this aspect of the Coastal Monitoring program.

2.3.9 Remote sensing and landscape change

Remote sensing techniques will be used to determine the extent and character of wetlands in northern Australia, and to evaluate the effectiveness of remote sensing techniques in monitoring coastal processes and change.

Remote sensing is cost effective and perhaps the only feasible way to monitor wetlands in the Wet-Dry tropics of Australia. In conjunction with the development of the GIS, ***eriss*** is collaborating with several organisations with expertise in remote sensing.

The following projects are underway:

- Preliminary investigation of saline intrusion in the Point Farewell area using Landsat TM (***eriss*** and the Northern Territory University Centre for Tropical Wetland Management)
- Investigation into the spread of *Mimosa pigra* in test areas using Landsat TM (***eriss*** and the Northern Territory University Centre for Tropical Wetland Management)
- Identifying and monitoring change in wetland inundation and vegetation patterns in the ARR using RADARSAT data (***eriss*** and the University of New South Wales)
- AIRSAR data is also being acquired for the coastal areas between the East and South Alligator Rivers and will be used for several Northern Territory University student projects to investigate its usefulness in the region.

The role of ***eriss*** in these projects is mainly to carry out fieldwork and to store and use the products of the remote sensing projects in the GIS for these and other projects.

3 Monitoring framework for georeferencing in the Alligator Rivers Region

A wide variety of field survey and monitoring programs are undertaken in the ARR. Generally these are conducted as stand alone surveys. If the surveys are to be linked for comparative or other purposes, they need to use a common standard for georeferencing purposes. Hence, the aim of the Coastal Monitoring program is to provide a survey framework for georeferencing and mapping of all spatial information. This will be done by ***eriss*** in collaboration with other agencies and institutions.

3.1 Objectives

1. The survey framework and procedures for georeferencing will be achieved by developing a capacity for differential GPS survey for spatial biophysical monitoring and field assessment surveys within ***eriss***. Field observers at ***eriss*** will then use mobile, single and dual frequency GPS receivers standardised with an AUSLIG GPS base station to be located at Jabiru airport;
2. Relocate existing survey benchmarks (BM) on and adjacent to the floodplains within Kakadu National Park;
3. Select and establish new survey benchmarks;
4. Use the existing and new benchmarks together with the AUSLIG base station, to provide differential GPS control for kinematic mapping and position fixing in the field;
5. Link all survey information in the ESRI (Australia) ARC/INFO Geographic Information System for spatial analysis and display.

3.2 Background

The hand-held GPS usually provides locational accuracy of 50 to 100 m. This might be reasonable for bushwalking or locating a distinctive feature in the field but is not acceptable when accurate mapping of features such as mangrove distributions, tidal extension of creeks etc is required. If greater accuracy is required then a differential GPS might be used.

3.2.1 Global Positioning Systems (GPS)

GPS collect signals from satellites orbiting the earth to determine positions on the ground and in the air. A minimum of three of the 24 satellites that continuously orbit the earth are required to accurately determine a position. The satellites are owned and positioned in orbit by the US Department of Defence to provide world-wide, continuous all-weather information on the user's location. Accuracy varies from a sub-centimetre level to within 100 metres depending on how the signals are collected and processed. Rodgers et al (1996) say that GPS satellites emit two signals: 1) a high precision 'P-code' that provides centimetre accuracy, reserved for the military, and 2) a C/A code that allows 25 m accuracy for civilian applications. The use of a reference receiver at a known or surveyed location can reduce the errors to obtain horizontal accuracy better than 5m. With highly sophisticated GPS equipment, accuracy in the order of a few centimetres can be achieved. This system is called a differential GPS.

Differential GPS is a data collection and processing technique in which two or more receivers track the same satellites simultaneously. One receiver is located over a known reference point (such as a BM) and the position of an unknown point is determined relative to the reference point (Morton et al 1993). ***eriss*** has recently purchased a differential GPS, comprising of a dual frequency receiver to be set up over known locations and a single frequency receiver to be used as the *Rover* or mapping receiver.

3.2.2 Survey base stations

AUSLIG has a network of 14 GPS base stations around Australia and Antarctica, taking readings at 3 minute intervals. The sites are geologically stable and have an estimated accuracy of 0.01 parts per million. The closest GPS base station to the ARR was at Manton

Dam (60 km south of Darwin) until August, 1997, when AUSLIG relocated it to Jabiru airport. This move is expected to increase the accuracy (twofold) of any differential GPS used in the ARR. Figures quoted by AUSLIG and supply companies such as SAGEM suggest that accuracy of ± 30 mm in the horizontal and ± 50 mm in the vertical will be achievable.

3.2.3 Existing survey benchmarks

Survey benchmarks have been installed throughout Australia, including the ARR, and incorporated into the Australian Geodetic Survey Database. They provide a broad grid from which a more detailed survey framework can be constructed by differential GPS and established by monumentation in the field.

An AUSLIG search of the Geodetic Database, between the Latitudes -13.0 and -12.0 and Longitudes 132.0 and 133.0 found 15 stations within the ARR.

3.3 Tasks

The establishment of differential GPS at ***eriss*** will provide flexibility in establishing reference sites as they are required. It will also provide a survey framework for spatial differential GPS and develop ***eriss*** capacity to locate and map features such as saltwater intrusions, mangroves, wetland areas, cross-sections, tidal creek extensions etc.

The following tasks were identified as essential to the establishment of a georeferencing framework at ***eriss***:

- The relocation AUSLIG GPS base station from Manton Dam to Jabiru Airport was considered essential to obtain the required centimetre accuracy and was operational as an AUSLIG GPS base station by the end of August 1997.
- Ashtech differential GPS equipment was selected and purchased after discussions with AUSLIG to ensure that there is easy compatibility between data obtained at the base station and the field data. The equipment has arrived and relevant staff are undergoing training in its use. In the course of training, several of the streets in Jabiru have been mapped with the single frequency receiver mounted on a vehicle.
- The relocating of existing Benchmarks and Geodetic points within the ARR will take place to begin establishing a grid of known sites throughout the region. The route taken to reach these benchmarks will be mapped using the differential GPS, imported into a GIS and annotated with road names and significant landmarks. Government departments, agencies and companies such as AUSLIG, NT Department of Lands, Planning and Environment, Jabiru Town Council and ERA Ranger Uranium Mine were contacted to determine the existence of benchmarks.

The establishment of field control points will be completed as projects are implemented. The following points need to be addressed:

- Site selection and stability – when selecting sites for the location of field reference control stations, it is important that the sites are within 10–20 kilometres of the proposed study sites and located on stable ground. Examination of aerial photographs and field inspections are required before field control sites are installed.
- Costs and equipment required to establish field control stations – temporary field control stations can be established using a power drill with masonry bits and coach bolts. The coach bolts will be hammered into the rocks, painted and then the antenna can be placed on a tripod at a known height over the coach bolt. A tripod with a 5/8 whitworth thread

needs to be purchased. A post hole digger, concrete mixer, generators, appropriate vehicles and tools (wheelbarrow, shovels, trowels etc) are available. Other costs such as cement, steel reinforcing, PVC pipe etc are ongoing.

- Estimated time to establish each type of remote field control station is: temporary – 0.5 days, 2 people; permanent – 3 days, 2 people.

4 Conclusion

The establishment of differential GPS at ***eriss*** will enable geomorphic, biological features etc to be accurately mapped and located within the ARR. The ability to georeference such features will be a valuable tool within the frame work of future coastal monitoring in the region. The AUSLIG base station will be in operation by August 1997 and Ashtech differential GPS equipment has been purchased. Fieldwork using the differential GPS is programmed for September 1997.

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