Conservation and Development: Issues in North Australia

Edited by Bill Moffitt and Amy Webb
CONSERVATION AND DEVELOPMENT ISSUES
IN NORTHERN AUSTRALIA

Edited by
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NORTH AUSTRALIA RESEARCH UNIT
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Ian Moffatt & Ann Webb
PREFACE

The chapters included in this edited collection were presented as papers at the North Australia Research Unit annual conference, Planning for environmental change: conservation and development in north Australia, which was held at the Northern Territory Museum of Arts and Sciences in Darwin during September 1991.

The thirty-six papers presented during the three day conference examined conservation and development issues including methodologies for environmental management. While a broad range of issues were raised, paradoxically some themes such as conservation and management of marine resources, cultural resource management and development of alternative energy strategies using renewable energy sources, were not addressed. Nevertheless, the theme of conservation and development is captured in the following chapters which give an indication of current concerns and possible new ways of promoting ecologically sustainable development in Australia's north.

In his opening address Steve Hatton MLA gives a useful insight into the ways in which an experienced politician views the conservation/development debate in northern Australia. Mr Hatton has held a number of different Ministerial posts in the Territory Government: he has been Chief Minister and at the time of the conference he was Minister for Industries and Development. The conservation portfolio has also been one of his former Ministerial responsibilities. He argues that essentially the relationship between development and conservation is complex and has regretfully been dogged by confrontationalist politics. He suggests that both the environment and the communities living in north Australia would benefit if the competing interests of conservationists and developers could be reconciled thus bringing the concept of a common ecologically sustainable future, as discussed in Our Common Future (WCED 1987, 1990), nearer to a reality. This theme was developed in many of the conference papers and figures prominently throughout this book.

In chapter one some of the environmental problems in the Northern Territory are discussed from a community perspective. In particular Jackson argues that the Territory Government's record on environmental conservation to date has not been a positive one and that there needs to be action rather than fine words. Clearly, there are perceptual differences between those interested in pursuing economic growth at all costs and others who wish to pursue different forms of ecologically sustainable development. For Lea, the differences between the actors involved in planning for sustainable development are partly due to the different values that the conservationists and developers cherish. In chapter two he argues that if we are to offer some practical alternatives to encourage sustainable development, ethical considerations of both the physical and human environment are essential for a new approach to planning and development practice and policy formulation. In an attempt to bridge the perceptual differences between conservationists and developers, Vemuri and Perfect present a conceptual framework for the different groups involved in the environmental debate. This framework seeks to identify the various positions of the participants in the debate about conservation and development in north Australia and then to plan for strategies to achieve a compromise. This theme of encouraging environmental conservation especially in the face of development in north Australia runs throughout the remainder of the book.

Chapters four through to seventeen examine current conservation issues in north Australia. Beginning at the northern coastline, Mulrennan provides an overview of the problems of protecting the coastline and the management of coastal resources. In particular she notes the need to develop a national coastal zone management strategy for Australia which would act as a framework for integrating and co-ordinating the various initiatives at State/Territory and local council level. Any successful coastal management strategy must involve local communities as these people, plants and animals are the ones which are often the first
involved in any changes in the coastal environment. In chapter five Kraatz focusses on the problems of coastal management in the Northern Territory. She notes the lack of objective information on which to base coastal plans, lack of clear guidelines for the coast and the current lack of restrictions on environmentally unfriendly activities along the shoreline near populated areas. Yet, it is this type of baseline information which is urgently required as input into coastal environmental management programs. In the following two chapters attention is given to the importance of mangroves in northern Australia. Hanley notes the global importance of the pristine nature of much of north Australia's mangrove communities. He does, however, point out that the future of these ecologically important areas is under threat from population growth, climatic change and resource development and warns that without a substantial change in public perception and valuation of these important ecosystems, the future of mangrove systems in northern Australia could be in jeopardy. McGuinness finds that the complex interactions of living organisms in the mangrove ecosystem make predictions of disturbance outcomes difficult however preliminary research findings from Darwin Harbour appear to bear out Hanley's concern. In the case of uncertainty in the response of mangroves to natural and human-induced disturbances, it would appear sensible to err on the side of caution rather than risk destroying these ecologically important resources.

Russell-Smith, McKenzie and Woinarski examine the distribution and conservation of the tropical rainforests in monsoonal north Australia. They suggest that over 2750 km² of tropical rainforest exist in the Northern Territory and Western Australia but generally in small, isolated patches surrounded by savanna. The patchy distribution of rainforest poses enormous problems for conservation as these patchy areas are difficult to protect from cattle, fire and feral buffalo and pigs. Effective conservation of these 'pockets' can be achieved only through the co-operation of all landowners; given limited resources, the conservation of these areas needs to be given higher priority in any vegetation management plan of the region. A similar problem of conservation and management is posed by the endangered palm *Phychosperma bleeseri*. Duff, Wightman and Eamus recommend some conservation and management strategies to protect and promote this species.

The wetlands of the Northern Territory's 'Top End' cover some 10 500 km² extending east of Darwin to Kakadu National Park and from the coast some 100 km inland. In chapter ten Freeman describes the ways in which these important habitats can be conserved whilst still allowing recreation and tourism in the area. Drawing upon wetland habitat protection in the United Kingdom and south-east Australia, he demonstrates the ways in which changing attitudes have helped in making wetlands an integral part of our lifestyle and the expectations tourists have of a wetland environment. In the next chapter Whitehead, Wilson and Saalfeld explore some of the approaches required to conserve the Magpie Goose in the Northern Territory. They argue that effective conservation of the Magpie Goose and other wetland fauna depends on maintenance of this habitat mosaic on the broadest possible scale. Furthermore, they argue that this can only be achieved by recognising and exploiting the coincident and compatible interests of pastoralists, traditional owners, hunters and fishermen. Clearly the need to involve the local community in protecting the environment is essential. This theme is reinforced by the study of multiple land use in the lower Mary River located approximately 100 km east of Darwin. In chapter twelve Sterling examines the ways in which the different uses of wetland resources can be conserved by integrated catchment management using the lower Mary River as a case study. By encouraging local landholders and conservationists to co-operate, she argues, it is possible to produce sustainable development strategies to overcome some of the severe environmental problems including saltwater intrusions, feral animals and infestations of *Mimosa pigra* which are common to these north Australian wetlands.

Despite the importance of fire in savanna regions (Goldammer 1990), there has been little detailed research into its impact on the north Australian environment. Chapters thirteen through to seventeen, which are primarily concerned with the impact of fire on the management of tropical savannas, represent significant contributions to this area of research. Andersen and Braithwaite provide an overview of the important issues involved in fire
management in the Top End's savannas. Whilst fire management is a 'burning issue', they note that little objective scientific research has been undertaken in north Australia and stress the importance of scientific research input into any overall fire management strategy in north Australia. In the following chapter, Cook reports on a series of investigations into the mechanisms by which fires affect the nutrient budget in savanna landscapes based on CSIRO's fire and water experiments at Kapalga Research Station in Kakadu National Park. The results of these investigations have obvious implications for both fire and vegetation management as well as contributing to the reduction of greenhouse gas emissions in the north of Australia.

Because fires affect extensive areas of land in the Australian savanna, it is important to be able to monitor this phenomenon. Remote sensing is one way of monitoring these changes. In chapter fifteen, Head, O'Neill, Malthick and Fullagar report their use of LANDSAT Thematic Mapper (TM) images to monitor fire patterns since 1988. By integrating remote sensing with a geographical information system, they examine the spread of Aboriginal and pastoral fires around the Legune Station sites in the north-west of the Northern Territory. The results of their investigations indicate the applicability of remote sensing and geographical information systems to fire management in the savanna regions of north Australia. In particular they argue the need for Aborigines to be recognised by governments as legitimate land users and to have a voice in fire policy.

One of the obvious signs of fire on the tropical savannas in northern Australia is the occurrence of palls of smoke rising over the landscape. Early European explorers commented on this phenomenon and noted that both lightning strikes and Aboriginal fire management practices were the causes. More recently concern about the emission of greenhouse gases has raised the need for further research into the impact of fire management regimes on the release of carbon dioxide and methane into the atmosphere as well as the vegetation responses to these radiatively active gases in the tropics. In chapter sixteen Eamus and Duff examine the response of leaf, whole plant and regional scale response of vegetation to the increased carbon dioxide levels in north Australia. In the next chapter Van der Sommen examines the need for a vegetation management strategy for the Northern Territory. He argues that the area of relatively undisturbed vegetation is extensive in both area and variety and offers an opportunity for biological conservation. The best way to conserve these important biotic resources is to implement an effective vegetation management plan so as to avoid the consequences of either inaction or exploitation experienced elsewhere in Australia.

Although conservation strategies at national, State/Territory and local levels are essential for the wise use of resources, a point acknowledged in A National Conservation Strategy for Australia (DHAE 1983), it would be wrong to assume that environmental conservation is anti-economic development. What many conservationists are urging is that the proponents of economic development recognise the importance of ecological systems in maintaining the health of the planet for current and future generations. In some cases, such as fishing, forestry, arable agriculture and the pastoral industry, it does not make ecological sense to 'mine' the resource base in an unsustainable manner. This perspective has been addressed in the recent volumes on ecological sustainable development in Australia (Ecologically Sustainable Development; A Commonwealth Discussion Paper 1990; Ecologically Sustainable Development Working Groups 1991). Although we need economic development to provide food, clothing, shelter and the myriad of other commodities we take for granted in contemporary Australia, we also need to evaluate past practices. If they are unsustainable, they need to be transformed and sustainable forms of economic activity be introduced. In some cases this may mean that some old industries die out but new industries based on ecologically sound methods of development can be introduced (Hare et al 1990). These important topics are considered in the remainder of the book.

In chapter eighteen Ash, McIvor and Winter provide a broad overview of the ways in which rangelands can be managed for production without degradation in the vast savannas of northern Australia. They also explore the effects of various forage management options on pasture and animal production together with a study aiming to determine the effects of land
condition on productivity. In the following chapter Millington provides a concise overview of the pastoral industry in the semi-arid zone of central Australia. This overview, as seen from the perspective of a pastoralist, indicates how more ecologically enlightened members of the pastoral industry view ecologically sustainable production as good economic land management. This theme of careful ecological management as part of sensible economic behaviour is echoed in the development of the LAMSAT model of land management for pastoral land use in the extensive semi-arid tropics. Hairseine, Silbourn and Dilshad describe progress in developing the LAMSAT model for land degradation in the semi-arid tropics. Like other similar models, it is expected that the LAMSAT model will introduce quantitative assessment of land degradation for different land management agencies operating in the semi-arid tropics. One important aspect of modelling vegetation changes in tropical Australia is the need to be able to monitor changes over vast areas of the land surface. Remote sensing and geographical informations systems can play an important role here. In chapter twenty-one Ringrose and Matheson report on the use of LANDSAT Thematic Mapper to attempt to quantify the residual vegetation cover of late dry season Thematic Mapper images of the Barkly region to help provide a basis for rangeland monitoring under the Northern Territory’s Pastoral Land Act 1992. Despite the use of sophisticated techniques they argue that further research still needs to be undertaken to determine the feasibility of this approach to vegetation monitoring of pastoral land.

Whilst advanced techniques such as remote sensing, geographical information systems and modelling are an indispensable part of scientific research, these methods are only part of the system of environmental management. It is vital to involve local communities in ecologically sustainable development. Often the translation of grand designs of land management have failed not only because of a lack of scientific information but also because of the insistence that only a ‘top-down’ approach be used rather than getting local communities to become involved as a ‘bottom-up’ strategy. In chapter twenty-two Dale highlights this problem. He seeks to explain why the Federal Aboriginal Employment Development Policy (AEDP) funded program has failed in its quest to promote community participation and planning in the Aurukun Cattle Project in northern Queensland. The importance of Dale’s in-depth study of this failed project lies in establishing some of the conditions which ought to be incorporated in any attempt to promote community involvement in conservation planning especially in Aboriginal communities since they represent an important group of landowners in northern Australia. Ledgar then considers the various perspectives on the sustainable management of rangelands in the Northern Territory. Unlike Millington, Ledgar argues that pastoralism is not sustainable as currently practised and he poses the question of whether or not pastoralism is the most appropriate use of land in northern Australia.

Mining is an important aspect of the north Australian economy. In some cases its importance is exaggerated by the mining companies and often denigrated by environmental conservationists. In particular, discussion of uranium mining in north Australia is likely to raise the temperature of any meeting of conservationists and developers. At present Ranger Uranium Mine is operational in the Northern Territory and its non-renewable resource is expected to last until 2012. One of the many environmental problems associated with uranium mining is mine site rehabilitation. In Ranger’s case, some effort has been put into rehabilitation of the spoil tips. Unger and Milnes report on a variety of investigations into specific aspects of rehabilitation at Ranger. Research in progress promises to provide short and long-term rehabilitation guidelines which Ranger and other similar mining operations could follow. The following chapter also assesses the restoration of previously mined land at Ranger uranium mine using ants as indicators of ecological restoration. Andersen stresses that restoration must be concerned with the proper functioning of an ecosystem and not merely with cosmetic conservation. He argues that currently employed revegetation practices based largely on Acacia species are inappropriate for successful revegetation at Ranger. These two chapters suggest that further investigation into rehabilitation of mine sites will not be without controversy.
Perhaps the most important question in mineral exploitation is the decision to mine or not. In 1988 the Coronation Hill Joint Venture proposed to develop a new mining operation to produce gold, platinum and palladium within Stage Three of Kakadu National Park, a World Heritage area in the Northern Territory. The Federal Government allowed the project to proceed subject to 'normal environmental, Aboriginal heritage and related clearances' (Joint Ministerial Statement of 16th September 1986). This site had already been mined in the 1950s long before the establishment of Kakadu National Park and prior to the politicisation of Aboriginal people in Australia. The attempt to re-open the mine site was proposed in 1984 and a final environmental impact assessment made in 1989 (Dames & Moore 1989). A further change to the decision-making process was made by the Federal Government's creation of the Resource Assessment Commission (RAC) in an attempt to develop an integrated approach to conservation and development at an early stage in the decision-making process to establish a mine. Galligan and Lynch draw upon the recent inquiry by the RAC into the proposed mining enterprise at Coronation Hill to evaluate the success of the RAC process.

The final group of papers outlines some of the ways in which sustainability can be incorporated into environmental conservation policy making. In chapter twenty-seven Moffatt outlines some preliminary results of a dynamic model of sustainable development. In particular, the model demonstrates that sustainable development can be achieved in theory but complex and difficult choices need to be addressed. While agreeing that more basic research into conservation needs to be undertaken, he argues that this, in itself, should not prevent policy-makers from arriving at a decision whether or not to adopt sustainable development strategies (which will, no doubt, vary as the specific ecological and economic systems vary). One way of checking that environmental policies are having the desired effect is to evaluate the program by using environmental audits. Aspects of auditing objectives and some of the problems associated with its application in Australia are reviewed by Read. This is followed by Dawson, who in the concluding chapter examines environmental assessment and planning law in the Northern Territory and asks whether there should indeed be some law reform in this area? Her answer to this question raises the fundamental issues of promoting a participatory, socially just and sustainable future for northern Australia.

Ian Moffatt and Ann Webb

References


OPENING ADDRESS

The Honourable Steve Hatton MLA,
Minister for Industries and Development

Members of the North Australia Research Unit, representatives of CSIRO and the Conservation Commission of the Northern Territory, conference delegates, ladies and gentlemen. This conference has become an important event in the Territory and I would like to pay tribute to the North Australia Research Unit for its organisation and in particular to the person who did most of the work leading to this year’s conference, Dr Ian Moffatt.

The conference title suggests an orderly response to the changing nature of our environment, because implicit in the planning concept is the reconciliation of the interests of environmental protection and industrial development. The reality is quite different. As someone who is intimately acquainted with the policy-making process, I can assure you that environmental policy and planning involves some of the most difficult tasks facing governments today. Before appropriate responses can be formulated we must know the nature and the extent of projected environmental changes; we must establish the price the community is prepared to pay — in real terms as well as opportunity cost — to maintain environmental quality; and we must respond appropriately to various industry and community-based lobby groups. This is a very complex situation and it would be a bold person indeed who professes to have all the answers.

Looking through the conference program I noticed that many of the presenters are concerned also with this issue of the relationship between development and environmental protection.

One of the major problems confronting our attempts to clarify this situation is the fact that we do not yet have a clear picture of our impact on the environment with a realistic world model that will allow the confident prediction of outcomes at the macro level. Our scientists can do a pretty good job of predicting environmental changes as a result of known inputs at the micro level, such as the extent of soil erosion resulting from water flow, but it is very much more complex to try to evaluate the consequential effect of changes in the reflection of sunlight and heat loss from denuded areas, and of the impact of additional nutrients on the marine environment. Currently, General Circulation Models (large computer models of the global atmosphere) can provide some indications as to climatic changes depending on variations in such inputs as soil hydrology, clouds and ocean/atmosphere interaction, but the links between cause and effect, at the micro and macro level, are still very indistinct. Until they can be verified the formulation of environmental policy will be based on limited data, best estimates and on political influence.

We are probably doing as well as we can in addressing the need for more and better data, but as far as the politics of the environment is concerned there is considerable scope for positive developments.

Environmental policy to date has been achieved in a climate of mistrust and confrontation, with environmental lobby groups on one hand, business and industrial interests on the other, and government in the middle. Of course this is an over-simplification, but it is essentially true that to date this background of conflict has dominated the community’s consideration of environmental issues. I would be very concerned if this was to be a long-term trend, because there is a danger that real solutions to real environmental problems become lost in ideological power struggles.

I am currently Minister for Industries and Development and I was previously Minister for Conservation so I have a reasonably good appreciation of the arguments on both sides of the fence. What has been most obvious to me is how close the opposing sides are in terms of their shared aim of securing the long-term viability of our natural resources — another way of saying that sustainable development should be attractive to both sides. Unfortunately, I have observed on occasions debate on particular environmental issues which has been obscured by bitterness, misrepresentation and attempts to limit discussion to the agenda of one party or the other. The environmental lobby groups in particular have assumed high-profile roles with clever use of the media and good political skills, but in the process they have alienated a large sector of the community which perceives them as too radical and inimical to development.
During my time as Minister for Conservation, the Territory Government formed a Northern Territory Landcare Committee to oversee activities of the Year and Decade of Landcare. We concluded an agreement with the Commonwealth regarding the environmental assessment of development proposals; I initiated the development of a recycling strategy, began Territory-wide consultation for a Conservation Strategy, and introduced Ozone Protection Legislation. In addition, the Northern Territory Government has for several years had a Greenhouse Committee to advise the Chief Minister and has endorsed the concept of a National Greenhouse Strategy.

Throughout all of these developments, environmental lobby groups have played an important role, often adversarial but sometimes supportive of Government initiatives.

My position is that as a Government we can achieve more with the support of the environmental groups than with their opposition. It is disappointing when so many members of these groups seem to see the Country Liberal Party as their natural enemy.

Environmental lobby groups have been an essential part of the policy development processes in which I have been involved and they may continue to perform very valuable and socially responsible roles. However, if they want to become a permanent fixture in the community, they need a valid role and this means much more than reacting to particular issues in ways designed primarily to raise their media profile and serve political ends. Organisations such as the Australian Conservation Foundation have evolved into multi-million dollar enterprises heavily funded by the Federal Government and deeply involved in political activity. I suggest that such organisations have a vested interest in maintaining a permanent position of political influence and patronage rather than working, first and foremost, to serve the community's environmental interests. Their participation in environmental debates and their adversarial approach to issues and projects often seems designed to meet political criteria at the expense of the community they are supposed to represent. If the environmental lobby groups are to have the respect of both sides of politics in Australia — and the respect of business and industry organisations — they will need to give credit to progress when it occurs and become more careful in their selection of issues.

There has been real progress in recent years, my current ministerial responsibilities have involved me in the consideration of new industrial projects, and I can assure you there is a very high level of awareness of environmental responsibility amongst our senior executives of industry these days. To some degree this is simply good business sense and recognition of the possibility of adverse publicity, legal actions and disruption to business which can follow environmentally damaging actions and decisions, but we should be aware that company executives are also members of the community, with the normal concerns that most individuals and families have about our environment.

In general, I think large public corporations are more environmentally responsible than most people give them credit for. But there is one problem that arises occasionally, particularly in relation to major projects: environmental assessment processes are conducted as external measures of a project's acceptability and almost as an afterthought. That is, you do your sums based on establishment costs, pricing, potential markets, etc., and then you look at how that stacks up in terms of environmental impact and make adjustments as necessary. My contention is that environmental considerations should be factored into the equation from day one, they should be an integral part of the planning process, not an adjunct to satisfy legislative requirements. If every industrial development project was handled in this way, both the developers and government departments would save a lot of the time and money now wasted in re-developing proposals and re-evaluating projects.

Some people would question whether we should be promoting industrial development at all, but it is clear that the community has opted for economic growth in view of the continuing community demands for increasing standards of living, high employment rates, better health care and education services, and improvements in public facilities and services — all of which can only be funded by economic growth.

There is also a powerful argument that adequate environmental controls and standards will only work in conjunction with economic growth. To give you an example: data collected by the steering committee of the United Nations-sponsored Ministerial Conference on Atmospheric Pollution and Climate Change two years ago showed that for about 1.5 billion of the world's people, firewood was the most important — sometimes the only — source of energy. Of these people, more than half lived in areas which already suffered from a scarcity of firewood and one in 15 could not get enough firewood for their basic needs. At that conference I listened to a delegate from Tanzania make an eloquent plea to the developed countries to help...
countries such as his — where 95 per cent of
domestic energy comes from firewood and the
forests are being rapidly depleted — to install
electricity systems and help raise their standard of
living because, as he pointed out, how do you tell
people to stop chopping down trees when the
alternative is starvation? This pattern is repeated
throughout the Third World, with over-grazing and
inappropriate agricultural techniques leading to
deforestation and land degradation on a massive
scale. Those resources will not be protected until
those countries are able to move away from the
situation of too many people subsisting through the
exploitation of inadequate natural resources. The
only way that can happen rapidly is through
economic development with finance technology
transfer and other assistance from the developed
nations.

If you accept this argument for economic growth,
you must then question the desirability of
preventing such growth through the application of
extreme environmental protection measures.

It is my opinion that major projects and
environmental protection measures should be
subject to an economic impact assessment so that
the other side of the argument is clearly defined and
can be measured against the environmental impact.
If environmental protection measures are
worthwhile, they should be able to stand scrutiny in
terms of opportunity cost and long-term economic
benefits.

The concept of sustainable development goes some
way towards reconciling the competing interests of
conservation and economic development, but there
will continue to be a range of opinions on what
constitutes sustainability, what is an acceptable level
of economic growth and the price the community is
prepared to pay for environmental protection. The
challenge is to define these issues clearly and to find
common ground.

For the benefit of all of us, we need less
confrontation and more progress in the debate
between the environmentalists and the business and
industrial sectors. It would help if both sides could
at least agree that they are working towards
common aims. Until this happens, much of our
planning for environmental change will continue to
be conducted on an ad hoc basis, dominated by
reaction to short-term issues and designed to placate
powerful lobby groups. Our common future
deserves a considered response.

Over the next three days of the conference,
dellegates from various research institutions and
both the private and public sector industry within
Australia will be present some of their research
findings. Some have come long distances to attend
and that is appreciated.

I wish you all a successful and rewarding meeting
and I look forward to reading the conference
proceedings in due course. Ladies and gentlemen, it
gives me great pleasure to open this conference on
Planning for Environmental Change:
Conservation and Development in North
Australia.
CHAPTER 1

ENVIRONMENTAL PROBLEMS IN THE NORTHERN TERRITORY
— A COMMUNITY PERSPECTIVE

Sue Jackson

Introduction

In order to be able to claim that the views expressed in this paper represent a community perspective, one must appreciate the role and functions of the Environment Centre in what is commonly, if not mistakenly, referred to as 'the conservation and development debate'. The Northern Territory Environment Centre is a community resource centre whose role is to encourage environmentally responsible attitudes. The Centre employs a number of staff and houses many volunteers who commit themselves to education, research, lobbying government and industry, providing information, policy advice and resources to the media, education institutions and the bureaucracy. The Centre has members residing throughout the Territory and encourages public participation in all matters affecting the environment.

It is not an easy task to categorise environmental problems as being specifically local, Top End or Northern Territory problems because what we are all learning very quickly is that there are no neat territorial barriers to most of the world's environmental problems or even those which are more localised. The ramifications of the Greenhouse Effect will be felt here in the Northern Territory and throughout the world; so too will the thinning of the ozone layer. Neither the Northern Territory nor any State in Australia can isolate itself from the changes which humans here and in the rest of the world are currently bringing about.

The Northern Territory, as part of an industrialised nation, suffers from many of the environmental problems characteristic of other states or regions. The impact of European development in the Territory has been devastating in some areas, such as the arid zone's rate of species extinction, and less so in other areas, such as industrial and urban pollution of marine environments.

If we look at most of the problems facing the Territory environment today and ask 'how well do we appreciate their extent and ramifications?' and 'what are we prepared to do to remedy and prevent further problems arising?', the answers are likely to be quite alarming. The answer to the first question appears to be relatively simple: we need to know more and to appreciate more thoroughly the impact that our activities have on natural ecosystems. Where we do not know enough we should err on the side of caution, ie, we should take a precautionary approach to decisions which affect the environment. In the Northern Territory many policy makers are willing to recognise how little is known, however few are willing to adopt a 'risk-averse' or precautionary approach.

The answer to the second question — 'what are we prepared to do to remedy existing environmental problems and prevent further ones from arising?' is less clear cut. The Environment Centre believes that we, as the Northern Territory community, are not doing enough. The government's attitude to conservation and the imperative that the global ecological crisis creates is far from reassuring. Industry groups are similarly slow to act yet public awareness and action has escalated in the past few years.

The Environment Centre frequently encounters a reluctance to acknowledge the full extent of environmental problems and a tendency to dismiss them, claiming that our problems are not as critical as elsewhere, that the Northern Territory is a big place with a small population. For instance, Darwin harbour is not as polluted as Bondi, the health and safety problems at Ranger are not as bad as at Roxby Downs, the Northern Territory does not release as much carbon-dioxide into the atmosphere as Victoria does. This parochial and defensive attitude is preventing us from actually acknowledging the real extent of the problems and doing all that we can to minimise the effects and, where possible, prevent them.

This attitude is nowhere more evident than in an address made to the Australian Mining Industry
Environmental problems in the Northern Territory

Council Conference in 1990, by the Territory Chief Minister, Marshall Perron, who said:

*Due to over-crowding and industrial concentration, it may be necessary to apply the development brakes in some parts of the country, but not in the Territory where we have less than one percent of Australia's population, and one sixth of the continent in which to spread our wings* (Perron 1990).

A less blatant example of parochialism can be found in a press statement made by the former Minister for Conservation. The Environment Centre has been concerned about Australia's largest known Ghost Bat colony at Pine Creek where mineral exploration of the roosting site is imminent. The Australian National Parks and Wildlife Service (ANPWS) has recommended that the species be listed as endangered and, in recognition of the importance of the Kohinoor Adit to species conservation, that 'the Adit be protected at all costs' (Macroderma Expert Group 1990). In defense of exploration of the Adit the last paragraph of the Conservation Minister's press release reads:

*The ghost bat is protected in the Northern Territory and is listed by the International Union of Conservation Nations as 'vulnerable'. However, it is the Territory's second most abundant cave-dwelling bat species and is not considered to be under threat in the Northern Territory* (Hatton 1990).

The Environment Centre believes that we cannot afford to be so parochial and apathetic about the problems we face, nor can we afford to scorn the lessons learnt in other regions. We have a personal, local and international responsibility to change our current way of treating the natural environment to ensure that we halt the loss of species, conserve a representative area of our wetlands, woodlands and arid lands, indeed of all land system types, and that we minimise our consumption of resources and production of wastes, — in short — that we live sustainably.

Given that species loss is irreversible and ecological degradation is reversible but only at an increased cost to future generations, it is an urgent responsibility of this generation to act to protect biodiversity and ecological integrity (Hare *et al* 1990). To add a temporal perspective, we also have an 'evolutionary responsibility' to leave the next generation with an environment at least as healthy, diverse and productive as the current one.

It is important that governments, industry, scientists and the public appreciate the state of decline that global and Australian environments are experiencing. Loss of biological diversity and the degradation of natural systems are accelerating. The world is threatened with unprecedented climate change which will require international effort to effect a global solution.

Here in the Northern Territory there is an opportunity to learn from the mistakes experienced elsewhere and to protect the wealth of natural resources remaining. The Territory Government, industry and many sectors of the community do not yet understand how critical it is that we change the fundamental way we interact with the environment and that we must find new ways of meeting needs and re-assessing wants. Almost ten years after the National Conservation Strategy was released, the NT still does not have a strategy or plan to ensure that conservation is given the priority it deserves. In August 1989 the Chief Minister directed the Conservation Commission of the Northern Territory to prepare a Conservation Strategy; two years later it is still not ready to be implemented.

Clearly over the past few years there has been some attempt by the Northern Territory Government to have its say in the 'environment debate' and to acknowledge the problems. The Draft Conservation Strategy, released early in 1992 for public comment, states that:

*It would be foolish to understate our problems, past, present and future. Substantial changes have occurred in the natural environment. Evidence points to rangeland and wetland degradation arising from a variety of impacts such as grazing pressures, feral animals, tidal intrusions, wildfires, weeds and infrastructural, urban and industrial developments* (CCNT 1992, 15).

Yet there remains no firm commitment by the Territory Government to provide direction and increase its involvement in managing and protecting the environment.

Some industry groups are working to lessen the impact that their activities have on the environment. But there is still a long way to go. The argument over the mining industry's access to land, particularly national parks, demonstrates how strongly the lines of conflict are drawn and how ecological imperatives still take second place to economic demands.
Only last year Chief Minister Marshall Perron, in his address to the AMIC conference, proudly claimed that the mining industry was welcome to explore and mine the Territory’s parks. He said on that occasion that ‘the environment is not a big issue in the Territory’ and that the NT serves as a quarry and cattle run for the rest of the country... parks created by the Territory Country Liberal Government will make miners welcome’ (Perron 1990).

Environmental problems in the Northern Territory

Any attempt to cover all the major environmental problems facing the Territory, and the causative factors would produce a very long list. The areas that would require attention would include:

- the NT’s past and present economic development
- biological conservation
- energy and resource efficiency
- urban planning
- transport
- waste and pollution
- sustainable land management and tourism
- conservation on Aboriginal land
- feral animals, weeds, fire
- social equity issues

They all of course overlap and are linked in many ways but in this paper a few major points will be focused on. They are:

1. Community attitudes and awareness
2. Conservation and biodiversity
3. Climate change and energy dependency
4. Mineral resource dependency

The first two topics will be given greater attention as they illustrate how far we have come as a community and how far we still have to go in successfully tackling the Territory’s environmental problems. The first aspect encompassing the change in public awareness and attitudes is heartening and encouraging; the second, addressing the Territory’s record of nature conservation, is far less so. Two global conditions which will become increasingly problematic for the Northern Territory’s natural systems are covered briefly: they are global climate change and society’s dependence on the mineral and non-renewable energy sector.

Community attitudes and public participation

One of the most important approaches that a community organisation such as the Environment Centre can employ in achieving its objectives is that of influencing perceptions and attitudes. Given the seriousness of environmental degradation and the urgency of finding ways and means of repairing this and preventing further degradation, the attitudes of many politicians, industry leaders, decision-makers and members of the public need to change if the Northern Territory community is to be set on an ecologically sustainable path.

There is little doubt, however, that attitudes are changing. At a Greenhouse seminar in 1988 the Environment Centre’s Co-ordinator, Mike Krockenberger, identified the Northern Territory Government’s convenient mask for inaction — the politician’s claim that ‘we have a conservative community’. Such a response is no longer given in response to the Environment Centre’s demands for action. The Territory Government is now recognising that the community expects some active and positive solutions to the problems.

The Territory’s so-called ‘conservative community’ is increasingly concerned about environmental issues and is willing to make some changes to its lifestyle to effect change; Government and the media are well aware of the change. On a political level, the force of green votes was demonstrated convincingly in 1989 when a Green independent won 18% of the vote in a Territory by-election bringing the ALP the Darwin seat of Wanguri on preferences. At a community level, proof of the change abounds.

The results from the community consultation program for the development of a Northern Territory Conservation Strategy provided an impressive level of interest in, and concern for, the environmental problems facing the Northern Territory. Most people found it difficult to focus on what an overall strategy should be and do, however they did want to have a say about particular issues and it was clear that they had devoted considerable thought to many of their local problems. Particular issues that arose were rehabilitation of mine sites, fire management, land degradation and pastoral activities, recycling, feral animal control, Greenhouse and ozone concerns, the need for local and regional strategies and the role of the public in making decisions that affect the environment.

In Darwin the results from City Council surveys provide evidence of a clear commitment on the part of the city’s residents to recycling and the protection of Darwin’s coastal zone. Approximately 80% of respondents felt that recycling facilities should be provided in Darwin. The majority of the survey preferred low-key development in a limited number
of designated coastal areas, while 20% believed that there should be no development at all on any foreshore areas (Darwin City Council 1990).

The establishment of local action groups devoted to protecting a local resource such as Rapid Creek or preventing a development such as the ten storey building at Nightcliff are evidence of greater public awareness and concern about environmental issues in the Northern Territory.

**Conservation and biodiversity**

*Northern Australia is in a magnificent position, with large areas of the wet-dry tropics in a relatively intact state, to do something no longer possible in other parts of the world ... it is part of our responsibility to the world not to miss the opportunity (Braithwaite & Werner, 1987).*

The composition of the Northern Territory's parks and reserves system and the Territory government's attitude towards the management of the conservation estate presents a test in any examination of the NT's record of nature conservation. Maintenance of biodiversity and nature conservation are such fundamental principles of ecologically sustainable development that it is difficult to imagine that a government which fails to recognise the urgent priority they deserve (or a community which allows this) will be willing to play a constructive part in global issues such as the Greenhouse Effect and Australia's high rate of resource consumption.

A representative conservation reserve system has been a priority for the Environment Centre since its first days of operation in the mid 1980s. Such a system is essential in protecting samples of ecosystem types and ecosystems of exceptional diversity, in achieving on-site protection of rare or endangered species to prevent extinction, and in protecting watersheds and catchments.

The maintenance of biodiversity however will, depend on more than the existence of a comprehensive reserve and park network. It will depend on sound, informed management of the reserve system and adequate protection for environments outside reserves. Management practices will need to concentrate on minimisation of loss of biodiversity outside reserves.

In the Northern Territory, we do not yet have a representative system of parks and reserves, either marine or terrestrial. Approximately 3.2% of the Territory is set aside for conservation purposes, about half of which is under management by Territory agencies, with the Commonwealth responsible for the balance (CCNT 1992). Before the announcement of the Beagle Gulf Marine Park in late 1991, the Territory had four marine protected areas comprising 0.258 million ha whereas the national figure is 237 covering 2.25 million ha. In comparison, in 1991 Western Australia had 17 marine and estuarine protected areas covering 1.095 million ha (Bridgewater & Ivanovic 1991).

In the Northern Territory many of the protected areas were so declared because of their tourist or scenic value and have been acquired in an ad hoc fashion. The Northern Territory's Draft Conservation Strategy states:

*With some notable exceptions, new reserves were acquired opportunistically, rather than in accordance with a master plan and the principles and criteria set up by the IUCN and the World Conservation Strategy (CCNT 1992).*

Areas that are particularly under-represented are the Barkly Tablelands and Mitchell grass areas, the northern fringe of the Tanami Desert, the Gulf of Carpentaria and eastern Armth Land, and the arid zone of Central Australia.

It has been acknowledged that the best way to protect species is to protect their habitats in substantial areas of natural ecosystems. These areas must be extensive enough to allow the capacity for a wide diversity of species not just to survive but to continue to evolve, especially during times of rapid and intense climate change. One recent authoritative publication has suggested that the amount of protected habitat around the world needs to be increased by a factor of three if these areas are to make the necessary contribution to conserving biological diversity (McNeely et al 1990).

Approximately one quarter of the vertebrate species known from the north-western region of Australia is not reserved by the current park system (Woinarski, in press). This proportion is very high compared with temperate regions of Australia.

An understanding of the Territory's ecology is absolutely essential in determining what areas need to be set aside and how they are to be managed. In 1987 CSIRO researchers noted:

*There is considerable alarm that perhaps only one in ten to one in twenty species in the tropics are known to science, and that much of this diversity will be lost through habitat*
destruction before scientific descriptions can be made (Braithwaite & Werner, 1987).

National parks are clearly the most important means of achieving ecosystem protection, and are therefore crucial for achieving a high degree of habitat conservation. However declaration of parks and reserves alone will not ensure their conservation. Conservation reserves must be managed so as to provide security to flora and fauna. In the Northern Territory an area requiring attention is the conservation value of land under Aboriginal ownership and the effects of management practices on those values. There are opportunities to do this through joint management arrangements of parks, as is the case with Uluru, Nitmiluk, Kakadu and Gurig National Parks, and through extensive consultation with traditional owners on Aboriginal land.

Most of the Northern Territory parks and nature reserves are being managed in such a manner that conservation objectives are not given the highest priority. In most parks recreation and tourism are promoted over nature conservation, and exploitative activities such as grazing and mining are allowed. Mining, mineral exploration, agriculture, and large-scale tourist developments will degrade the natural values of these protected areas and will not ensure that natural areas are available for wildlife to survive and evolve. These areas should be protected from incursions of industrial activity where the effects are felt well beyond the period of activity, irreversible damage may occur, and the landscape is disrupted.

In the Northern Territory we have a number of inappropriate developments being promoted, often well before management plans designed to canvas public opinion have been developed. The Conservation Commission has been actively promoting tourist developments such as hotels and wagon tours in parks and has allowed, or plans, to allow cattle and buffalo to graze on nature reserves, for example, Mary River Nature Reserve and Connell's Lagoon Nature Reserve.

Connell's Lagoon represents approximately 0.05% of the total area of Australia's Mitchell grasslands (Fisher 1991). It is acknowledged that the Reserve is important as "a refuge for those native fauna whose habitats have been seriously disrupted by pastoral activities". Yet in the Draft Management Plan it is proposed that one of the objectives of the reserve should be "to design and conduct fire management and grazing experiments with a view to arriving at management prescriptions for the region". The Centre maintained in its submission to the Draft Plan that the values of the reserve in its current ungrazed state are too high, and the area of the reserve is too small, to encompass experiments which may later put at risk this habitat. Such experiments should be carried out on neighbouring pastoral properties.

Litchfield Park provides a vivid example of where inappropriate developments have been planned and have resulted in public outcry when the details have come to light. A hotel was planned for construction within 500 metres of Wangi Falls, a bridge was proposed over Tolmer falls and mineral exploration has been going on in the southern part of the park. When questioned about the hotel proposal, the former Director of the Conservation Commission of the Northern Territory claimed that the Commission needed to privatise provision of services in the park and that 'Commission officers were not garbage collectors' (Fuller, pers comm, October 1990). The information base for Litchfield is extremely poor, making it virtually impossible to produce adequate management prescriptions aimed at protecting natural conservation values. Biological and land capability surveys should be a high priority and precede all future developments within the Park.

The Environment Centre views the management of Territory parks and reserves as a very serious issue. At the 18th General Assembly of the IUCN in Perth in 1990, the Commission on Parks and Protected Areas reaffirmed its commitment to an international system of conservation areas free from mining and other exploitative activities, where, as the IUCN advocate:

The ecosystems are managed to sustain tourism and educational activities on a controlled basis. The area is managed in a natural or near-natural state. Visitors enter under special conditions for inspirational, educational, cultural and recreational purposes (IUCN 1990, 16).

Yet in the Territory, the Government and mining industry continue to promote the concept of multiple land-use where 'anything goes anywhere'. This attitude will not ensure that those areas set aside for biological conservation are managed as such and will be increasingly criticised by the public who value the Territory's park system highly. Over 3500 people recently signed a petition opposing development of Litchfield Park, further demonstrating that a large sector of the Territory public acknowledges that conservation should come first in park management.
Climate change and energy dependency

Greenhouse is but one expression of the changes humans have induced through pollution. The hole in the ozone layer is another. Changes in climate, for example in weather patterns, have the potential to produce serious environmental, social and economic problems for the Top End.

A recent study predicted that by 2030 average surface temperatures will have increased by some 1 or 2 degrees Celsius in northern coastal areas, and 2 to 4 degrees inland, especially in the dry season (relative to the 1980 levels) (CSIRO 1990). Sea level rise, as a consequence of temperature increases, will exacerbate the effects of local and regional extreme sea level events, which will also change as a result of enhanced Greenhouse Effects on ocean currents, tropical cyclones, river flow and other factors. The potential effects on low lying coastal areas in the Northern Territory, especially Kakadu, may be quite dramatic according to the CSIRO. It is likely that tropical cyclones will, on average, become more intense.

In per capita terms Australia is a major contributor to the Greenhouse Effect, with the fifth highest emission of carbon-dioxide in the world. Coal combustion and petroleum consumption, most of which is used in road transport, accounted for over 80% of emissions.

Australia's relatively high levels of energy use are expected to continue to grow (ANZEC 1990). The Electricity Supply Association of Australia, in November 1988, found that the Territory had the highest projected growth in CO₂ of all States and Territories between 1987 and 1997. New South Wales was expected to increase its growth by 22% whereas the Territory's growth was expected to grow by a huge 75%.

In the Northern Territory there has been little evidence of government commitment to addressing the Greenhouse Effect — either preventive measures designed to limit the degree of change and/or planning and adapting for the already unavoidable ones. However, the Northern Territory Advisory Committee on the Greenhouse Effect is currently working on a welcome initiative, a Northern Territory Greenhouse Strategy, and has recently released a discussion paper, Greenhouse Strategy for the Northern Territory (NTACGE 1991). There is certainly little or no attempt to integrate Greenhouse projections into planning procedures. For example, the Conservation Commission requested the developer to investigate the potential impacts of the Greenhouse Effect on the Cullen Bay marina project. Consideration by the developer was inadequate and failed to satisfy the Bureau of Meteorology (Whitting 1991).

As an example of the type of message which the NT Government is sending the public with regard to its energy/Greenhouse policy consider that a number of years ago the Government removed the subsidy from solar panels and placed it on airconditioning units dependent on electricity.

The primary cause of increased atmospheric CO₂ is combustion of fossil fuels and since transport and electricity generation account for most fossil fuel use, it is logical that these are prime areas on which we should concentrate. Per capita consumption of fossil fuels in the NT is high relative to most other communities, particularly where transport fuels are concerned. Other sources of Greenhouse gases include land clearance, agricultural activities, fires and industrial use of CFCs. The Territory Government has taken action to regulate the use of CFCs in its Ozone Bill.

It is necessary that all economic decisions take into account their contribution to the Northern Territory's Greenhouse gas emissions. The Northern Territory will need to reduce the amount of oil and distillate used in its remote power stations and low carbon yielding natural gas may provide an interim alternative. Gas is still a CO₂ pollution source however. The Territory's gas reserves have an important part to play in an interim strategy for reducing the amount of carbon, and could be exported when we have guarantees that countries are phasing out the use of higher carbon emitting fossil fuels.

Public transport must be given greater attention as must energy efficiency in the office and home, urban planning and design, revegetation programs, and a concerted effort should be made to reduce the dependence on freight where vast amounts of petrol are consumed.

The Northern Territory could be leading the way in the development of non-fossil fuels and Greenhouse management in Australia and further afield. Renewable energy forms such as solar, wind and tidal require urgent attention and encouragement. Most of the barriers to greater use of renewable energy sources are social and political; they are not technical or economic in nature.

There is no single solution to the problem of global climate change. What is required is a variety of integrated responses in the areas of energy efficiency, resource conservation, pollution control
and land management. Decision makers should not fear taking strong preventative actions in response to the Greenhouse Effect. In most cases the steps towards Greenhouse abatement are positively related, that is, other problems will be addressed simultaneously. Significant benefits will be gained in developing sustainable lifestyles which will ensure a cleaner, more diverse and healthy environment.

**Mineral resource dependency**

There has been a great deal of conflict between the mining industry and environmentalists in the NT over the past few years. In the past it has focused predominantly on the issue of mining in national parks and on uranium mining.

The Environment Centre does not expect that conflict to subside in the next few years. As ecological sustainability is given greater attention nationally and internationally, the focus will turn to the fundamental issues of resource use, its consequent environmental impacts and the depletion of non-renewable resources.

Globally, unprecedented rates of resource consumption and pollution are two of the most important factors contributing to environmental degradation. A recurring theme throughout any discussion of the ways and means of reducing environmental degradation and achieving ecological sustainability is the need to reduce society's intense use of resources.

Current patterns of resource use from mining of non-renewable resources through production, processing, distribution and disposal allow for a great deal of waste and pollution and as a consequence a high scale of impact on the environment. At present our natural capital is being depleted without the proceeds from this depletion being used to create other capital assets for ecologically sustainable production.

Governments overseas are looking into ways of closing, as far as possible, the cycle of resource use by closing substance cycles which aim at a whole life cycle approach from raw materials through to waste products and emissions, saving energy, and prolonging the use of substances in the economy.

Such plans are trying to tackle resource use, pollution and energy use in an integrated and precautionary manner and will have positive effects on water and air quality, on energy demand and its consequent cost, and on the very real problem that countries are having with disposal of waste.

As countries attempt to embrace the concepts of ecological sustainability, environmental standards are improving all over the world. There is an argument that the achievement of further international competitive advantage for Australia might actually be enhanced through environmental regulation and that this way firms will get a head start in developing products and services that will be valued elsewhere.

In the Northern Territory we should be looking at what impact increased environmental standards and lowered rates of resource consumption, and the consequent technological change, will have on our resource driven economy, and whether such dependence will inhibit the development of a more efficient and hence competitive economy in other sectors. When one reads about the initiatives other countries are implementing, it is clear how much we have to learn in the Territory.

The government's attitude towards the Territory's mineral dependency is captured in a section of the aforementioned Chief Minister's speech to the Australian Mining Industry Council in 1990.

*I believe strongly that we should not only be developing the north, but doing so in such a way that we populate it at the same time.*

*Hand in hand with the exploration of the petroleum and mineral wealth of the Territory and other parts of Northern Australia, we need to create infrastructure and establish and develop industries that will enable the north to attract and sustain a population many times larger than it has to date.*

*The Northern Territory alone has the natural resources to support a substantial increase in Australia's population and to develop an economy that could outstrip the gross national product of many countries.*

The absence of any mention of the ecological limits to the kind of development the Chief Minister envisages, locally or globally, is striking.

However not only do we have to tackle our resource dependency on a macro level, we must also see environmental reform at a micro level — that is, at individual mine sites. The Environment Centre has been directly involved in a number of mine related pollution problems and, in recent times, the potential for pollution from offshore oil exploration and production in the Timor Sea.
The role of government regulations are vital in this area. Yet in the experience of the Environment Centre the government has failed to commit itself to a high standard of environmental impact assessment for exploration and extraction, strong regulatory mechanisms which are enforced, and adequate monitoring and auditing programs. A host of pollution problems have occurred at various mines around the Northern Territory including Nabalco's bauxite mine and processing plant, Ranger, Woodcutter's silver-lead and zinc mine, and Pine Creek and Tom's Gully gold mines.

As one officer within the Northern Territory Department of Mines and Energy noted in a memorandum to the Secretary of the Department:

As an Environmental Project Officer ... I must express my concerns about the Department’s preparedness to cope with potential environmental problems arising from discharges from mine sites ... my efforts to implement these initiatives in a timely manner have been continually frustrated by internal wrangling, complacency and poorly defined responsibilities.

The most blatant example is that of Pine Creek Goldfields where the Department of Mines and Energy was embarrassed in February 1989 when cyanide contamination was picked up by the Power and Water Authority instead of by this Department. My efforts to improve data collection at this mine have involved an excessive amount of justification and negotiation.

There are several other mines in the NT which have the potential to discharge contaminated water into rivers and streams and for which, as you are fully aware, the Director of Mines has responsibility. I am concerned about the Department’s commitment to maintaining an adequate standard of data collection on these mines (K Mallatt, Environmental Project Officer, Re: Potential Environmental Hazards at NT mines, ref 87/200, 10 January 1991).

These claims were quickly dismissed by the Department and the government as inaccurate and false. Indeed the media were informed that the Officer responsible had ‘personal problems’.

Conclusion

The Northern Territory obviously has many of the problems characteristic of an industrialised nation, especially land degradation, species decline (particularly in the arid zone), pollution and lifestyle patterns which depend on high rates of consumption of natural resources. Currently the scale and intensity, in some instances, may not be as great as in other more densely populated and industrialised regions, but if the Territory’s ecological integrity is to be maintained then they are problematic for the environment.

The challenge for decision-makers in the Northern Territory is to learn from the mistakes experienced here and elsewhere and to protect the wealth of natural resources remaining. Ultimately if the Territory is to prosper, economic development must not result in a continuing decline in the value of its non-renewable natural resource base, nor in its biological diversity, or in the environment’s capacity to assimilate wastes.

In the Northern Territory environmental awareness continues to rise. Recognition of the problems and concern for the health of the environment has in many instances translated into community demands for action and solutions. There is now a strong perception that we have finally reached a time of doing, rather than merely talking about environmentally responsible actions.

Notes

1. The specific proposed development in Litchfield Park was a hotel/resort within 500 m of Wangi Falls. The petition, however, opposed any commercial developments within the Park including the controversial resort.

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CHAPTER 2

SUSTAINABLE DEVELOPMENT, PEOPLE, PLANNING AND ETHICS

David AM Lea

The basic questions and choices facing those advocating or implementing sustainable development programs are essentially moral. While technological, economic or political actions, innovations and changes such as those mentioned in the last three chapters of the Brundtland Report (WCED 1987) may provide many solutions to specific problems, the underlying causes leading the world towards an unsustainable future are very obvious but usually ignored because they are unpleasant and apparently intractable to those with the capacity to bring about change. Inequalities of power, information and resources and the resultant contrasts of poverty and affluence mean that an affluent group with about 20% of the world’s population live in an unsustainable state of affluence, prodigal consumerism and wasteful resource use. Many of the remaining 80% live in a very different but equally unsustainable state of obscene poverty with few choices but to degrade environments.

At a world scale the environmental issues arising from global warming, land degradation, population growth, pollution, managing the common (including Antarctica), and other issues arising from the Brundtland Report are relatively easy to discuss and define. They are being acknowledged by most intelligent and responsible world leaders and commentators and addressed by governments and international organisations with varying degrees of success and commitment. Nevertheless even at these scales we see signs of an accelerating breakdown in global systems. Around the world there is deepening poverty, increasing inequality and vulnerability (especially in the Third World), pervasive communal violence, increasing land degradation, growing intensification and spread of pollution and a growing number of political, economic and environmental refugees. However, a promising start has been made at the ‘top’. Most world organisations, some national governments and quite a few transnational corporations are at least getting their rhetoric right, responding quickly when they are found wanting, making international agreements and trying to develop appropriate attitudes to and implementable policies on environmental problems.

But sustainable development is not just about conserving the environment for the needs of future generations as well as ourselves and dealing with current world environmental issues (although this is the major thrust of the Brundtland Report). It is about sustaining societies and cultures. The Brundtland Report, while coy about what individuals, communities and regions can do, is rightly quite specific that for a ‘good’ common future change is necessary at all scales. The Commission states unequivocally that there are no universal solutions and that each place and culture has certain specific problems. While changes of economic, political and social policies and systems are needed (and they are possible as world events are now demonstrating), they have to be based on a sound understanding of physical and biological systems and empathy with countless cultures: this is where ethics comes in. 1

Real difficulties emerge when we attempt to define ‘sustainability’ at any but a high level of generalisation because people, communities and organisations have their own needs, wants, prejudices and values. In spite of a high degree of approbation in both the popular and scientific press, both ‘development’ and ‘sustainability’ are value loaded terms and can mean all things to all people. How do we plan and manage something that is so vague and defies sharp definition? There are some constructive and yet apparently ambivalent ways through this minefield. Ironically I believe that the solutions, or at least sensible new approaches, lie in the very vagueness and ambiguity of the two terms and the impossibility of finding universal solutions. It is obvious that large bureaucracies (armed with ponderous power, red tape, files, questionnaires and meaningless socio-economic and performance indicators) cannot plan for ‘good’ common futures because, in the real world they are meant to be making better, there are so many environmental and social values and rapidly changing local and regional needs involved.
A common set of laws, rules, procedures or even guidelines at any but a very high level of generalisation is as meaningless as loose talk about 'an environmental or conservation ethic'. Ethics 'bear a normative relationship to behaviour: they do not describe how people behave, but how they ought to behave' (Callcott 1983, 249). But 'oughtness' can only be culturally defined. To talk of elevating sustainable development to 'an effective global ethic' (Engel 1990, 20) that recognises and promotes the mutuality of ecological and social values (Engel 1990, 19) is to my way of thinking unethical pie in the sky. If people are hungry or need firewood is it unethical for them to degrade fields or to chop down trees? The dilemmas of the Stockholm conference and the differing world views of the rich and the poor have not yet been resolved. As Peter Singer has recently said the only universal moral touchstone, a truly ethical position, is to put ourselves in the position of all those affected by what we are doing, and asking [ourselves] would [we] want this done if [we] had to live not just [our lives] but the lives of all those affected by either doing or not doing this (Singer 1991, 46).

To plan and develop policies with this alone as our guiding principle would probably mean that we would all end up doing nothing! It is pointless trying to change anyone's ethics and it is simply unethical to define a preferred ethic. What I attempt to do is to use an ethical approach to suggest new approaches to planning and development policy formulation that offer some practical alternatives for planning sustainable futures.

The very diversity arising from the differences of time, place and culture is an advantage in ethical planning for only people being affected by change can say what is sustainable, what sort of sustainability is necessary, what future they would prefer so that their needs and aspirations and those of their children and their community are not compromised. The only caveat is that they cannot compromise the future of their neighbours or the rest of the world. As Korten (1984, 302ff) points out this calls for new people-centred planning tools, reorientation of bureaucracies and professions, and programming strategies aimed at empowerment of people and communities. This will ensure that economic criteria and 'Western values' do not dominate and that planners will see that the future requires an ethic for life that transcends both material well-being, conventional wisdom and even knowledge (while, hopefully, being consistent with it and guided by its findings).

Some assumptions

Underlying the argument are some assumptions. The first is that good policies have to be both ethical and practical or they are both bad and ineffectual. Secondly, having ethical standards in turn means accepting that: (a) conditions, standards and values change over time; (b) there is a need to control the ability of the powerful to exploit or harm the weak; and (c) there is considerable diversity in the perception of what is 'good', not just for nations and states but for communities within them. What is one person's sensory enriched environment is another's sordid slum; what is honourable and just in one society is wrong or unjust in another. The third assumption is that planners and decision-makers can accept the need to make intuitive judgements and to change not just their procedures but their objectives: that they are able to act in an incremental or piecemeal way while living with uncertainty and contradictions (see Friend & Hicking 1987). Fourthly I assume that decision-makers act in the best interests of the people they serve and are prepared to consult with them. As Ivan Illich et al in Disabling Professions (1977), Sir Humphrey Appleby in the BBC/TV series 'Yes Prime Minister' and Wyn Reilly (1987) have shown, this is perhaps an unreasonable assumption. Questions of group and self-interest do arise. Finally I assume that sensible decision-making best operates following free and open discussion, the acceptance of trade-offs and compromise, and participation by all those concerned: any other approach will lead to either polarisation and confrontation or lack of action. Issues like abortion and birth control, conservation, uranium mining, warfare, state aid for schools, voluntary euthanasia and attitudes to issues like welfare provision and Aboriginal land rights illustrate how ethical questions can be divisive and are of great sensitivity. There are never any absolutely correct moral positions and few people are ever completely happy with the ways in which these sorts of issues are resolved. However, it is obvious that the way forward does not lie in heavy handed legislation, bureaucratic fiat, inquisition or confrontation.

What then are some creative, yet ethical and practical approaches to sustainable development?

An ethical concept of development

First, there is a need for a more ethical concept of 'development'. Development is always about change but it is not solely about building structures, providing education and other government services, the generation of wealth or even jobs. It is about...
• improving life. For the vulnerable in society this means raising levels of security (and this includes rights to land and resources, having reserves and assets to offset risk and contingencies, having a safe and pleasant environment for work and living);

• ensuring human dignity and this can only be culturally defined; and

• giving people the freedom to make choices (Goulet 1975). What Nugent Coombs calls the opportunity to choose and make effective a lifestyle which provides physical and psychic health and joy of living (Coombs 1990, 80).

Development can only be assessed in terms of the total human needs, values and standards of the 'good life' and the 'good society' as perceived by the societies undergoing change. Development implies economic, political and other changes but these are not ends in themselves but indispensable means for enriching the quality of human life (Goulet 1975). What is development to me is not development to you and is certainly different from the perceptions of development of someone younger and older than me or from another culture.

How can this be translated into policy? It is not easy but by taking an ethical approach some possibilities become apparent. First, although development can only be defined in cultural terms, the perception of what are unethical or unsustainable practices have a high degree of commonality across cultures (e.g. transfer pricing, tax evasion, stealing, contempt for individual or common property rights, arrogance, selfishness, contempt for the rights and values of others). Recognition that this underlying cross-cultural, cross-temporal core of 'ethics' exists, makes the acceptance of flexible codes, legislation or even treaties and ad hoc agreements all the more promising than heavy handed George Orwell's '1984-type' approaches. Secondly people have to actively control their own development. I deal with this in more detail below.

Thirdly when dealing with indigenous groups there has to be a conscious effort to incorporate traditional and local knowledge and traditional resource management systems into modern life and to realise that many forms of conventional economic development are not necessarily best and are often in conflict with traditional systems (see Clarke 1990). It is also likely that many aspects of traditional culture are necessary for an ethical form of development. In terms of environmental change, conservation and development — central issues of this volume — this is not asking us to be romantic about Aborigines for example or to assume that they either had a conservation ethic or, if they did, that it preserved their habitat as an unchanged paradise that led them to eschew major disturbances or land degradation. But their knowledge was derived from long-term experience and observation and they did have an intimate knowledge of their local area. That knowledge can surely enrich modern science and resource management. Not only do they have knowledge about food and water resources as we are now discovering from books and television programs like the 'Bush Tucker Man', but they see their economy not as an abstraction that determines how land and resources are used but as something integrated into land and life. Therefore seems to be some point in:

a) encouraging indigenous people to continue or revive appropriate traditional resource management practices;

b) encouraging the setting up of community based conservation areas;

c) establishing a set of procedures for government planners and developers to ensure that traditional knowledge and customs are not brushed aside but are incorporated as appropriate (e.g. building into environmental and social impact assessments an obligatory assessment of each proposed project's impact on traditional knowledge and resource use; the assembly, maintenance, and promotion of data bases; the institution of tribunals or other arbitration procedures to hear disputes between developers and customary rights holders);

d) establishing a set of procedures to alert and remind people of the value of traditional knowledge and customs (e.g. integration of traditional lore into school curricula; promotion of research; use of workshops and training courses; dissemination of traditional environmental information in popular forms).

An ethical approach to planning: participation and local empowerment

There is a need for 'top-down' development planning because international conventions, standards and treaties must be observed. Also central
bureaucracies have an important role in that they can and should consider wider national interests, they can stop the worst abuses of those holding fanatical or extreme positions, and they can control unfettered capitalism. However, a 'bottom up' learning process approach is equally important. This means that people's interests and priorities should be put first. This usually involves all, or a combination of, the following:

Securing rights and gains for people

Certainly my experience in developing countries shows that where land reform has been carried out and security of tenure and rights to land are guaranteed, not only does production increase, but land degradation is lessened or controlled. I suspect this would equally apply to mining in Aboriginal areas as it has applied reasonably successfully to the management and development of Aboriginal owned but jointly managed national parks. I remain amazed and disappointed that governments and mining companies have not realized that it is more civilized, probably more efficient, certainly easier and probably ultimately cheaper to involve effected people and to give them considerable say in the planning and management of anything to do with development. Where land provides not only daily sustenance but also spiritual validity, we find an obligation of stewardship to care for and sustain the land (eg Chief Seattle's Testimony; Coombs et al 1990, 7). As Chambers (1988, 3) points out:

Contrary to popular professional prejudice, there is mounting evidence that when poor people have secure rights and adequate stocks of assets to deal with contingencies, they tend to take a long view, holding tenaciously to land, protecting and saving trees and seeking to provide for their children. In this respect, their time perspective is longer than that of commercial interests concerned with early returns from capital, or of conventional development projects concerned with internal rates of return. Secure tenure and rights to resources and adequate livelihoods are prerequisites for good husbandry and sustainable management.

This does not mean no change or no big development projects. It does mean ensuring sustainability through self-help, community development and participation by giving local stewardship and control of common property and environmental resources (Korten 1990,11).

Participatory planning

Planning, however, is not and never should be about the production of a plan. It is a process that has been going on since time immemorial in all cultures. In all but the most straightforward infrastructural or engineering-type projects successful planning has always been a learning process—flexible, adaptive and incremental. Only the desk bound experts, the professional planner working with limited funds and operating with tight deadlines, and the grossly insensitive social engineer now see social and development planning as a cyclic or linear process from goal and objective setting, to data collection and analysis, and on through appraisal, implementation, monitoring and evaluation, and finally completion and handover. Good planning is a highly interactive process with feedback loops, acceptance of Hirschman's 'hiding hands', and a ready acceptance of uncertainty. It requires an ability to recognise and learn from mistakes and even to be flexible about objectives and processes.

Sensible evaluation

An essential element of good planning is also effective consultation and participation by the supposed beneficiaries at all stages of the development process including evaluation and monitoring.

Standard bureaucratic procedures, cost-benefit analyses, environmental impact assessment, logical frameworks and quantitative performance indicators may be important in setting basic guides, check-lists and agendas and providing some basic indicators of outcomes. But they are usually Western, very susceptible to duplicity, insensitive to local differences, needs and cultural values, and attuned to outcomes of production rather than how people react, suffer and benefit as a result of actions. In a recent book Porter et al (1991, 193) saw close affinities between the cost-benefit analysis of the economist and African divination rituals. As Crittenden and myself have demonstrated in recent articles, the evaluation and monitoring techniques of many aid agencies are likewise bureaucratic rituals reflecting the logic and needs of institutions rather than the logic and needs of aid recipients (Crittenden & Lea 1989, 1991).

Cultural, historical and geographic diversities do mean that every situation is unique so standard approaches using quantifiable indicators or implementation procedures and delivery systems have their limitations and, if overdone, are unethical. Many years ago a Zulu sociologist
pointed out that indices of Western progress can in reality be indices of African degradation (Magubane 1971). Professor Fay Gale pointed out in the Australian recently (4 September 1991, 14) that central planning leads to a dull uniformity because of loss of freedom, and an intolerance of difference and originality. The reality important things in life — creativeness, good work, happiness cannot be measured by economic or quantifiable performance indicators — come from lack of control! One does not need performance indicators to find out whether a plan is working. It is much easier to ask the supposed beneficiaries.

Realities and ethics

By looking at realities and problems and asking, as Aristotle did, whether outcomes are intrinsically noble, useful or pleasurable (is are they ethical), corollaries become obvious. These all illustrate the practical advantages of flexible, participative, learning process approaches to planning from the bottom as the main-stay for sub-national sustainable development.

a) 'Self-interested professional and bureaucratic monopolies have come to control nearly every sector of human activity and have successfully fashioned a complex web of governmental regulations that sustain their interests, from building codes to professional licensing requirements' (Korten 1984, 302). Much of this is inappropriate, stultifying and unhelpful in generating any form of meaningful development. There are other very useful things bureaucracies could do. They can defend the weak and the poor against assaults by the elites. They can be idea brokers, catalysts on matters of social mobilisation, trainers, organisers of market information. Most importantly they can be co-ordinators of information.

b) Research in the United States has found that small firms produce as much as twenty-four times the number of innovations per research and development dollar produced by large firms. A study of the most successful large corporations of America and Japan concluded that they circumvented the sluggishness of more typical large firms by organizing around small units that operated as almost independent business. . The firms found that their smaller production facilities were consistently their most efficient. Theoretical economies of scale often fail to materialise in real-world settings' (Korten 1984, 303). Unfortunately for universities, Mr Dawkins and over-ambitious Vice-Chancellors have not realised this yet. Small is not only beautiful — it is often more efficient and more human even in big business. In many cases, economies of scale or agglomeration are misrepresentations.

c) Powerful interests and affluent consumers, especially foreigners, not only neglect local people, and the poorest in particular, they often cause wilful damage to local environments and bring few economic benefits to communities and regions (see for example Dixon and Dillon 1990; O'Fairchealllaigh 1991). Instead of making the poor and minority groups the 'victims of progress' (Bodley 1975), development should promote a just society and not deny natural justice or basic human rights to even a few isolated and powerless people. So consultation, participation and negotiation with traditional owners, inhabitants and perceived beneficiaries are essential parts of the development process.

d) The greater the extent of local control over resources and land and the more the community relies on them to meet its basic needs, the greater the natural incentives for responsible stewardship. Indeed in small and remote communities, as Young (1990) has pointed out, local self-sufficiency is essential for the effective provision of economic and social services.

e) In post-industrial societies the primary resource is information, not money, and the flow can easily be two way through conventional information hierarchies and modern networking. Fortunately information is an inexhaustible resource and will provide the key to creative initiatives within the next few decades. New technologies allow dispersal of enterprises to rural areas and rapid flows (and leaks!) of information to anyone with access to a personal computer and modems, programming skills, and readily accessible software.

f) There is no such thing as a social constraint to development. All so-called constraints are negative interpretations that could be expressed positively. As Ponte points out 'a distrust of
persons beyond the family' can become 'a primary loyalty to the family'; interruption of work programmes by lengthy traditional ceremonies becomes 'a strong respect for tradition'; 'reluctance to work longer hours' becomes 'a desire to preserve leisure periods'.

Tradition is neither a passive acceptor of change nor an active resister of change. It is a dynamic system which absorbs or rejects change according to how the socio-economic costs and benefits are perceived by members of the group. Tradition is not a refusal to change, it is a proved response to existing local conditions coupled with a correct evaluation of the risk involved in a drastic rearrangement of lives (Ponter 1974, 38).

g) Increasingly the ethical foundation of Australian society over the last two decades is a market system based on self-interest that requires savings, investment accompanied by large-scale businesses and bureaucratic organisation. An ethical form of development in all its manifold forms requires policies not predicated on individual self-interest (Grynberg 1988, 154–5).

h) We need to accept that the normative framework which has developed is largely economic and ethnocentric and is inappropriately narrow in scope (Beatley 1991, 3). The logic that the West is often so proud about is beguiling in its apparent simplicity. As a Bougainvillean member of the BRA said, following the savage and disruptive disputes about the Panguna Mine, 'logic is a white man's trick' (J Griffin, pers comm 1990). Unsustainable production may be economically rational but by all sane criteria very undesirable for all sorts of reasons. The dominance of the economic rationalist is antithetical to a meaningful form of sustainable development

Conclusion

Just as there are no easy solutions, there are no simple procedures. Alternatives should be prepared by and presented to both policy-makers and affected communities. Both should be consulted and both should then decide about trade-offs and the implications of the cruel choices they may have to make. Overall there is a need to take creative and flexible steps towards new possibilities; not to lurch from one palliative to another. Stereotyping and failing to be flexible, open and empathic to the needs of others is ultimately unethical, expensive, counter productive and, most importantly, bad planning. Good planning is accepting the realities of the human condition and the environment — both the physical and human environment — in which we live (Friend & Hick 1987). Moral and practical imperatives are mutually supportive in the context of sustainable development. As Bill Clarke has recently said:

If the primary ideal is to meet material needs — which quickly become infinitely expandable as desires — then humankind will devour the earth. Admonitions, education, and technical procedures will not save us. Changed ecological ethics and aesthetics offer more hope (Clarke 1990, 249).

Notes

1. Ethics here is a reflective study of what is good or bad human conduct and it attempts to explain the 'rightness' in human conduct and experience. Means and ends are good because they are intrinsically noble, useful or pleasurable. Ethics in the context of what I am discussing is useful as it: (a) teaches people to be critically aware of the moral content of their choices; (b) coerces them to the extent that it commands good, and forbids bad; (c) it gives exploitors a bad conscience and exploited victims rational grounds for revolting against their lot; and (d) it builds institutions inasmuch as norms must be embodied visibly in rights, duties and laws (Goulet 1975 331–3).

2. Blaikie and Brookfield (1987,26) wisely make the point that even land degradation can only be defined or judged to be 'bad' in relation to the people who use the land now and in the future.

3. I am particularly grateful to sections from Clarke 1990 for these suggestions.

4. In fact Australia and other nations are often forced or reluctantly dragged into action by international pressures.

5. See for example Crough's recent paper on the need to have Aboriginal affairs directed by a Federal bureaucracy (Crough 1991).

6. Hirschman (1957) in his 'principle of the hiding hand' held that if planners knew about all the difficulties in advance they would not undertake any initiatives. However, the difficulties and the ensuing search for solutions often set in motion a train of events that not only rescues projects but often makes them both different and valuable. The only way in which we can bring our creativity into play is by misjudging the nature of tasks. A 'hidden hand' beneficially hides difficulties from us.

7. Expressed as 'logic is a capitalist cover-up' in Connell 1991, 73
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CHAPTER 3

IS CONSERVATION AN ANTONYM FOR DEVELOPMENT?

SR Vemuri and JE Perfect

Introduction

Planning for environmental change fundamentally depends on the approach one adopts. At the very outset there is a need to consider various approaches that are available for embarking on such an exercise. Such a task is rather complicated as it simultaneously involves many aspects such as culture, subject disciplines, time and space. This chapter discusses whether there are ways of bridging the perceptual differences between conservationists and developers, and what would be the implications for northern Australia if conservation and development were not considered as mutually exclusive. We feel that this is a crucial exercise as the approach one adopts has a bearing on all aspects of ensuing analysis. In this chapter it is suggested that we need to reformulate development and conservation issues, therefore we examine conservation and development rather than conservation versus development.

Because of the importance we accord to approaches to environmental change, in this chapter we first detail the important factors that shape these approaches. Secondly, we detail the implications of such a conceptualisation in the north Australian context. Finally we propose a conceptual framework which considers both notions of conservation and development as important for planning deliberations.

Factors of Influence

A cursory examination of plausible alternative approaches suggests they centre around judgements about three basic issues. These issues are (1) underlying reasons for environmental changes; (2) levels at which remedial measures are prescribed and analysed; and (3) the actual planning process.

It is imperative that our judgements about these three issues be made explicit for any productive discussion.

Reasons for environmental change

Various perspectives of environmental change exist. However, they can be divided into two categories. Environmental changes are thought to emanate either as natural and adaptive phenomena, where everything depends on everything else, or as policy induced economically motivated forces, where every action is subjugated to an equal and opposite reaction. In the literature (White 1967; McDonagh 1988) this is familiarly known as the 'nature versus nurture' argument. Each of these perspectives furnish directives about adopting distinct planning approaches. If environmental changes are perceived as products and by products of deliberations arising in a natural and evolutionary manner, then planning must be concerned with a number of issues. For instance, planning with such a perspective should focus on factors responsible for the perceived environmental changes. In particular we should be concerned with the reason for the failure of self equilibrating structures and what actions should be taken today to ultimately preserve and ensure the efficient continuation of self propelling checks and balances. However, if the perspective is one where environmental changes are regarded as intended or unintended 'spin offs' due to past policy actions, then planning must involve itself with deliberations about attempting to reverse or at least discontinue 'old' practices and ensure that present and future policies either circumvent actions that would eventuate in environmental degradation or suggest measures by which environmental improvements can be sustained. Although these are presented as simplifications in this chapter, a majority in the real world do not perceive environmental changes in such a definitive manner.

On balance, we feel there is no conclusive evidence to support either of the two extreme positions. In the absence of any conclusive evidence concerning reasons for environmental change, we suggest that the best approach is to consider the coexistence of natural as well as induced forces being responsible for propelling environmental changes.
Levels of analysis

Environmental changes can either be considered at the micro or the macro level of analysis. Changes deliberated at the micro level would imply analysing environmental outcomes as partial or piecemeal. This implies an adoption of a pragmatic approach involving individual or, at best, a sectoral strategy. In contrast to this, a macro analysis is where one is invariably involved with providing a general, aggregative, inter-sectoral and a conceptual framework for establishing rules and procedures to be followed in planning for environmental change. The present chapter adopts a macro framework as it is concerned with providing an alternative conceptual framework. There is a dire need for this type of work as the more established, conceptual frameworks are under severe strain as they are thought to be insufficiently rigorous or helpful in analysing environmental change.

The planning process

The planning process involves recognition of the relative importance of society and its institutions responsible for various actions involving causes and effects, as well as the overwhelming importance of time, where past is evaluated and future is predicted. The three main institutions involved in any planning process are the market, the government and the international sector. Markets provide a rudimentary form of institutional setting which facilitate the working of an implicit mechanism through price and quantity signals between buyers and sellers. Markets are fundamentally useful forms of providing an economically simplified informational structure and can be regarded as implicit forms of planning processes. On the other hand, in the present context the role of the government, at Commonwealth, State or Territory levels, becomes an explicit form of planning process where its existence and interference in the market process is seen as having the role of an ombudsman. In many cases the international factor is taken as an autonomous and external influence in creating or augmenting environmental change.

In this chapter we shall continue to assume that the responsibility of planning explicitly rests with the government sector where its actions will provide a direct and interventionist effect on environmental change. The role of the market as an institution should neither be undermined nor should it be disregarded. Although markets exert implicit directives, they are essential institutions. Their deliberations have behavioural implications which are slow to change. Because of this, we propose that there is sufficient justification for market processes to work efficiently and effectively by providing better information flows through space and time.

An understanding of the time dimension involves the past and the future. Planning therefore takes the form of a series of actions that are advocated and put in place to redress the already predicted onslaught of changes based on certain criteria. In evaluating the past record, two distinct versions of environmental change emerge in the literature about the North (Broome 1982; Dingle 1988; Altman & Nieuwenhuysen 1979; Maddock 1975; Beckett 1988); the romantic interpreters and the pragmatic growth proponents. The romanticists interpret the 'good old days' as being pre-conditioned by various versions of 'Aboriginality'. One of the versions perceives Aboriginal peoples as possessing a vision for future generations and hence ordaining their daily behaviours towards minimum consumption levels and least amounts of damage to the environment. On the other hand the pragmatic growth proponents are portrayed as profit oriented, surplus extractors championing the cause of excessive generation of wealth at the expense of the environment.

Because time is continuous, it is not surprising that the vestiges of old conundrums might dominate our present thinking. Popular literature seems to have embraced the dichotomy of extremes. The sense of irreconcilability between the ideas of conservation and of development are presented as a faul accompli in the popular literature. A call for conservation is almost regarded as a call for there not being development (see Henderson 1978; Neef 1982).

We believe that it is unfortunate that the irreconcilable dichotomisation between conservation and development has resulted in an ideological debate. The current controversy between the two protagonists, conservationists and developmentalists, is portrayed as being irreconcilable. What emerges is a position of being either exclusively right or wrong. The persistence of polarities is shunting the issue of environmental change into a cul de sac and existing frameworks are fast reacting, in a calculated manner, to defend their positions. What seems to emerge is a consensus or corporatist approach that encourages trade-offs, allows for fudging issues, all of which can lead to politically prompted prevarication and consequent dissatisfaction of all parties in a dispute. Unfortunately 'conflict resolution' may belie its name, with neither major protagonist satisfied with the ultimate results.
In this climate of opinion, *reductio ad absurdum* arguments may incense the opposition and be counter-productive, though to us it may already seem to be the case that protagonists in the current debate are not talking with each other but past each other in attempts to persuade the wider audience of the unsure, the indifferent and the uncommitted.

Planning for environmental change in this ambience requires more than providing further sophistication to the already existing techniques. Existing techniques of cost-benefit analysis (CBA), environmental impact assessment (EIA) or social impact analysis (SIA) may well not help in providing long-term solutions to irreconcilable standpoints where proponents of conservation and development appear diametrically opposed. This is because the already existing techniques have been unable to satisfactorily address conflicts between conservationists and developmentists which basically stem from the way discount rates (values of future costs and benefits in today's terms) have been calculated. There tends to be an implicit notion that such rates are either standard or that after due consultation or demonstration or argument they will be agreed. This may well not be the case when conservation and development have to be addressed simultaneously.

The political as well as market decision making processes are already addressing the issue of conservation and development although unfortunately their treatment can at best be charitably described as doing so in an *ad hoc* manner, or muddling from one decision to the next. As our concern is to consider both development and conservation we thus need a methodology that explicitly recognises the twin objectives of achieving development and maintaining conservation. In attempting to do so, we adopt a macro policy analysis rather than examine particular community issues or specific development projects at this stage.

**The northern context**

In the north Australian context, four phases can be detected in the evolution of economic thought applied to the issues of conservation and development. We concentrate on the post-European contact phases though it should be borne in mind that in the pre-contact phase there had already evolved amongst the Aboriginal peoples quite complex interrelationships between man and the environment. It is but natural to recognise that the elements of such ecological and environmental economics have continued and persisted in varying degrees during the three post-contact phases. Approximately these three post-contact phases in the north Australian context can be delineated to correspond with the following time frame. Phase I corresponds to the period from the mid 19th century through to the mid 1960s. It is in this phase that issues of conservation and development were explicitly the concern of the white settlers. The starting point for Phase II was when legislative changes eventuated in the 1976 *Aboriginal Land Rights (Northern Territory) Act*. The end of the next ten years, by which time some 25 per cent of land in the Territory had been returned to the traditional owners, marks the end of second phase and the beginning of the third and current phase.

Aboriginal opinion is by no means unanimous either with regard to development or with reference to conservation. Moreover, past experiences suggests that Aboriginal people do not have an invariant set of perceptions, over time and space, about conservation and development. This suggests that the three fundamental tenets of this paper equally fit the Aboriginal perceptions about development and conservation as much as non-Aboriginal perceptions. Thus in the north Australian context, discussion should actually be focussing on more non-racial lines. For example the way values can be traded, as illustrated by the coordinates of externalities and planning horizons (Fig 1).

Historically, the North provides excellent opportunity to examine various aspects of values being traded (see Perfect 1984, for an illustration of cross referencing of historical events over time which provides potential periods where value trade off can be examined). Admittedly, some of these aspects have nothing to do directly with notions of development and conservation. However, they almost invariably relate to some consideration of trade-off between 'traditional' versus 'modern' evaluations. These northern experiences can result in lessons which we feel will be of benefit in planning for environmental change in north Australia.

**First phase**

During the first phase, attention was by and large focussed on microeconomic viability. Development perception, planning and policy making all highlighted the importance of actively participating in and taking advantage of the existence of markets, where both supply and demand factors were mostly guided by international considerations. For example, consider the decisions by the UK based multinational food conglomerate, Vestey's, to invest in the 19th century, reinvest in the early 20th century
and shortly afterwards disinvest and finally, most recently, announce their exit from north Australia (see Perfect 1984). While the demand aspect is apparently clear, it is the influence of international factors on the supply side that is of significance here. It is important to note that even factor inputs, capital, management and labor (ie other than natural resources) were predominantly international. Therefore, any discussion involving the North must recognise that, historically, development has been established by organisations outside north Australia. These organisations have been operating on principles related with international market signals. In this phase, decisions affecting the North were dictated by development oriented cost-benefit exercises in the pursuit of identifying the so called 'break-even points'. The over-riding question was not whether to exploit the natural endowments of the North but one of recognising the appropriate timing for maximising gains from exploiting resources. It was also the period when economic literature was embracing the investment methodology of costbenefit analysis. In this phase, the twin issues of conservation and development were subsumed into one. It basically was a notion of development over time. A liberal interpretation of conservation in this phase that we can accord in the present context is one of conserving resources for future economic returns or developments.

Second phase

In the second phase, attempts were made, to a certain degree in response to recognition of Aboriginality and the collapse of assimilation policies, to direct attention in the North towards considering resource ownership privileges and custodian rights. Although a plethora of research has emerged portraying Aboriginal custodians as protagonists of conservation and non-Aborignines as champions of development, in this phase there has been little change as far as development deliberations are concerned. (As noted earlier, in this chapter we question the importance of such a dichotomy and believe that Aboriginal and non Aboriginal people portray values that by and large exemplify concerns for environmental and economic development.) Development decisions by and large were taken keeping international considerations, employing cost-benefit or modified cost-benefit calculations (CBA) in a similar fashion as in phase one. The modifications in these calculations basically emanated from considerations regarding various actologies of ownership of resources. These modifications were enhanced by methodologies similar to Environmental Impact Assessment (EIA) and Social Impact Analysis (SIA). The significant effect of these revisions in the North has been to appropriate benefits more congenially to various custodians of resources. In this phase, again, the question was not whether or not to exploit resources as much as who should justifiably reap the benefits of exploitation of resources. This phase can also be associated with a period when economists recognised the importance of environmental impacts of economic policies. The majority in the profession felt that environment was another factor of production which was scarce and a price had to be paid for using it. Thus methodologically the significant impact was to incorporate environmental concerns into mainstream decision-making. Because of this, the break-even point in the time span remained a target. It also performed the task of a reference point from which calculations for environmental use could be made. All these events assisted in continuing with development deliberations analogous with phase one.

There were a number of reasons for such a continuation in the northern context. Decisions about development in the North occurred outside the North. The existing methodology treated environmental issues by assigning monetary weightings. A compensatory mechanism would be proposed by assigning dollars to values being traded. In this phase, conservation was recognised as a symbol of traditional perspective. However, the notion of conservation simply assisted by providing guidelines for determining positions of values that could potentially be incorporated into development deliberations.

Phase three

Phase three is a culmination of trends within phases one and two. It is in this phase that the conventional forms of conceptualisation fail to provide sufficient results in providing compromises between development and conservation. Conservationists and developmentalists play a waiting game in re-evaluating interpretations by keeping resources on the one hand and waiting until overseas considerations make it worthwhile to exploit them. Meanwhile, people involved with such economic and environmental considerations are at loggerheads and the process of dialogue breaks down. While developmentalists regard this as an ample opportunity to have steady exploration which would add to the bank of these resources continuously, there is a breakdown of communication between the two groups.
A conceptual framework

The issue of conservation and development, as suggested earlier in this chapter, has a long history. We believe that perceptions about conservation and development are actually outcomes of habitual thinking. Past events and experiences suggest three fundamental tenets which we shall take as initial conditions in formulating this framework. They are:

1. Individuals or groups in any society formulate opinions about what they regard as acceptable levels of conservation and development. This implies that people, in general, form opinions about both conservation and development as well as having some idea of the implicit importance they attach to conservation and development.

2. At any given point in time, some individuals or groups of individuals perceive notions of conservation and development differently to some others. This suggests that in every society, at any given time, there is bound to be multiplicity of perceptions about conservation and development.

3. Perceptions about conservation and development are not static. In fact there is overwhelming evidence to suggest that perceptions change over time and space. Some of the factors responsible for these changes are education, individual experiences, group awareness, lobbyists, news media and presenters.

If the dynamics of the real world are adequately represented by these three precepts then the logical step in working towards a framework where conservation and development are considered simultaneously is to parameterise conservation and development.

Let us take two parameters of interest such as externalities and planning horizons. Here the term externality means action for which costs are not borne by the activity responsible for it. Conservationists tend to stress these. In addition to pollution and infrastructure costs met by the general taxpayer but largely benefiting a development, it may be argued by conservationists that there are costs of a social fabric nature. For example, large scale tourist development is sometimes criticised on this score.

In contrast, development is usually viewed as providing a tangible product or recognisable service to be 'consumed' in the near future, and with few recognised externalities. A further consideration is that 'development' is proposed and effected by corporations be they shareholder/investor driven, eg pastoral stations or mines, or taxpayer/administrator/politician driven, eg transport infrastructure.

Such corporations, be they privately or publicly owned, seem to have a life of their own. Their raison d'etre and the livelihood of their workforce depends on successful activity, and in the case of interstate and overseas companies, it is crucial for their continued presence in north Australia that they show a positive return on shareholder funds.

The other factor influencing conservation and development is the planning horizon. Developers see the immediate and near future as being important. Though a project may take years in the feasibility, planning and development stages, and perhaps last more than a generation in active life, time is parcelled into discrete units, each with projected and realised budgets. On the other hand, a conservationist is more likely to regard time in non-discrete or continuous terms, with the distant future being as important as that of the near one. For practical purposes these parameters can be represented in varying degrees of relative importance by assigning weights from 0 to 1, a scale that respectively attaches either no importance whatsoever or attaches complete importance.

When one is planning decision-making at any period of time one is actually planning for some form of shift in these weights. When we talk of planning we talk of the present, past and future. There is a time dimension involved. When talking of planning for development and conservation, we talk about the level of acceptable externalities amongst other considerations. For example, those who believe in the results of development and assign a low weight to sustainability emphasize the immediacy of returns and downplay possible externalities. Such an approach means firstly there is one dimension — that of immediate surplus secondly, a specific level of development to be attained and lastly, little or no concern for environmental issues.

At the other extreme of this contrast in polarities, we may have people who have a conception of conservation whose planning horizon is the far future, whose timetable as to when to commit themselves to a decision is indeterminate, and for whom externalities are of paramount importance.

For the purposes of graphic display, the weights, of O up to 1, can be described on a four quadrant axis (Fig 1), or a two sided graph (Fig 2) or parallel to each other (Fig 3).
Fig. 1: A Co-ordinate Sketch of Relative Positions

- Concern for the Future or Planning Horizon
- Concern for Externalities

- C: Conservationist
- D: Developer

Fig. 2: A Four Quadrant Sketch of Relative Positions

- Concern for Externalities
- Concern for the Future or Planning Horizon

Fig. 3: An Expandable Multifactorial Sketch of Relative Positions

- Conservationist
- Developer

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Given the structure of the economy and the criteria whose weights are represented, the resultant graphs depict the possibilities of a combination of weighted criteria, for example planting horizons and externalities. One might equally well plot degrees of importance attached to other key concepts by interested parties such as sustainability, native fauna/flora preservation, life style quality for those inhabiting or using an area of proposed development, or general public opinion input. The last held conviction seemed as strongly held a belief as the actual conservation issues addressed, to the extent of being an integral and not peripheral part of the discussions held at the Commonwealth Government sponsored Ecologically Sustainable Development seminar in Darwin on 11th June 1991.

It is most important to recognise the structure of society because it is the many faceted aspect of that structure, its multidimensionality, that will ultimately decide the number of points on the graph. Who makes the decisions, who do they consider as well as what, and who revokes or aborts decisions? It is important to consider all the participants and their concerns.

If every individual in society had identical perceptions about the importance of planning horizons and externalities (to use our first example), they would each assign identical weights to them with the result that there would be only one point in the graph's co-ordinate space. However, if there is more than one viewpoint either concerning the planning horizon or with respect to acceptable levels of externality, there will necessarily be more than one point in the co-ordinate space.

A corollary of the argument we have been developing is made by Nesbitt (1990, 37). Discussing planning and the environment in the cross cultural situation in the contemporary North West Territories of Canada, he says,

*Impact assessment is most effective when used in the clear policy context of an environmental plan. It can then dispense with issues of policy and can focus on its intended task: the assessment of potential impacts against commonly agreed environmental objectives and standards. Pursued in the absence of or as a substitute for environmental planning, however, impact assessment is less effective. Used as a forum for determining policy, impact assessment can generate as many conflicts as it resolves.*

In the terms of our argument, if the weights accorded to various concepts by conservationists and developmentalists are too opposed at the policy level, then impact statements cannot proceed smoothly, with the possibilities of stalemate or controversy. Where the points in co-ordinate space are widely divergent, there is fertile ground for disagreement.

It appears to us that most existing methodologies have implicitly assumed that there is only one point or should be only one point in this co-ordinate space. But there are potentially as many points as there are opinions, particularly across cultures or generations or ideologies.

As a result we propose that the issues of conservation and development be approached in the following manner:

**Step 1:** Identify the points in the various co-ordinates.

**Step 2:** Develop a methodology that could allow for possible comparisons between these points.

**Step 3:** Identify a target combination for the planning process.

**Step 4:** Apply to the existing methodologies of CBA, EIA and SIA, the weights to derive the appropriate discounting.

**Step 5:** Apply the rates to various projects.

The five step procedure is not proposed as a painless circumvention of present or potential conflicts between development and conservation. Indeed, it is difficult to suggest a method leading to compromise between the groups when the impression is given by developers that conservation will lead to the destruction or debilitation of our economic system, while equally paradoxically, it is proposed by conservationists that development will result in destruction of the environment.

This five step procedure can be criticised further on the grounds that it embodies an additional concept, presented here, of weighting. This may further complicate discussion of the already complex issues involved. However, we think that:

- it simplifies issues by concentrating on a few co-ordinates.
- a plethora of concerns can be subsumed under these.
the weighting concept is simple to envisage and reach an initial judgement on, while the graphs are tools easy to handle.

With such a tool, initial positions are easily presented, so that subsequent discussions or negotiations have readily identifiable positions to discuss or bargain or argue from, towards a target.

The weight system by itself does not bridge the perceptual differences between development and conservation. It may, however, provide a tool for concerned parties to a proposal to use, and for analysts and others to utilise in descriptions. It does, we hope, put those differences on common ground, not, obviously, at the same place on that ground, but within the context of a shared map. Once within that map, they might progress to an agreed policy.

With the methodologies currently applied, there is an assumption that a combination of research, commonsense and patient dialogue will reasonably lead to a convergence towards a particular and preferred viewpoint. If, alternately, on the tests of initial positions on the weight graphs, opinions are quite opposed, then no amount of sophisticated methodological treatment will bridge this initial perceptual gap.

Coming to the framework presented above in this chapter, we suggest it may help resolve the current dilemma in the north Australian context. We feel that there is an urgent need to devise a framework that will help in establishing initial positions of various participants in the debate about conservation and development in the North and to plan strategies for compromise. Once these two steps are taken then the traditional techniques can be adopted for more appropriate planning for environmental change. For example, our proposal can be adapted to work with various accepted and widely used conflict avoidance/resolution mechanisms, such as outlined by Ahmad and Sammy (1985).

In the north Australian context, the principles of policy regarding conservation and development are not always clearly enunciated and separated. As Nesbitt (1990) says, failure to distinguish these issues can — paradoxically — lead to EIAs creating more problems than they solve. Strong or extreme views of environmentalists and developmentists may attempt to subvert the intent of EIA. Current examples are the on-going debate about sand mining on Tiwi land or the continuing impasse over flood mitigation along the Todd River through Alice Springs.

References


CHAPTER 4

A NATIONAL COASTAL ZONE MANAGEMENT STRATEGY
FOR AUSTRALIA

Monica E Mulrennan

Introduction

With a coastline 36,735 km in length and a population of 16.54 million one might expect that Australia's coastal zone would suffer relatively little environmental pressure. Vast stretches of the coastline are certainly sparsely populated or uninhabited. However, because more than 75% of Australia's population lives within 50 km of the coast (DASETT 1991), where population densities can be as high as 6000/km², many areas have been severely stressed and degraded over recent decades. It is not surprising then, given the geographical extent of Australia's coastline and the diversity of ecosystems therein, that issues of coastal management are complex and varied. What is surprising is that Australia, as the largest island nation in the world, has yet to develop a national coastal zone management program.

The issue of coastal management in Australia is debated widely in association with a plethora of government reports, academic papers, conference proceedings and community submissions. Appendix 1 lists several reviews, which have been directly or indirectly concerned with the coastal zone, within the Commonwealth alone. Many of these reports and inquiries contain valuable insights and recommendations which reflect considerable understanding of the central issues and limitations of the present system of coastal policy and planning in Australia. For example, in March 1980, a report of the House of Representatives Standing Committee on Environment and Conservation entitled Management of the Australian Coastal Zone presented a thorough evaluation of the issues and problems associated with coastal management in Australia. Arising from its findings, the Committee recommended that:

The Commonwealth Government, in consultation with the States, develop and promulgate national policies and objectives for the conservation and preservation of the Australian coastline (HORSCEC 1980: 38).

In April 1991, another parliamentary report of the House of Representatives, The Injured Coastline: Protection of the Coastal Environment, further reviewed the main issues associated with coastal management in Australia and came up with similar recommendations to those proposed more than a decade earlier, that:

The Commonwealth Government develop without further delay a national coastal zone management strategy in co-operation with the States and Territories and local government to provide a framework for the coordination of coastal management throughout Australia (HORSCECA 1991: 84).

There is clearly a need for coordination of coastal management policy. Under the current system coastal issues are dealt with separately by the largely autonomous state governments. Problems relating to conflicts of interest, duplication of resources and bureaucratic inflexibility have been clearly stated in many of the above mentioned reports. These problems are only briefly outlined here. Of more interest at this stage is the question of why, given the widely acknowledged need for a national strategy for coastal management, there has been little or no progress on the issue in more than a decade?

This paper attempts to move the discussion along by looking at United States initiatives in relation to coastal zone management. The latter, through effective integration of coastal issues within a single major legislative and procedural system, provides a useful model for Australia. Some general principles, guidelines and cautionary comments are presented which may also assist in the formulation of an appropriate and effective national management strategy for the Australian coastal zone.
The present system

Comprehensive reviews of the historical and contemporary context of coastal management in Australia are available elsewhere (Cullen 1982; Lawrence 1985). Since the 1960s a number of states have established regional or state-wide management agencies in response to coastal erosion, coastal land-use conflicts, and an obvious lack of coordination between state agencies interested in the coastal zone. State management of the coast has generally been approached on two fronts: (i) the establishment of special beach or bay authorities to manage problem areas; and (ii) the inclusion of coastlines with significant scientific or amenity values within national parks and reserves. Details of the approaches taken by each State/Territory vary according to the different philosophical bases of environmental management and the level of technical understanding at the time when legislation was passed. For example, the Victorian legislation emphasises coordination between agencies and the planning of public lands, the Queensland approach is based on technical expertise, the South Australian on planning and state-local collaboration and the New South Wales legislation on planning controls (HORSCEC 1980).

Over the past decade most States and the Northern Territory have acted to change or refine their approach to coastal management. This has involved the preparation of clearly defined policy statements, a trend towards increasing the role of local government in coastal management and the establishment of advisory and co-ordinating committees to oversee coastal management. Examples of the latter include the New South Wales Coastal Committee, the Western Australia Coastal Management Coordinating Committee and the Northern Territory Coastal Management Committee. The development of statewide and regional coastal zone management strategies is, therefore, nothing new in Australia and continued developments at this level illustrate that, while Federal initiatives have made little progress over the past decade towards the development of a national coastal strategy, the States and the Northern Territory have been getting on, to different extents, with the business of their own coastal legislation.

In addition to the State/Territory level, coastal management systems in Australia also exist at an international level. A comprehensive summary of Australia's involvement in international fora is given in the Australian National Report to the United Nations Conference on Environment and Development (DASET 1991). Participation includes membership of the International Whaling Commission (IWC), the International Maritime Organisation (IMO) and the Intergovernmental Oceanographic Commission (IOC), in addition to being a signatory to the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention), the Convention on the Conservation of Natural Resources in the South Pacific (SPREP), the Convention on the Conservation of Antarctic Marine Living Resources and the Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific. Australia has also signed the UN Convention on the Law of the Sea (1982) but has as yet to ratify this important legal regime. Furthermore, Australia is party to the Torres Strait Treaty (1975), a vital and in many ways unique agreement between Australia and Papua New Guinea.

Important though these various State/Territory and supranational approaches are, they do not replace the need for national coastal management programs. Indeed, the development of a separate, viable national coastal management program would greatly strengthen the basic structures and organisational frameworks of existing local, regional and international cooperative projects.

Current problems

Coastal management in Australia is described as 'complex, fragmented, uncoordinated and interwoven between various layers of government agencies and programs' (HORSCEA 1991, 38). The major difficulties arise from the existence of so many public agencies with different responsibilities, objectives and interests in the coastal zone, and the absence of focus, vision, common purpose, or co-ordination at local, state and/or Commonwealth levels. These difficulties are exacerbated by a lack of adequate information, resources and expertise, especially at the local government level where many of the crucial decisions are made. A detailed consideration of these problems and limitations is given in the recent parliamentary report (HORSCEA 1991).

A possible solution

Of more immediate interest to the present discussion are the solutions proposed by the inquiry (HORSCEA 1991) to ameliorate these problems. Central to the overall findings of the Committee is the recommendation that the Commonwealth should take a greater role in coastal zone management. More specifically the Committee recommends that:
The Commonwealth initiate and develop a national coastal zone management strategy, in cooperation with State, Territory and Local government, which would provide a framework for the national coordination of coastal management (HORSERA 1991, 81).

According to the Committee, responsibility for initiating and developing the national strategy should be vested with the existing National Working Group on Coastal Management (1991, 84), but upon completion and agreement of the national strategy, responsibility for the coordination of coastal matters should be transferred to a proposed Commonwealth Environmental Protection Agency (1991, 85). Recommendations are also made regarding the provision of financial assistance to state and local governments on fulfilment of certain performance criteria which ensure consistency of objectives between all levels of government (1991, 84).

Details of the proposed strategy receive less than eight pages of coverage in a document of 126 pages (including appendices) so that it is difficult to make an adequate assessment of its merits and limitations. However, the Committee suggests (1991, 85), that the US Coastal Zone Management Act 1972 presents a useful model for the proposed legislation in that it also establishes a federal interest in the coastal zone, while responsibility for managing the coastline remains with the individual states. Close parallels between the political philosophies (ie federalism) of Australia and the United States, together with similarities in the geographical extent and diversity of their coastal zones (coral reefs, barrier beaches, etc) and the associated range of management issues (including storm hazard mitigation), suggest much potential for the application of the US model to Australia. The development of coastal zone management in the US is, therefore, outlined below; a discussion of its application to Australia’s coastal context follows.

The concept of Coastal Zone Management

The formal concept of comprehensive, integrated ‘coastal zone management’ is barely two decades old. Its objective, in current jargon, is to provide for the ‘sustainable utilisation’ of coastal resources. Coastal zone management differs from other forms of land-use or environmental management in that it affects an assemblage of terrestrial and aquatic environments, and therefore incorporates a ‘total catchment management’ approach (HORSERA 1991, 48). This multifaceted approach to management, unlike many single-purpose programs, is sensitive to interactions among coastal resources and uses. However, the multiple objectives addressed by coastal zone management means that every objective cannot be met fully so that coastal zone management generally involves making rational choices among competing objectives (Knecht 1979).

The United States Coastal Zone Management Act (CZMA) 1972

Coastal Zone Management in the United States is internationally recognised as one of the most comprehensive and best funded coastal management initiatives in existence, and is frequently contrasted to the ad hoc approach favoured by many countries, including Britain and France (Mitchell 1982; Rickets 1986; Carter 1988).

The US Coastal Zone Management Act, enacted in 1972, established a partnership between federal and state governments. The federal government lays down general policy and management guidelines, reviews and approves state programs, and provides funds for planning and administration. States are required to develop plans and — in concert with other local governments — take necessary legislative and other steps to ensure effective implementation (Mitchell 1982). This division of responsibilities recognises several limits to federal action. First, the varied physical and social nature of the nation’s 140 000 km shoreline poses great difficulties for the application of a single, national management plan. Second, in 1972 many states already possessed some elements of general coastal management programs. Third, decentralised planning of this type helps to meet the widely desired goal of increased public participation in governmental decision-making.

Basically this coastal zone legislation uses federal grants to entice states into drafting plans for protecting their coastlines from the adverse impacts of development. In order to receive federal planning grants, participating states are required to delimit coastal zone boundaries, identify permissible land and water uses, inventory areas of particular concern, identify proposed controls and authorities pertinent to achieving desired uses, set out guidelines on use priorities, and provide a description of the organisational structure proposed to implement the management program (US Congress 1990a). In this way the legislation ensures that state plans are consistent with national objectives and, as of December 1990 (US Congress 1990b), it also promises states that federal coastline
activities will be consistent with federally approved state plans.

One of the most interesting components of the US approach to management is that coastal erosion is seen as an integral part of the whole framework of management within the coastal zone (Carter 1988). The integration of such coastal objectives seems a logical provision for any coastal management program but many deficiencies in international coastal management policy, most notably the British approach, result from the deliberate separation of sea defence, coastal protection and the planning process (Mitchell 1982; Rickotts 1986). This artificial division of responsibilities militates against any major improvements in the system because all three areas of concern are inherently part of the same problem and should be dealt with as such.

Ironically, the establishment of the Beach Erosion Board in the United States was inspired by the British Royal Commission of 1911 and had by 1945 achieved what Britain has yet to achieve: an established legislative and financial procedure to undertake a program of scientific investigation and research into coastal geomorphology and hydrodynamics on behalf of local authorities before the adoption of particular remedial measures. Today the Coastal Engineering Research Centre (CERC), which replaced the Beach Erosion Board in 1963, acts as a public research institution on all aspects of the coastal physiographic system as well as a consultant to government agencies concerned with coastal processes. As a result of the importance of geomorphological investigation within the decision-making structure, national responses have been more open to the development of non-constructional 'soft' management strategies, such as beach nourishment and dune protection (Psuty 1987).

**Current status of the CZMA in the United States**

While the 1972 CZMA was originally envisaged as a unified and comprehensive approach to the resolution of coastal problems, it did not survive for long in that form (Mitchell 1982). Throughout the past two decades a variety of new federal laws and executive orders have been issued which have both complemented and conflicted with the CZMA. Perhaps the best example of this is the National Flood Insurance Program (NFIP), established by Congress in 1968 to provide flood insurance coverage to owners of flood-prone lands (both inland and coastal). However, the NFIP inadvertently became a stimulus to development and reconstruction in coastal hazard areas (US General Accounting Office 1980). The NFIP cover was revoked in 1982 under the Coastal Barrier Resources Act (CBRA) which expresses a federal policy not to subsidise future development on hazardous, undeveloped coastal barriers — it does not prohibit building but shifts the cost of infrastructure to the private sector or state or local governments (Godschalk 1987). Its purpose is to minimize loss of life, wasteful expenditures of federal revenues and damage to natural resources and in this sense sets a new course to the right by withdrawing rather than adding federal incentives to achieve public purpose. In this regard it has been anticipated that the CBRA will save the federal government approximately $5.4 billion over a period of 20 years in addition to enhancing the protection and conservation of coastal barrier and wetland systems in the US (US Department of the Interior 1979).

Another major development which has influenced the form of coastal zone management in the US was the establishment of a 'new federalism' in the early 1980s as the main component of the Reagan administration's commitment to limit the general scope of national government activities (Galloway 1982b). This new federalism departs significantly from the concept of 'cooperative federalism' which involved a joint sharing of powers and responsibilities between federal, state, and local governments in a host of policy areas. In its place a 'layered cake' federalism, with non-overlapping responsibilities between levels of government has been proposed which would eliminate federal funding to approved coastal state agencies for administration of their programs (Mitchell 1982). This shift from a national to a state-oriented federalism certainly has the advantage of increasing the involvement of 'grass roots' government, local governments in particular who are best equipped to diagnose and deal with problems (Galloway 1982a). Furthermore it encourages state and local government cooperation and reduces the role of a federal government, considered too large, too influential and too costly to be effective. In this sense the new federalism is actually closer to the original concept of the CZMA which proposed that the states should administer their own coastal zone programs but with the caveat that there is a national interest in coastal management that pervades all coastal states.

The problem with the new federalism, if fully implemented, is that it would involve 50 state political systems instead of one national approach to a particular problem. In this regard the new federalism threatens to undermine the two most
fundamental provisions of the original 1972 CZMA, it is the federal consistency provision and federal funding. The original program was sold as being in the national interest and in the states' interest, with continued federal funding as an incentive. Now under the guise of new federalism, the federal government wants to shift the financial burden on to state and local governments while at the same time insisting that the national interest remains (Galloway 1982a). The problem of adequate state funding is equally significant, as illustrated by the predicament of Florida where the entire state is arguably in the 'coastal zone' and comprehensive coastal land management is considerably more difficult and more expensive to achieve than elsewhere (Hildreth & Johnson 1983). These circumstances, combined with the fact that there is no state income tax in Florida, no inheritance tax and very low property tax, result in serious fiscal problems and a great reluctance to spend public money, so that in the absence of federal funding incentives, there would be no way of ensuring coastal management as a political priority.

Despite the fears of the early 1980s, which suggested an undermining if not the total disintegration of the CZMA under the Reagan administration, Congress has continued to reauthorise the CZMA and its attendant programs throughout the past decade. In December 1990, under the Bush Administration, the CZMA was further expanded, revamped and reauthorised for another 5 years, together with a guaranteed authorisation of appropriations over this period at continually increased levels, totalling $85.75 million in fiscal 1991 and $119.24 million in fiscal 1995 (US Congress 1990b).

In addition, the recent rewrite of the CZMA declares that all federal agency activities, whether in or outside of the coastal zone, will be subject to the consistency requirement unless the President grants a waiver in respect of a specific activity found to be 'in the paramount interest of the United States' (US Congress 1990b). This provision is extremely significant as it provides the states with increasing powers to block or alter federal decisions that affect their coastal zones. The objective of this clause is to bolster the so-called 'consistency provision' and in doing so it reflects the present government's support for the so-called new federalism, albeit in a more moderate form.

Similarly, rather than reduce federal funding to the states, additional grants known as Coastal Enhancement Grants have been established to entice states to improve their coastal plans in one or more of eight areas: coastal wetlands protection, natural hazards management (including potential sea and Great Lake level rise), public access improvements, reduction of marine debris, coastal growth and development impact assessments, special area management planning for important coastal areas, ocean resource planning, and siting of coastal energy and government facilities (US Congress 1990b).

The update of the legislation also requires the Environmental Protection Agency to establish uniform national guidelines for controlling non-point-source pollution to coastal waters and compels all states to follow these guidelines in developing coastal non-point pollution control plans (US Congress 1990b). States will receive new grants to assist in the development of these plans, but the government will withhold parts of their CZMA and Water Pollution Control Act grants from 1996 if they fail to submit 'approvable' non-point pollution plans. The latter certainly reflects a strong national-oriented federalist philosophy, with the federal government continuing its policy of environmental conservation through fiscal control.

A further controversial provision in the 1990 legislation was that aimed at encouraging states to adopt 'no net loss' wetlands policies. The bill was defeated by members from states with sizable amounts of wetland as they feared it would stifle development (US Congress 1990a). Nevertheless the proposed bill was significant in indicating a desire on the part of the Bush Administration to firmly establish environmental conservation on their political agenda and there seems every indication that the stability of the National Coastal Management Program is assured at least in the immediate future.

**Evaluating the success of the CZMA**

By some standards, the federal Coastal Zone Management program is a considerable success. As of December 1990, most coastal states and territories were participating, although the omission of the Great Lakes States has been interpreted by some as reflecting the poor suitability of the federal program to regional needs (Ricketts 1986). Other yardsticks of success are equally conflicting because the program is really a process of encouraging states to achieve good management, rather than a blueprint for the attainment of shared national goals. States approach the program with varied problems, commitments and expectations so that only a state-by-state evaluation is appropriate. Consider the following example. In recent years there has been a growing recognition in the US of coastal
environments as dynamic geomorphic systems (Swift 1975) and national objectives have generally encouraged a move away from the 'quick fix' of groynes and seawalls to 'softer' management strategies. However, statewide initiatives and responses to problems of coastal erosion or barrier migration vary considerably. Louisiana, for example, has allotted millions of dollars to stabilise its shoreline, in North Carolina regulations have been established to halt all stabilisation on the open ocean shoreline, while in Texas they are taking the approach of shoreline retreat in the belief that 'it would be better to begin an orderly, strategic retreat now than to retreat in tactical disarray later' (Pilkey 1987, 280).

The fact that the individual responses of the states vary is not to say that coastal zone management serves no particular national interests nor advances no specific federal goals. On the contrary the CZMA includes detailed federal consistency and national interest clauses and a number of direct or implicit statements of national policy regarding land-use controls, environmental preservation, energy development, beach access, erosion control and other matters.

A United States model for Australia?

Several close parallels between the social and physical nature of the US and Australia, mentioned above, suggest the likely appropriateness of much of the US model to the Australian situation. A more considered evaluation, presented below, finds that there are many indications that the CZM legislation could in fact be more effectively employed in Australia than it has been in the United States.

Firstly, the political and administrative framework of the United States model has direct application to the Australia context, except that rather than accommodate a large number of individual states, the Australian national program would only involve six states and the Northern Territory. The Australian program should, therefore, be considerably more effective and easier to administer as a coordinating body than the US model. The successful implementation of a national CZM program is, however, dependent on the nature of intergovernmental relations. The introduction by the Fraser Government in 1975 of a new policy of 'cooperative federalism' did much to enhance intergovernmental relations in Australia (Haward 1991). Its commitment, embodied in the 'new federalism', was that the Commonwealth would reduce its influence in policy areas considered to be the responsibility of the states. The new federalism promoted intergovernmental co-operation and negotiation and a maintenance of the states' role in policy areas with overlapping responsibility (Peachman & Reid 1980).

An illustrative case study of this new approach is provided by changes in Commonwealth powers and responsibilities in the offshore (Haward 1991), where despite the fact that the Seas and Submerged Lands Act 1973 vested sovereignty over the seabed and territorial waters in the Commonwealth, the Commonwealth returned power over the three nautical mile territorial sea to the States and Northern Territory in 1980. This was in fulfilment of the conditions of the Offshore Constitutional Settlement (OCS), an agreement which embodied the essence of the new federalism's intergovernmental co-operation. In recent years, the Hawke Government, with its 'official policy of dismantling the settlement' (Cullen 1985, 141), has promoted the view that the States and Northern Territory should be excluded from any role beyond the low water mark. The Government has decided for the present time not to take action to regain title but this approach remains contingent on the continued satisfactory operation of existing OCS arrangements and the Commonwealth promises to resume title should any State or the Northern Territory act in ways considered incompatible with the national interest.

The conditions underpinning the new federalism continue to be highly controversial with the present Minister for the Environment, Ms. Ros Kelly, resisting all attempts to lessen federal environmental powers. At the time of writing, however, the Special Premiers' Conference process is examining detailed proposals for more consensual federal-state approaches to environmental policy-making. This was heralded in the Communiqué of the first such conference in October 1990 (Special Premiers' Conference 1990). It is well known that the States are concerned about the 'too blunt' use of federal powers, such as the External Affairs power, for the regulation of environmental issues in the States, eg., the Franklin Dam case. The review provides an important and immediate opportunity for new forms of cooperation to be considered.

Some level of national involvement in coastal management is crucial. The predominant theme in the submissions and other evidence presented to the Parliamentary inquiry (HORSCEBRA 1991) was a demand for a greater Commonwealth role in coastal zone management. This is considered particularly important in areas of research and monitoring; the result would be a saving of taxpayers' money, prevention of a duplication of expenditure and
provision for continuity through the establishment of national objectives and guidelines. Notwithstanding this, what Australia now needs is a national program founded on intergovernmental partnerships but taking the bottom-up rather than the top-down approach.

Decisions in coastal management should be made at the lowest level of government capable of handling the problems. This would usually mean State, or local government with State advice. This form of decentralised decision-making is crucial to effective co-operation in management. However, decentralised decisions should be consistent with policies determined at higher levels if the overall result is to be coordinated planning (HORSCEC 1980:8).

Intergovernmental relations will always generate tension — indeed such tension is often constructive. For example, joint federal and state involvement in the Great Barrier Reef Marine Park Authority (GBRMPA) illustrates that while differences occur in the political arena there is much intergovernmental agreement on issues of policy and implementation. A resolution of the present political uncertainty is needed before any national environmental program, and particularly one so dependent upon intergovernmental cooperation, can be effectively implemented. Indeed the nature of intergovernmental relations in the past may have been largely responsible for the failure to initiate and develop a national CZM program before now.

A second reason for the likely success of the United States model in Australia is that the legislation of 1879, which declared public ownership of the shore, ensures that Australia does not have the problems of private ownership experienced in the US. This tradition of collective (national) rather than individual (landowner) responsibility for coastal erosion and environmental planning provides for potentially more effective implementation of such policies than can ever be achieved in the United States, where the autonomy of local authorities and private property owners continues to play a major role in reducing the effectiveness of federal and state coastal zone management policies.

Thirdly, Australia has already established a substantial level of technical expertise in the area of coastal management and many effective regional and statewide management programs have been in operation since the 1960s and 1970s. Concepts such as Marine and Estuarine Protected Areas (MEPAs), which include 'marine parks' and 'marine reserves', would be readily encompassed in a national CZM strategy, as well as many of the other principles and mechanisms of current management approaches (eg environmental impact assessment, buffering and other zoning practices). What is lacking is a mechanism to co-ordinate these initiatives and the proposed national CZM program would provide just that.

Fourthly, Australia has the benefit of almost twenty years of US experience with their national CZM program — many of the varying successes and mistakes encountered have direct application to Australia. The Commonwealth would be well advised to undertake a thorough review of all aspects of the US model before proceeding with the formulation of Australia's national coastal legislation.

A cautionary word

The development of a National Coastal Zone Management Program should not be seen as the panacea for all coastal planning and policy ills. Neither can the adoption of the United States model be considered as a blueprint for coastal management in Australia. A CZM strategy is not an ointment nor is it a repair kit — it simply provides the framework within which the various initiatives of the States and Northern Territory can be integrated and co-ordinated. This latter point is crucial — Australia's coastline is too vast and diverse to attempt a single national program which can cater for the regional needs of each individual State/Territory or coastal environment. The Parliamentary Committee involved in the recent report The Injured Coastline: Protection of the Coastal Environment (HORSECA 1991) seems to have missed this point. The inappropriateness of their approach is illustrated below with respect to the problems and needs of the coastal regions of northern Australia.

Northern Australia: a case study

The title of the Parliamentary report suggests that the inquiry was directed at a need to 'repair' Australia's 'injured coastline' and therefore concentrated on those areas where high population density and pressure on the coastal zone has created problems which require urgent attention. Fortunately, the coastal regions of north Australia have suffered relatively little environmental degradation. However, this condition should not discriminate against the importance of providing a national coastal zone management strategy which is both appropriate and responsive to the needs of the north Australia coastline and its associated resources.
A number of factors serve to highlight the contrasting experience of Australia’s northern coasts from those of the more developed and settled south. These include:

- scarcity of industrial activity or accompanying pollution;
- relatively pristine and often exotic ecosystems;
- significant coastal resource use by indigenous peoples and Torres Strait Islanders who occupy significant lengths of coastline (72% of the Northern Territory’s 6200 km coastline is Aboriginal land), people who retain unique and invaluable traditional knowledge of coastal ecosystems;
- a relatively 'clean slate' for policy development and management of the coastal zone.

New objectives from the Commonwealth should recognise these factors as presenting a unique opportunity for ‘getting it right’ in the development of north Australia, both in terms of comprehensive coastal zone management and in ecologically sustainable development. The success of this development will be largely dependent upon the involvement of the indigenous peoples who inhabit large portions of these coastal regions. The social, economic and cultural needs of these peoples together with the needs of the unique and sensitive environments they occupy must be central to the development of appropriate coastal management strategies for these regions. Other states have other demands — for example Queensland’s Gold Coast where much of the coastline is indeed ‘injured’, perhaps critically! The success of any national coastal zone management program can only be judged on its ability to provide a framework within which the variety of needs and issues associated with Australia’s extensive coastline can be accommodated.

It is now time!

The Parliamentary Committee makes the point that ‘it is now time for the Commonwealth to initiate and develop a national coastal zone management strategy’ (1991, 83). The wording is interesting — there are many who would suggest that it is long past time — yet, with respect to the Committee there may indeed be something in the timing of this most recent initiative.

Within the last ten years, international initiatives and precedents have served to firmly establish environmental conservation on the political agenda of all OECD countries. The World Conservation Strategy has stated that each country should review and consolidate its legislation concerning living resources to ensure that it provides sufficiently for conservation. Each country should also review — and if necessary strengthen — its capacity to implement its conservation legislation, both existing and required (IUCN 1980).

Similarly, since the publication of the Brundtland Report (WCED 1987), the concept of ecologically sustainable development has gained increasing acceptance by world governments (Pearce et al 1989). Issues such as the protection and management of our natural resources and the rights of indigenous peoples have become firm requirements on the international agenda so that national governments are being forced to comply with a world standard. This shift in focus and accountability is already doing much to encourage real progress in these fundamental issues.

A final word

Federal initiatives regarding the development of a national coastal zone management program have been slow in coming and the States and the Northern Territory are getting on, to different extents, with the business of their own coastal legislation. The Commonwealth is already behind — it must not lose further time in co-ordinating these efforts.

Close parallels between the social and physical nature of the United States and Australia suggest the possible application of the United States CZMA model. The formulation of Australia’s national CZM strategy has much to gain from the pool of international expertise and experience but the ultimate success of its coastal legislation will be largely determined by the establishment of effective intergovernmental cooperation and negotiation.

No single blueprint of coastal zone management exists. Australia must work out its own policy implications. This will involve the establishment of national principles and guidelines but the decisions must be made at the local level so that the national framework accommodates the needs and issues of all coastal regions.

The traditional indigenous users of important areas of the north coasts of Australia have much to contribute to any future coastal and marine management plans. The Torres Strait Islanders have proposed in a letter to the Queensland Premier, May 16, 1991, with copies to the federal government,
that a regional ecologically sustainable development strategy be developed with marine and coastal ecosystems and the traditional knowledge of the local people at its centre. This sort of initiative is clearly the wave of the future and deserves full support by state and federal governments.

APPENDIX 1: Federal Reports on Coastal Zone Issues

The Senate Select Committee on Water Pollution (1970)
The Committee of Inquiry into the National Estate (1974)
The National Conference on Coastal Management (1986)
The Review Committee on Marine Industries, Science and Technology (1989)
The Industries Assistance Commission (1989)
The House of Representatives Standing Committee on Environment, Recreation and the Arts (1991)
The Resource Assessment Commission is presently conducting an inquiry into coastal development issues.

References


Platt H, Pelerzelski SG & Burbank BKR (eds), Cities on the Beach: Management Issues of Developed Coastal Barriers, Research Paper 224, Department of Geography, University of Chicago, Chicago.


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CHAPTER 5

COASTAL MANAGEMENT IN THE NORTHERN TERRITORY:
A PERSPECTIVE

Maria Kraatz

Introduction

The population of the Northern Territory is 156 000. Of this population, 76 000 or 49% of people live in the major coastal centre Darwin and in the smaller coastal town of Nhulunbuy. In addition, there are numerous smaller settlements along the 72% of the coastline which is Aboriginal land (Bergin 1991).

A coastal degradation survey conducted in 1990 found that the majority of coastal degradation associated with the major centres was a result of uncontrolled pedestrian and vehicular access. This degradation was evidenced by damaged or destroyed dune vegetation and by accelerated erosion. Coastal erosion in some areas, however, is not thought to be a product of degradation, but rather a consequence of a natural and seasonal cycle involving both erosion and deposition. Inadequate planning in past years and the construction of high value capital structures in close proximity to the high water mark has meant that the effect of this seasonal cycle has threatening consequences. The problems which the Northern Territory faces can be summarised as:

1. Lack of restrictions which enables uncontrolled vehicular and pedestrian access to sections of the coastline adjacent to high population centres.
2. Lack of clear planning guidelines for coastal areas.
3. Lack of objective information on which to base planning.

The effects of the first two problems can be illustrated by changes in the usage and management of foreshore areas at Mindil and Vestey’s Beaches and Casuarina Coastal Reserve in Darwin and along the Cox Peninsula. The third problem is being addressed to some extent by a Beach Monitoring Program. This program was established to develop a data base of objective information and is described below.

Foreshore management

Foreshores are dynamic environments and by their very nature can be subject to significant periods of erosion or deposition. As reported in Coalsdrake (1976) the width of oscillation of foredunes can be considerable, and movements up to 100 metres are not uncommon. This is particularly the case along Darwin’s coastline where flat profiles, high tidal variations and severe seasonal storms are part of the coastal environment.

Problems arise, therefore, for two reasons. One occurs when the seasonal cycle is interfered with by the construction of high value capital structures in close proximity to the high water mark or on top of the foredune. The second occurs when degradation of the foredune reduces its resilience to erosion.

As mentioned earlier, the coastal degradation survey conducted in 1990 around Darwin and Nhulunbuy indicated that the majority of degradation at these locations was associated with uncontrolled vehicular and pedestrian traffic.

The following section summarises specific problems and the changing pattern of foreshore usage at Mindil and Vestey's Beaches and Casuarina Coastal Reserve in Darwin and the Cox Peninsula as outlined in Kraatz & Letts (1990) (see Fig 1).

Mindil Beach

In 1944 Mindil Beach was described as a 'well established sand dune spit approximately 140 metres wide and backed by lower ground which was subject to tidal flooding from a meandering creek at the southern end of the beach' (Coalsdrake 1976). This lower ground was used as a refuse dump prior to the development of a caravan park in 1966. The park was owned by the Corporation of the City of Darwin and catered for less than 100 caravans.
Foreshore erosion at the mouth of the creek was an ongoing problem and was regarded as both a safety hazard for beach access and playing children and as a threat to the park. Consequently, a revetment wall was constructed in 1978, and was justified on the grounds that relocation of the park (in 1976) would cost in the order of $450,000, as opposed to that of $30,000 for construction of the wall. Erosion adjacent to the revetment wall has continued, however, and is documented in numerous reports (Brown 1986; Kraatz & Lets 1989, 1990). This is an ongoing concern to the operators of the Diamond Beach Hotel/Casino which was built on the caravan park site in 1982. This concern was momentarily alleviated by a major replenishment program conducted after serious erosion in 1989. The Department of Transport and Works coordinated the transfer of large quantities of sand from the lower tidal areas of Mindil Beach to the depleted foreshores. The purpose of this exercise was to provide safe access to the beach over the foredune.

The increasing popularity of the weekly Sunset Markets has placed considerable pressure on the northern shores of Mindil Beach. Regular trampling of the dune has led to degradation and has increased the susceptibility of the foreshore to accelerated erosion.

As a consequence, and on advice from the Conservation Commission of the Northern Territory (CCNT), Darwin City Council fenced the entire foredune in July of this year, increased the number of access ways to the beach and erected public education signs.

It is envisaged that while the fencing will require ongoing maintenance and will be prone to complete breakdown during severe storm events, the improved vigour of the dune vegetation will increase the dune’s resilience to long-term impact.
Vestey's Beach

From inspection of aerial photography and the available literature, it becomes apparent that the extent of erosion along Vestey's Beach has not been as severe as that along Mindil Beach or Casuarina Coastal Reserve. Erosion, however, has become significant due to the threat it poses to the Trailer Boat Club, the Darwin Sailing Club and the Ski Boat Club. These buildings have been constructed much too close to the high water mark and on top of the foredune. Protection of these buildings, rather than conservation of the foreshore environment, has therefore become the primary motivation for works along this section of the foreshore.

Concrete structures such as boat ramps and revetment walls associated with these dwellings tend to reflect wave energy, therefore leading to erosion in adjacent, non-armoured areas, or in some cases to undermining of the structure itself. Aerial and ground photography showed in 1989 that the revetment wall at the southern end of the Sailing Club had exacerbated erosion on the adjacent foreshore. Poorly constructed armouring immediately in front of the Club had been effective in protecting the foreshore in terms of pedestrian activity but was not sufficient to withstand the storms of April 1989. Following these storms the foreshore was replenished with sand to its pre-storm alignment and in 1990 an improved revetment wall was constructed along both the Sailing and Trailer Boat Club frontages. This wall has, as yet, not been tested by significant storm events. Access to the beach in most parts has been formalised and the dune vegetation remains healthy.

The replenishment program mentioned previously was also conducted along this beach to cover rocks exposed during the 1989 storms and to provide a more amenable viewing platform for the National Ski Titles of that year. As expected these rocks have again been exposed during subsequent wet seasons.

Casuarina Coastal Reserve

Sections of the foreshore along Casuarina Coastal Reserve have been shaped by sand mining and the subsequent rehabilitation of the foredunes. In the early 1960s changes in the profile due to mining activity enabled the intrusion of high tides to the extent that a small pocket of tropical rainforest was threatened.

Works to rehabilitate this area were estimated to cost in the order of $5000. At that time it was considered that:

The cost of stabilising this beach area may at first appear to be high. When compared with the value of a half a mile of beach frontage, and a forest reserve, however, it does not seem great. As the population grows, and the town spreads, the demands for beach areas will increase. To continue to neglect this area would be adopting a very short sighted approach (Richards 1972, 3).

During the 1970s several trials were carried out to determine the most appropriate methods for revegetating the dune area including the use of sand trapping fences and the planting of native grass species such as Sporoebolus, Spinifex and Paspalum. After the successful rehabilitation of the area following these trials, it was noted that the main threat to the dune system would then be the destruction of vegetation by ever increasing numbers of pedestrians, trail bikes and dune buggies (Richards 1974, 31). This problem has subsequently been addressed to some extent by the declaration of this area in 1983 as a Coastal Reserve managed by the CCNT. The majority of the foreshore subject to intensive usage has been fenced, (with the exception of Lee Point and the frontage at the Surf Lifesaving Club) and pedestrian access has been formalised. Vehicular access is prohibited with the exception of service vehicles.

Erosion has been most significant at the mouth of Sandy Creek and the smaller creek to the north of the Surf Lifesaving Club. Such erosion often occurs as a result of creek migration.

The Plan of Management for the Reserve has recently been tabled and is available from the Park Planning Unit of the CCNT (CCNT 1991). This plan outlines management zones within the Reserve, incorporating management prescriptions for the natural resources, visitor usage, administration and research of and on the Reserve.

Cox Peninsula

Uncontrolled pedestrian and vehicular access across the foreshore and the construction of residential dwellings very close to the high water mark characterise foreshore usage along the Cox Peninsula.

Pedestrian and vehicular traffic along the beach adjacent to the Mandorah Hotel has resulted in degradation. Any further development adjacent to the Hotel should be placed well back from the foreshore and should involve formalising beach access and relocation of the hotel access road further away from the foredune.
In 1983, the foreshore along Wagait and Imaluk Beaches was declared a Restricted Use Area (RUA) under the *Soil Conservation and Land Utilisation Act (1980)* (see Fig 2). Details of this Act are provided in Appendix A.

This declaration was made in response to evidence of ongoing degradation of the dune system. At the time of the declaration, signs were erected and two car parks were constructed. One was adjacent to a boat launching area and another adjacent to a board and chain access ramp. It was hoped that these measures would encourage more sensible usage of the foreshore and would promote the regeneration of the dune area. This, however, has not occurred and it is likely that usage of the dunes will not change until a continual presence in the area is possible to enable enforcement of the regulations.

In 1989, beaches along the RUA suffered similar erosion to that along Darwin’s beaches. While this prompted some concern from local residents, no capital structures were threatened. It is likely that the impact of these storms was amplified by the poor condition of the dune vegetation. This was particularly the case in front of the Golden Sands Hotel which is a popular camping ground.

Several proposals have been put forward by the management of Golden Sands to develop the camp ground within the RUA, including the construction of a revetment wall and a number of small huts. An application to convert this land to freehold title was refused on the grounds that the CCNT did not wish to set such a precedent which would restrict government control and possibly public access. It was also considered that such development would prompt further similar proposals along the RUA.

Foreshores to the north of Imaluk Beach and around to Oak Point are lined with numerous tracks which run indiscriminately across foreshore areas and are associated with small dwellings and campsites. Vegetation has been damaged or destroyed and it is likely that some of these dwellings may be threatened by erosion in the future.

Given the isolation of these areas, it is difficult, if not impossible, to control disturbance to the foreshore. As was indicated in the Mandurah Land Use Concept Plan, population growth within the region will create demand for more intense recreational use of this area, and therefore more structured management (Department of Lands & Housing 1990, 19).

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**FIGURE 2** Restricted use area adjacent to Imaluk and Wagait Beaches, Cox Peninsula
Beach monitoring program

Background

The Beach Monitoring Program is a project initiated by the CCNT in 1989, designed to develop a data base on sediment movements on Darwin's beaches.

The need for this information was highlighted some two years ago when several days of high tides and winds combined to erode significant quantities of sand from Darwin's foreshores. During this time, the CCNT received numerous calls from concerned residents about eroded sand dunes and loss of Casuarina trees. After years of educating the public that erosion is an undesirable process, it is difficult to convince them that such erosion may be part of a natural and seasonal cycle of erosion and deposition.

Observation of sand movement on Darwin's beaches over a number of seasons indicates that during the wet season beaches can be subjected to periods of high tides and winds which combine to erode large quantities of sand. This sand is transported down the beach to the low tide area and remains in a reservoir available for re-transport back to the upper tidal/foredune areas during the dry season.

Purpose

The purpose of the Beach Monitoring Program is to confirm these observations and to:

- determine if this natural cycling is indeed occurring on Darwin's beaches;
- determine if there is a net accumulation or erosion of sediments from our coastline;
- enable more accurate and informed planning; and
- ensure that this cycling is not interfered with by new activities or developments.

Method

A series of transects have been located along three Darwin beaches and are tied into the Australian Map Grid. There are four along Mindil Beach, five along Vestey's Beach (one each in front of the Sailing and Trailer Boat Clubs), and twenty-four along Casuarina Coastal Reserve (see Figs 3 & 4).

The surveys are undertaken during tides of less than two metres and out to 200 metres on Mindil and Vestey's Beaches and 300 metres on Casuarina Coastal Reserve on a three monthly basis. An electronic notebook is used so that data can be downloaded directly into a civil engineering software package called CIVILCAD which is then used for reductions and to eventually generate long sections. Sections from successive surveys can then be overlain and compared.

Results

It is anticipated that the prime value of these surveys will be long-term monitoring (in the order of ten years). However, four consecutive surveys along Casuarina Coastal Reserve have confirmed a seasonal oscillation of sand movement.

Exceptions

There will, of course, be other natural and less natural factors which have a bearing on the stability of the foreshore. They include tidal influences, creek outlets, headlands, the pattern of dune usage and the way in which the dune is managed.

Conclusions

In the past, there has been a lack of planning guidelines and access restrictions in populated coastal areas of the Northern Territory. Coupled with an inadequate appreciation of coastal dynamics, this situation has enabled the construction of high value capital structures in inappropriate locations and has led to degradation of the foreshore.

While planning issues still need to be addressed, improved awareness of coastal degradation problems has led to changes in foreshore management in some areas of the coastline around Darwin and the Cox Peninsula.

A Beach Monitoring Program has also been initiated to develop a better understanding of coastal dynamics at Mindil and Vestey's Beaches and Casuarina Coastal Reserve. Long-term analysis of this information will enable more informed planning for foreshores along Darwin's coastline.
FIGURE 3  Beach monitoring transect locations — Mindil and Vestey's Beaches
FIGURE 4 Beach monitoring transect locations — Casuarina Coastal Reserve
APPENDIX A:

Soil Conservation and Land Utilisation Act (1980)

20c. OFFENCE RELATING TO USE OF A RESTRICTED USE AREA

Except with and in accordance with the written permission of the proper authority, a person within a Restricted Use Area shall not —

a) unless he is on an exempted road, have in his possession or use a motor vehicle;

b) remove or damage any vegetation;

c) take or remove any sand, gravel, rock, clay of earth;

d) interfere with any erosion prevention works; or

e) cause water or other fluid to be drained or flow over the area.

References


CHAPTER 6
CURRENT STATUS AND FUTURE PROSPECTS OF MANGROVE Ecosystems IN NORTH AUSTRALIA

JR Hanley

Introduction

About one third of the Australian continent lies north of the Tropic of Capricorn. It is the mangroves of the coastal zone of this northern, tropical region which are the subject of this chapter. Although mangroves occur at subtropical and temperate locations on the Australian coastline, in general they do not exhibit the area, diversity or productivity of those mangroves lying north of the tropic.

This chapter examines the current status of mangroves in northern Australia. An explanation of prevailing climatic conditions in northern Australia is provided and the resulting distribution of mangrove resources discussed. The productivity and diversity of northern Australian mangrove systems (flora and fauna) is then compared with those elsewhere in the Indo-West Pacific region.

There then follows a discussion of the concept of the 'value' of northern Australian mangrove resources in terms of conservation, exploitation, reclamation, gene pools, buffer zones and primary production. The likelihood of large scale disturbance of mangrove ecosystems in northern Australia is then examined in terms of population growth, industrial development/mining projects and Greenhouse Effect. These potential human induced changes are compared with the evidence of change due to natural processes. The final part of the chapter deals with public perceptions of mangroves in Australia and how these are likely to affect the future management of mangrove resources.

Physical features, climate and distribution of mangroves

The coastline of northern Australia is vast, more than 10,000 km in length. This coastline passes through nearly 17° of latitude and 40° of longitude. The entire area lies within the monsoon belt, characterised by south-easterly winds during the months May to October, and north-westerly winds during November to April. Nearly all rainfall occurs during the monsoon period November–April. The amount of rainfall is correlated with both latitude and longitude. Rainfall is generally higher in the lowest latitudes and generally much higher on the east coast of the Australian continent when compared with similar latitudes on the west coast.

In general, the mangroves of the top end of the Northern Territory and the eastern side of the Cape York Peninsula are more diverse than those of the north-west of Western Australia and the Gulf region (Hutchings & Saenger 1987). The major determinants of the distribution of mangrove plant species are thought to be rainfall and temperature (Hutchings & Saenger 1987), therefore it is not surprising that rainfall and the number of mangrove plant species present are correlated.

For example, rainfall at Broome on the Western Australian coast (Lat 17° 58'S) averages 580 mm, while Darwin, on the north coast (Lat 12° 28'S) averages 1500 mm, and Cairns (Lat 16° 55'S) on the north east coast has an average rainfall of 2200 mm (Saenger et al 1977).

At Broome there are only 13 species of mangrove plant recorded (Semeniuk et al 1978), while both Darwin and Cairns have in excess of 25 species. In addition, the mangroves of the Cairns region are structurally more complex, and individual trees are generally larger than those of the same species in the Darwin region. The mangroves of the Darwin region show a similar trend when compared with those of the Broome area.

Much of the northern Australian coast is subject to very large semi-diurnal tidal movements. On the Kimberley coast spring tides of 10–12 m are commonplace and the western part of the Northern Territory has spring tides of 8 m. Tidal amplitude on the Arnhem Land coast, the Gulf region and both the western and eastern sides of Cape York are smaller, averaging 3–4 m on springs. Tides at
Mackay approach 7 m, but in general there is a gradual decline in tidal amplitude from the north-west through the Top End and Gulf region to the north-east coast.

The level of tidal amplitude is also an important determinant of mangrove distribution. In areas where fine silts are deposited such as river deltas, large embayments and ria systems, the slope of the shoreline is typically very gradual. A large tidal range produces a broad intertidal zone with many different microhabitats, allowing colonisation by many species of mangrove plant. Distinctive zonation of mangrove flora in the intertidal zone is then usually evident, with different parts of the intertidal zone occupied by characteristic plant species associations.

Although mangroves are found on many parts of the north Australian coastline, they are best developed in large shallow embayments and around the mouths of large rivers, environments where deposition of fine sediments is occurring and there is a seasonal depression of salinity. In these areas, mangroves are usually a dominant feature of the intertidal zone, however the area, individual size, species diversity and productivity of mangroves is heavily influenced by local, interdependent conditions such as rainfall, tidal range, soil type, temperature and salinity.

**Primary productivity of mangroves**

The measurement of total net primary productivity as defined by Hutchings and Saenger (1987) is extremely difficult. Usually, one feature associated with primary productivity is measured and used for the basis of comparison. Such features as biomass, litter production, gas exchange of leaves, and chlorophyll/light attenuation have been used in various studies which are discussed by Hutchings and Saenger (1987).

There are surprisingly few studies on primary productivity of tropical Australian mangroves. On the north-east coast, Bunt (1982) used litter fall as a measure of productivity in mixed mangrove forest on Hinchinbrook Island, and Duke et al (1981) examined litter fall in a range of mangrove species associations. There has been one study on productivity in mangroves in the Northern Territory where Woodroffe et al (1988), measured litter fall beneath several mangrove flora associations at Creek H in Darwin Harbour. There have been no productivity studies in the mangroves of the Kimberley coast. Woodroffe et al (1988) discussed the evidence for a latitudinal gradient in productivity rates of Avicennia marina in Australia and demonstrated that their estimates for productivity of A. marina at Creek H fit into the observed trend (Table 1).

**TABLE 1 Mangrove productivity rates in Australia**

<table>
<thead>
<tr>
<th>Productivity (g/m²/yr)</th>
<th>Latitude (° S)</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-300</td>
<td>38</td>
<td>Clough &amp; Attiwill 1975</td>
</tr>
<tr>
<td>580</td>
<td>34</td>
<td>Goulter &amp; Alloway 1979</td>
</tr>
<tr>
<td>800</td>
<td>18</td>
<td>Duke et al 1981</td>
</tr>
<tr>
<td>1250</td>
<td>12</td>
<td>Woodroffe &amp; Bardsley 1988</td>
</tr>
</tbody>
</table>

Comparisons with data on productivity of A. marina from other parts of the Indo-West Pacific region also support the observed trend of a decrease in productivity rates with increasing latitude. Steinke and Charles (1984) estimated a productivity rate of 710 g/m²/yr for A. marina at 30° S in South Africa and Sasekumar and Loi (1983) estimated a rate of 1 540 g/m²/yr from 3° N in Malaysia. However, Woodroffe et al (1988) caution that it is possible to find variations in productivity of A. marina at one site which parallel this observed latitudinal variation in A. marina. Similarly, at any one site, productivity estimates for different vegetational associations may show wide variation.

Estimates of litter production in various vegetational associations at Creek H (Woodroffe et al 1988) are presented in Table 2 and show a similar range of values as those seen over a large latitudinal gradient (Table 1) within Australia. The most productive mangroves at Creek H are those of the creek margins, the least productive are those fringing the salt pans which are common in the upper intertidal. These variations in local productivity reflect the interplay of factors such as frequency of inundation, substrate type, height on the shore, salinity, rainfall, availability of nutrients, temperature and humidity.

The most productive mangroves at Creek H (Table 2) with an estimate of 1200 g/m²/yr, show a productivity rate comparable with other regions of the tropical Indo-West Pacific where mangrove productivity rates have been estimated.
TABLE 2  Mangrove productivity rates at Creek H

<table>
<thead>
<tr>
<th>Productivity (g/m²/yr)</th>
<th>Species Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>Ceriops tagal</td>
</tr>
<tr>
<td>750</td>
<td>C. tagal/B. exaristata</td>
</tr>
<tr>
<td>1000</td>
<td>Sonneratia alba/Rhizophora stylosa</td>
</tr>
<tr>
<td>1200</td>
<td>A. marina/B. parviflora/R. stylosa</td>
</tr>
</tbody>
</table>

The large range of variation in productivity rates which can occur among different vegetational associations at the same site suggests that extrapolation of productivity rates between sites is unwise, particularly as Woodroffe et al. (1988) have shown that estimates of productivity rates for specific vegetation associations at Creek H can vary by as much as 33% between subsequent years.

Unfortunately, there is a total lack of information on productivity rates for various mangrove vegetational associations throughout most of northern Australia. Therefore the design of mangrove resource management strategies has been based, and will continue to be based, on a very small data set. For example, the Northern Territory Government is currently considering the implementation of a management strategy for the mangrove resources of Darwin Harbour. The proposed strategy seeks to maintain 80% of the annual productivity of the mangroves in the harbour. This is a commendable aim, however the only data which provide estimates of the productivity of the various mangrove vegetational associations in Darwin Harbour are that collected by Woodroffe et al. (1988) over a two year period at Creek H. Out of necessity, the productivity rates estimated at Creek H have been extrapolated to similar vegetational associations elsewhere in the harbour. The accuracy of estimates of overall productivity in the harbour, and the suitability of Creek H as an indicator of productivity rates for various mangrove vegetational associations are unknown. More estimates of productivity rates of mangrove vegetation at a range of sites throughout northern Australia are urgently needed. Ideally, such productivity studies would collect data over a 10–15 year period to allow estimates of annual variation to be made.

Unfortunately there are no studies on mangrove productivity currently in progress in the Northern Territory or the Kimberley region of Western Australia.

Diversity of mangrove flora and fauna

Flora

As discussed previously, the diversity of mangrove flora varies considerably along the northern Australian coastline. Two trends in diversity are apparent. As latitude increases the number of species of mangrove flora decreases, and diversity of species is positively correlated with rainfall, hence the Kimberley coast has fewer species of mangrove flora when compared with similar latitudes on the Queensland coast.

The distribution of mangrove flora and common mangrove vegetation associations in northern Australia have been relatively well documented in recent times. As part of the celebrated crocodile survey undertaken by the University of Sydney Physics department during the 1970s, 1 Wells (1982, 1983) recorded the mangrove flora observed on hundreds of tidal rivers, creeks and bays throughout northern Australia.

The mangrove flora of north-western Australia has been documented by Semeniuk (1980, 1982, 1985a) and Bridgewater (1985). In the Northern Territory, Wightman (1982) has recently completed an extensive survey of mangrove flora and the geomorphology and mangrove flora of Darwin Harbour were examined by Semeniuk (1985b). The species composition and distribution of mangrove flora in Queensland has been the subject of a number of surveys (eg Bunt et al 1982).

Fauna

By contrast the fauna of mangroves in Australia is, in general, poorly known. Hutchings and Recher (1982) provided a species list of Australian mangrove fauna derived from extensive review of the literature. Hutchings and Saenger (1987) provided a comprehensive review of the literature to 1985 and noted that many of the literature records of fauna are dubious and certainly incomplete, particularly for regions such as the Northern Territory and Kimberley coasts.

Our knowledge of the mangrove fauna in northern Australia is indeed patchy. Several taxa, such as the
vertebrates, are relatively well known, although few vertebrates are full time residents of mangroves. The distribution and ecology of mangrove associated birds (Schodde et al. 1982; Ford 1982), mammals (Hutchings & Saenger 1987) and reptiles (Cogger 1979) is reasonably well documented, however even for these well known taxa, there is little information on their status in mangroves on more remote sections of the northern Australian coastline. 

The majority of mangrove animals are invertebrates and can be divided into two major groups: those associated with the canopy and those associated with the substrate. Most of the invertebrates associated with the canopy are insects and other arthropods, although some molluscs are arboreal in mangroves. Hutchings and Recher (1982) and Hutchings and Saenger (1987) review the literature and suggest that a rich and diverse insect fauna with a high level of endemism is awaiting study. The invertebrate fauna of the substrate in mangroves is, by contrast, mainly marine in origin. The major groups, not surprisingly, are molluscs, crustaceans and polychaetes.

Of these three groups, the molluscs of Australian mangroves are probably the best known. It is now relatively rare to find new species of molluscs appearing in surveys of mangrove faunas, although the ellobiids may prove to be the exception to this generalisation. Saenger et al. (1977) and Hutchings and Recher (1982) provide lists of mangrove molluscs recorded from Australian mangroves. The most common crustaceans in mangroves are the crabs, particularly those of the families Sesarmidae, Grapsidae, and Ocypodidae. Davie (1982) compiled a checklist of known species and their distributions. It is likely that many more species of crabs remain to be described from mangroves in tropical Australia where they usually form a diverse and conspicuous component of the mangrove fauna. For example, Hanley and Couriel (in prep) have recorded 16 species of crab from the Bruguiera/Rhizophora/Ceriops zone at several sites in Darwin Harbour. At least three of these species are undescribed.

Polychaetes in tropical Australian mangroves are probably the least well known, and although recent research has enlarged the number of species recorded (Hanley 1988, in press), there are still many undescribed species present. In addition, there are numerous other invertebrate groups represented in mangroves. They are poorly known, and will presumably remain so as there are very few individuals conducting research on mangrove fauna in Australia.

While it is true that much of the mangrove fauna is poorly understood, some of the relatively common species have been the subject of recent ecological studies. Wells (1983, 1984) examined the distributions of marine invertebrates in mangroves at a site in north–west Australia and documented the various feeding strategies of molluscs and crustaceans. He also found that the densities of larger invertebrate species were higher on the mudflats in front of the mangroves. Robertson (1986) demonstrated that the Sesarmid crab Sesarma mossa has a significant impact on energy flow in mangrove forests through its practice of burying and consuming fallen mangrove leaves.

Further research on the ecology and physiology of individual species and on the ecology of various mangrove communities is essential to understanding mangrove ecosystems. Studies of this nature are more likely to be undertaken in the mangroves of north Queensland where large research centres such as the Australian Institute of Marine Science and James Cook University are relatively close to extensive, undisturbed mangrove habitats. The recent establishment of the Northern Territory University in Darwin will hopefully also lead to many research projects on the ecology of local mangroves. (See for example McGuinness in this volume.)

**Biogeography of Australian mangrove fauna**

Northern Australia lies within the tropical Indo-West Pacific region, a vast area stretching from the east coast of Africa to the islands of the western Pacific Ocean. Many species of the flora and fauna of this region are widely distributed, including many species which inhabit mangroves. Prominent examples are animals like the mud crab Scylla serrata and the mud lobster Thalassina anomala, both of which are common in mangrove habitats from Mozambique to Fiji.

All these widely distributed species presumably have a long lived planktonic larval stage in the life cycle. Species which do not have such long lived planktonic larvae usually are distributed over a much smaller area. The fiddler crabs of the genus Uca are one example. The genus is found throughout the Indo-West Pacific, but individual species are much more localised in their distribution. Many of the Australian species are endemic (known only from Australia), while others occur both in Australia and nearby islands of Papua New Guinea, Indonesia and the Philippines. Even within Australia there are differences in the crab
faunas of mangroves west of Torres Strait and those of north-east Queensland (Davie 1985).

In some taxa such as crustaceans (especially the crabs), the proportion of endemic Australian mangrove species is relatively large while in others such as molluscs and polychaetes it is relatively small.

It is important to note, however, that records of endemic species must be viewed with caution. A species may appear to be restricted to a small range because it has been overlooked elsewhere, either by a lack of specialised collecting or a lack of collecting altogether. A fine example of this is the polychaete species *Dendronereis heteropoda*, first described from the Chilka lakes in the Bay of Bengal by Southern in 1921. That was the only known record of the species until I collected it from mangrove habitats on the large macrotidal rivers of northern Australia. Therefore it now has a greatly expanded range. It has not as yet been recorded from any of the areas between the Bay of Bengal and northern Australia, but given the amount of suitable habitat available it must surely be present, as must many of the other species currently recorded from northern Australia. There are very few published records of the fauna of mangroves in the Indo-Malay archipelago, a reflection of a low level of research interest in the mangroves of the region. Lists of mangrove fauna from Thailand (Frith et al 1976) and Malaya (Sasokumar 1974) show many similarities with lists of fauna recorded from local mangroves (Hanley, in press; Hanley & Couriel, in prep). Given the similarities in flora and fauna throughout the region, research undertaken on mangroves in northern Australia has importance throughout the region. Similarly, research undertaken elsewhere in the Indo-Malay region can provide useful information about local mangroves. As the level of research funding devoted to mangroves is generally poor throughout the region (including Australia), each nation's research program is regionally important and perhaps should be subjected to more international consultation at the planning stage.

The 'value' of northern Australian mangrove resources

Under the present tyranny of the 'economic rationalists' who dominate public debate in Australia, everything on the planet must be assigned a 'value' in purely anthropocentric terms before its fate is decided. This arrogant, unimaginative process usually begins by assigning a 'value' of \(x\) dollars per hectare to a mangrove area then weighing up the various 'benefits' of leaving it alone or turning it into something useful like a marina, airport runway, shopping centre, car park and so on.

This is not the place for a discussion of the shortcomings of this process, but what is the value of the mangroves of northern Australia?

Conservation

Many of the best stands of mangroves in northern Australia lie in remote areas far from large populations of humans. As a direct consequence, these stands are in pristine condition and seem likely to stay that way for the foreseeable future. As such they represent a valuable conservation resource because they have not yet been impacted by human activities and there is little likelihood of large scale human impact in the near future. In contrast, the mangrove resources of many other countries in the Indo-West Pacific region have already been substantially altered by the impact of human activities, and in the short term at least these impacts are likely to increase. Therefore the conservation value of tropical Australian mangroves is also high in a regional sense. In addition, the maintenance of these areas as pristine mangrove resources requires practically no effort in terms of manpower and finance simply because they are so remote.

This does not mean however we can continue to get away with doing nothing. The advanced state of modern technology means that within a very short time any currently pristine area can be subjected to a large impact through such activities as mining. Ensuring that at least some of our mangrove resources remain pristine will require some commitment by state and federal governments to the future establishment of reserves and national parks which are created specifically to afford protection to mangroves. This will require greatly increased financial support for research on mangroves in general before areas best suited for conservation can be identified. In the current economic climate this seems highly unlikely; and furthermore I suspect the overall funding for research on mangroves has actually fallen in recent years.

Exploitation

Having said that the conservation value of most northern Australian mangroves is high, it must also be true that the level of exploitation is low. By comparison with our Asian neighbours we tend to ignore mangroves as a potential resource. Elsewhere in the region mangroves are utilised for timber, tannins, charcoal, and mangrove areas are
important sources of protein. Most Australians see mangroves as wastelands, devoid of any 'useful' products other than mud crabs and barramundi.

Due to the relatively low rainfall over much of northern Australia and the protracted dry season it is unlikely that mangroves here constitute a valuable source of timber. Perhaps some of the mangroves in the higher rainfall areas of the north Queensland coast may contain economically attractive timber resources, but there seems to be little interest in their exploitation.

One area where mangrove trees might prove to be valuable is in the rehabilitation of salt affected agricultural land, although research into this potential is in its infancy.

Reclamation

This peculiar word is used to describe the process of filling in swamps, foreshores and other low lying land. The implication inherent in the word is that the process represents the 'taking back' of land which had somehow been 'lost' previously. In my experience this is hardly ever the case.

Throughout Australia, waterfront land is in high demand, and tropical Australia is no exception. Much of the tropical coastline experiences large tidal ranges, is gently sloping and therefore colonised by mangroves. Reclamation of these areas invariably means loss of the mangroves as the height of the shore is built up. It could be said that mangroves have a 'high reclamation value' in northern Australia. This 'value' seems unlikely to change in the near future.

Reclamation of some foreshore areas is undoubtedly necessary in some cases as there are many occasions where waterfront access is essential to the conduct of many industries. However, much of the demand for waterfront access in tropical Australia may simply reflect the valuations put on intertidal (mangrove) areas. A low or negative value on intertidal land may encourage reclamation of an area that otherwise would attract very little interest from developers. Receiving what amounts to a subsidy to reclaim intertidal land may be viewed as an attractive investment by developers with no real need for direct waterfront access.

Gene pool

Proponents of the gene pool argument for the conservation of natural resources note that the evidence of the fossil record serves to remind us that no species is guaranteed a future. Consequently they claim the maintenance of as diverse a gene pool as possible is essential, in order to ensure the maximum amount of genetic material survives the next large scale extinction event. In that context, the maintenance of pristine mangrove habitats is praiseworthy, for much of the flora and fauna of mangroves exhibit many physiological and other behavioural adaptations which are unique. Presumably these various adaptations are expressions of genetic material which is itself unique, and therefore worthy of preservation.

On a more pragmatic, anthropocentric note, the proponents of this argument also suggest that it does not make good sense to actively promote the extinction of species by habitat destruction before we know whether those species could be useful to us.

Buffer zones

Mangroves are often described as providing a buffer zone which protects the shoreline against the erosive forces of wind and waves. There is no doubt that mangroves do have some attenuating effect on wave heights and on currents, however I consider this is usually overstated. Mangroves characteristically grow on prograding shorelines where fine sediments are being deposited. Once mangroves become established they generally enhance the sedimentation process, as the physical barrier provided by roots and trunks impedes current flow.

Sedimentation usually takes place in locations where there is an absence of strong wave action or currents. If physical conditions change so that a mangrove is subjected to sustained strong wave action, it is not likely to provide much protection to the shoreline. If erosive conditions persist for any length of time, the mangroves will disappear.

Where mangroves do appear to be capable of providing a powerful buffer is in the entrapment of heavy metals. Saenger et al (1991) have demonstrated that mangroves lying between a tip site and an estuary have effectively prevented heavy metals leaching from the tip from reaching the estuary. The metals have been entrapped in sediments and the mangrove trees themselves. It may be that the large areas of mangroves on the northern Australian coastline have been acting as sinks for various heavy metals, some of which can occur in high concentrations adjacent to naturally eroding ore bodies. The removal of these mangroves could liberate large amounts of these heavy metals into estuaries, whereupon they may be taken up into the food chain. Basic surveys are required to determine the concentrations of naturally occurring heavy metals in mangrove environments.
particularly in those areas where mangroves are likely to be cleared in the near future.

**Primary production**

There is no doubt that mangroves represent an important source of primary production and that there is a link between the productivity of mangroves and the standing stocks of various commercially important species such as prawns. The exact nature of this relationship is difficult to quantify. There is a lack of information on total mangrove productivity, annual variation, net export of primary productivity from mangroves, food chains in nearshore waters and their dependence on mangrove productivity, and so on.

The primary productivity value of mangroves can be said to be relatively high when compared with most terrestrial habitats in tropical Australia. The majority of the northern Australian tropics is characterised by open woodland in which most of the substrate is occupied by annual grasses. During the wet season, the amount of atmospheric carbon assimilated by these grasses must be immense. However, a very large part of this carbon is liberated back into the atmosphere again during the dry season when the dead grasses burn. During these fires, many trees are also burnt. This does not happen to mangroves, where fire is generally a rarity, and presumably a greater proportion of the carbon assimilated during the year is retained in organic form, even though it may not remain in the mangrove.

**Large scale disturbance of mangroves**

I have concluded that, in general, Australia's tropical mangrove ecosystems are in pristine condition. This is primarily due to the lack of nearby, large scale human activities. Although it is unlikely that all the mangroves of northern Australia will eventually experience some impact from human activities (at least in the short term), it is certain that some large mangrove areas will be placed under increasing pressure. What sort of deleterious effects might be expected and how will these compare with the deleterious impact of natural events such as cyclones?

**Population growth**

The human population of northern Australia is low when compared with other parts of Australia, except the inland deserts. In addition, it is unevenly distributed, with the majority of people living in a few towns. The greatest population densities are in north Queensland, where in addition to the large towns of Cairns, Townsville and Rockhampton, the milder climate and higher rainfall have allowed the development of various forms of agriculture and a sizable rural population. In contrast, the Northern Territory and the Kimberley and Pilbara regions of Western Australia are sparsely populated with few towns of any size and hardly anyone living outside these centres.

In recent years, population growth has been steadily increasing in north Queensland, and growing slowly in the Northern Territory and Western Australia. Consequently, it would appear that mangroves in north Queensland, and particularly those near the larger population centres, will be placed under increasing pressure as the population continues to grow. This pressure will be manifested in a number of ways. Clearing of mangroves is usually accelerated by population growth. The rationale ranges from the acquisition of land for housing or industrial development, to the eradication of biting insect problems.

Other more subtle pressures come in the form of such things as sewage disposal and waste water runoff; leachates from rubbish tips, which are usually sited on low lying coastal land; increased fishing pressure; illegal dumping of refuse; construction of roads, bridges, breakwaters, wharfs, all of which can dramatically alter drainage patterns; dredging of channels; and spraying of some insecticides.

Within the Northern Territory, the only area of mangrove likely to experience an increase in pressure from population growth will be those of the Darwin Harbour. Unfortunately, those mangroves constitute one of the largest stands of mangroves in northern Australia. The present planning strategy of the Northern Territory Government aims for an eventual population of 1 million people to be residing around the Darwin Harbour within the next 100 years. Leaving aside objections that this aim is completely at odds with the concept of 'sustainable development', if this goal is achieved it is unlikely there will be much left of the existing mangrove resource within the harbour.

Even without reaching a population of 1 million, such a planning policy places enormous pressure on all existing natural coastal resources around the harbour, simply because large scale industrial, housing and recreational projects become desirable.

In the Kimberley region, the only coastal population centre which was (until recently) increasing significantly is Broome, and there are few mangrove
stands of any note near the town itself. South of Broome, the low rainfall limits the development of mangroves and there are few large stands. The Pilbara region will probably experience continued population growth associated with the inland mining operations and offshore gas fields and the several ports handling these materials can also be expected to grow. As a consequence there will be an increase in the impact on mangroves near these centres. Most of the Kimberley coast north of Broome is unoccupied and looks set to remain so for the short term. What appear to be the 'best' mangroves in Western Australia are in this remote region, and will remain protected (for the time being at least) from large numbers of humans by their isolation.

**Industrial development/mining**

Although large scale population growth is unlikely in much of northern Australia, the potential for disturbance due to industrial development and/or mining is high over most of the northern coastline.

The level of mining activity in the north can be expected to increase over the next few decades. Areas of particular interest appear to be oil (offshore), uranium, gold, lead and zinc. If mineral prices rise and remain high it will stimulate extraction operations and may even allow the development of some refining processes within northern Australia. Many of the mines and refining plants would have a potential impact on mangrove resources. Some mangroves may be cleared as part of the extraction process, but the most likely pressure would come from the siting of refining plants on the coastline, in or adjacent to mangroves.

Activities such as offshore oil extraction pose a threat to mangroves from oil spillages. In spite of generally stringent environmental safeguards, there are many oil spills annually around the world. If large oil fields are developed off the northern coastline — and if the oil is there, they will be — then there will be a chance of a substantial spill eventually. The existing arrangements for dealing with such a spill in the remote north may prove to be as inadequate as those which failed to protect a large section of the remote Alaskan coastline recently.

Another area of concern is seabed mining in coastal waters. It is likely that at least some applications will be made for licenses to extract seabed minerals. On a large scale, these have the potential to cause considerable damage to nearby coastal mangrove systems.

Australia is moving toward a uniform set of environmental standards which, when implemented, will provide more stringent environmental safeguards than previously existed in most states and territories. Northern Australia poses two problems which will prove difficult to overcome in the short term. There is a general lack of information on the existing environment and the remote nature of most potential development sites makes monitoring by regulatory bodies difficult, if not impossible.

**Greenhouse Effect**

Although the original prediction of this phenomenon was made a long time ago, it has been largely ignored until just recently, whereupon it became extremely popular, to an extent which allowed it to displace the 'El Nino' phenomenon as the major topic of dinner party conversation in some circles.

Sea level is expected to rise in the next twenty to fifty years by an amount which is considerably less than the figures first postulated in the mid 1980s. Recent predictions by CSIRO suggest a rise of somewhere between 20–40 cm is the most likely scenario. Although it is lamentable that the activities of humans should have led to any change in sea level, I doubt that a rise of this magnitude will have much impact.

There is no doubt that any change in sea level would affect mangrove ecosystems. However, most species grow in a sufficiently broad range of the intertidal zone and the majority of existing stands will be little affected. The major impact will be on the seaward edge of the mangrove, where the increased height of mean sea level will push back the limit of suitable mangrove habitat toward the land. At the same time, land at the landward edge of the mangrove will become intertidal, and therefore available for colonisation by mangroves. The amount lost on the seaward edge of any mangrove will be offset to a greater or lesser extent by the gain to landward.

It is important to bear in mind when discussing the impact of the Greenhouse Effect on mangroves that mangroves are generally dynamic systems. Changes in levels of flood plains, the course of rivers, rainfall patterns, sedimentation rates in estuaries can all have an immediate and devastating impact on mangrove ecosystems.

It is possible that in the short term at least, sea level rise might lead to an expansion of the total area of mangroves in northern Australia. Woodroffe et al (1985) present evidence which suggests that during the mid-Holocene period some 6500–7000 yrs BP, extensive mangrove swamps developed in northern Australia during the period of sea level rise. Once
sea level stabilised, sedimentation of flood plains progressively removed mangrove habitat and by about 5500 yrs BP, the area of mangrove had been reduced to something similar to that seen today.

Tropical cyclones

Mangroves are susceptible to cyclone damage. Very little information is available on the rate of recovery of mangroves after cyclone damage, but what is available suggests that a considerable period of time may be required before complete regeneration takes place. Aerial photographs taken in the years immediately after Darwin was struck by tropical cyclone Tracey in December 1974 show widespread damage to mangroves in the area. The mangroves at Ludmilla creek were almost totally destroyed by the cyclone, and still have not completely regenerated. The zonation typical of mangroves in the Darwin region is absent from Ludmilla creek, and the trees are yet to achieve the dimensions common in similar mangrove habitats nearby.

Bardsley (1985) recorded the damage suffered by various species of mangroves on the MacArthur River on the Gulf of Carpentaria after the area was struck by cyclone Kathy in 1984. Bardsley suggests that although damage was extensive, many of the mangrove areas showed signs of recovery, and that in some areas at least, the cyclone had changed environmental conditions to such an extent that there would be a permanent change in the mangrove community.

The likelihood of cyclone damage at any one site on the northern Australian coastline is low. However, when an area of mangroves is severely damaged by a cyclone, the primary productivity of that mangrove must be reduced for at least several years. Therefore care must be taken when designating mangrove reserves to ensure that sufficient areas are set aside to ensure that in the likelihood of extensive cyclone damage to one, the overall primary productivity of mangroves in the region will not be seriously affected.

Public perceptions of mangroves

It is sadly true that most Australians have a very poor view of mangroves. They are seen as wasteland at best, at worst as dangerous places full of unpleasant animals. This view is primarily due to a lack of contact with mangroves. Most Australians do not live anywhere near mangroves and those few that do, tend to avoid them. The majority of Australians have a largely European cultural heritage which has no experience of mangroves in contrast to Aboriginal and Asian views of mangroves where they are seen as valuable resources. While mangroves in northern Australia have generally remained remote from large population centres and therefore have suffered very little impact, there is a negative side to this isolation. The average Australian’s lack of experience with mangroves means that there is very little regard for the future of mangroves, and very little public support for the concept of mangrove reserves.

Environmental consciousness is improving in Australia, particularly among the young, as a direct consequence of the teaching of biology centred on Australian flora and fauna in schools and universities. There is, however, a critical shortage of teaching materials which provide information on tropical Australian ecosystems in general, and mangroves in particular.

If the present general attitude to mangroves is not modified by familiarity through education then one can assume that the remoteness of tropical Australia will not provide a secure refuge for a mangrove resource which is of increasing importance as mangroves elsewhere in the world disappear.

Notes

1. Professor Harry Messel of Sydney University’s Physics department led a team of researchers who spent several years assessing the crocodile populations in every major creek and river in northern Australia. The results are published in a series of monographs.

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CHAPTER 7

DISTURBANCE AND THE MANGROVE FORESTS OF DARWIN HARBOUR

Keith A McGuinness

Introduction

Mangrove forests are one of the most important coastal habitats in tropical Australia; over 90% of Australia's 11,550 km² of forest is found north of the Tropic of Capricorn (Bunt 1982; Galloway 1982). The potential significance of mangroves to coastal foodchains and fisheries has long been recognised (e.g. Odum & Heald 1975; Griffin 1985). These forests produce large amounts of organic matter, much of which may be exported to nearby habitats (Odum & Heald 1975; Clough & Attiwill 1982; Bunt 1982). They may also act as significant nursery areas for fish and prawns (Staples et al. 1985; Griffin 1985; Robertson & Duke 1987). Robertson & Duke (1987) found small fish, including 13 commercially important species, were 4-10 times more abundant amongst mangroves than in seagrass beds nearby. In the Northern Territory, Staples et al. (1985) noted that the commercially important Banana Prawn was only found on coasts with mangroves and Griffin (1985) stressed the importance of the forests to local fisheries.

Australia's developing population is placing an ever increasing pressure on coastal resources and habitats but our understanding of the effects of many human activities on natural marine communities is currently inadequate (Bird & Barson 1982; Hegerl 1982; McGuinness 1988b). McGuinness (1988b) introduced a classification of some of the factors affecting natural communities to clarify the research and management questions which were relevant. On the basis of the effects of physical factors on the habitat and the community, he constructed three broad categories: stresses, disturbances and catastrophes.

Stresses are relatively predictable and do not permanently alter the habitat. For example, exposure of intertidal habitats at low tide represents a natural stress; the continuous release of a pollutant to a river may be an artificial stress. A stressed community may change to some new state as some species increase in abundance and others decrease.

Disturbances are relatively unpredictable and may cause some damage to the habitat. A cyclone represents a natural disturbance; an oil spill (if there are minimal residual effects) is an artificial disturbance. Disturbed systems are likely to go through unpredictable bouts of destruction, followed by recolonisation and, sometimes, recovery. It is possible that several alternative communities may be capable of occupying the same habitat. This situation is referred to in ecological theory as 'alternative stable states' and means that there may be recolonisation of the habitat without recovery of the community previously existing (Connell & Sousa 1983).

Catastrophes are unpredictable events which cause major changes to the habitat. An earthquake is a natural catastrophe; reclamation represents an artificial catastrophe. Catastrophes reduce populations and usually change environmental conditions in such ways that the community cannot recover.

Recent work in marine habitats reveals that many are often normally disturbed — by events such as storms or cyclones — but in time the communities may recover (e.g. Connell 1978; Sousa 1979; Bardsley 1985; McGuinness 1987a & b, 1988b, 1990a). These communities are, therefore, commonly in a state of recolonisation, or recovery, from the last disturbance. In fact, a considerable body of theory and empirical evidence exists on the effects of natural disturbances and the mechanisms of recovery in some communities (see Sousa 1984; McGuinness 1987b). This has important theoretical and practical implications. From the viewpoint of ecological theory, it is clear that natural disturbances may be significant determinants of community structure. It is, therefore, important to understand how communities are affected by, and recover from, these disturbances. The practical implication is that because these communities exist in the face of natural disturbance, they may be able to cope with some artificial disturbance. From the viewpoint of environmental management, therefore,
it is necessary to understand the differences in effects and responses between natural and artificial disturbances.

Unfortunately, we know less of the responses of mangrove communities to disturbances than is desirable (McGuinness 1988b, 1990b; Hatcher et al 1989); this greatly hampers the use of existing theory for management (Simberloff & Abele 1982; McGuinness 1984, 1988a). Of course, the gross effects of a major disturbance, such as a cyclone, are relatively obvious (eg Stocker 1976; Bardsley 1985). Less obvious, and far less well understood, are the factors influencing the rate and nature of recolonisation and/or recovery, and the effects on other organisms, particularly the fauna.

The mangrove forests of Darwin provide a unique opportunity to address these issues. Fully 36% of Australian mangroves are in the Northern Territory (Galloway 1982), giving it per unit area and coastline the greatest amount of this habitat in the country. Further, the forests around Darwin are some of the most speciose (Hutchings & Saenger 1987) and extensive in the north (Woodroffe et al 1988). For more than 20 years the forests around the developing port and city of Darwin have experienced both natural and artificial disturbances (Stocker 1976; Davie et al 1985; Guinea 1988), and the latter will increase with further development. These disturbances range from minor clearing to whole-scale felling of hundreds of hectares of forest (Davie et al 1985; Guinea 1988). The area has experienced several natural disturbances, the most notable being Cyclone Tracy in December 1974 (Stocker 1976); but because the forests are extensive, covering some 25,000 ha, patches which have been little disturbed, or not disturbed at all, still remain (Stocker 1976; Davie et al 1985; pers. obs.). The extent of the habitat, and its ease of access, allows the development of powerful and detailed sampling studies and experiments. Finally, as a result of the need for planning of the city and port, the area has been extensively surveyed from the air at regular intervals enabling a detailed picture of disturbances to the area to be constructed.

In the last couple of years I have commenced studies of the mangrove forests of Darwin Harbour aimed at addressing some of the important issues. This chapter describes results from studies of three particular topics:

1) the rate of recovery from natural and artificial disturbance;
2) some factors influencing the rate of recovery; and
3) the responses of some other organisms in mangrove forests to disturbance.

Methods

The habitat and study sites

Semeniuk (1985b) classified the mangrove assemblages of north and north-western tropical Australia according to their habitat. The most extensive such assemblage was the main tidal flat. This ranged in width from 100 m to 1 km — depending upon gradient, tidal range, and other factors — and was divided into five zones:

1) a landward salt flat with scattered Ceriops;
2) zone of Ceriops (locally mixed with Avicennia);
3) zone of Bruguiiera mixed with Ceriops;
4) Rhizophora zone;
5) a seaward Sonneratia zone (Semeniuk 1985b).

Semeniuk (1983) grouped zones 1, 2 and 3 of this classification together as the landward zone of the main tidal flat: this usage will be followed here.

The landward zone of the mangrove forests around Darwin Harbour is not a homogeneous stand of trees, but is interrupted by individuals and stands of differing sizes (and probably ages), and by individuals and stands of other species (particularly Bruguiiera, Avicennia and Aegilurus; pers. obs. and see Semeniuk 1983, 1985a). There are also many patches of dead and fallen trees: some are the result of natural disturbances (eg cyclones, lightning strikes); others have been created by human disturbance (eg clearing, drainage works). (The origins of some patches can be identified from historical records and aerial photographs; the origins of others are as yet unknown.) These patches of dead or dying trees lacking leaves and canopy are a conspicuous feature of forests in Darwin Harbour (hereafter they are referred to as 'disturbed patches'). The work described here has been done in the landward zone at three main sites around Darwin: Rapid Creek, Frances Bay and Ludmilla Creek, with work to date concentrated at the latter. The main reasons for concentrating on this particular zone are that it is the most extensive in Darwin Harbour and is also easily accessible.

Recovery from artificial and natural disturbance

Aerial photographs were used to compare recovery following natural and artificial disturbance. Results for only one artificially disturbed and one naturally disturbed site are reported here. The naturally disturbed site is Ludmilla Creek, which was extensively damaged by Cyclone Tracy in December 1974. The artificially disturbed site is
Rapid Creek; this was cleared in July 1974 for a development which did not proceed.

One large (~50 ha) area was defined at each site and regrowth of the canopy in this was monitored by recording the percentage of the area occupied by mangrove canopy in all available photographs. Percentage cover was estimated by dropping a quadrat with 25 randomly placed dots onto the photograph and recording the number of dots which fell on mangroves; this was done five times for each photograph. It is important to note that only the regrowth of the canopy — some of which may be from defoliated adult trees — has been examined at this stage.

Factors affecting the rate of recovery

The recolonisation of a patch of habitat will be influenced by the rate at which propagules enter the patch, and their subsequent survival and growth. Some of the factors which may influence seedling survival and growth — such as inundation time and nutrients — may not be greatly affected by disturbance to the forest. Other factors, such as light and amount of debris, may change dramatically after disturbance. Preliminary experiments have been done to examine the effects of some of these changes.

Light

The removal of adult trees, or at least the canopy, will obviously have a great effect on the light environment of the seedling. Casual observations indicate that away from the main forest, seedlings are most abundant under adult trees; something also noted by Smith (1987b) and Ball & Pidgley (1988). This may be because seedling survival is greater (because of protection provided by the canopy of the adult), or it may simply be that this area receives more seedlings. These hypotheses were tested by marking out three 1 x 1 m plots under isolated adult trees, then trimming the branches of the trees so that the seedlings in the plots were no longer shaded. Three patches under undisturbed trees served as controls. Numbers of seedlings in the plots were counted on several occasions over the following year.

Debris

Debris is an obvious feature of many patches of local mangrove forests. This is particularly so at Ludmilla Creek where massive drifts of material up to 1 m high occur. This material moves with the tide and could retard recolonisation by smashing or crushing seedlings. Some aspects of these processes were tested by piling debris onto four 1 x 1 m plots of seedlings and constraining its movement with stakes; debris was periodically removed from four other control plots. This experiment, of course, only simulates crushing because it does not allow material to move greatly. Numbers of short (<25 cm) and tall (>25 cm) seedlings in the plots were recorded at the start of the experiment and on three occasions over the following year.

Responses of animals to disturbance

Work to date has concentrated on Cerithidea antecipata. This snail is commonly found attached to the trunks of mangroves in the main tidal flat; during spring tides it descends to the substratum at low-tide to feed, climbing back up the trunk as the tide returns.

The abundance of this snail was sampled in transects through disturbed patches at Ludmilla Creek and Frances Bay. Two disturbed patches were sampled at each of these sites. Two transects were run downshore through each patch. Ten 2 x 2 m quadrats were sampled in the living forest above and below the patch; ten quadrats in the centre of the patch; and ten quadrats in the fringe between the patch and the living forest above and below. Each patch was sampled on two different occasions.

Results

Recovery from artificial and natural disturbance

Figure 1 illustrates changes in mangrove canopy over about the last 15 years at both sites. Analyses indicate that the pattern of change differs between the two sites. At Ludmilla Creek, regrowth followed a parabolic pattern, rapidly reaching an asymptote (fit to quadratic polynomial: $r^2 = 0.73$; $p < 0.001$). In contrast, regrowth at Rapid Creek was essentially linear (fit to line: $r^2 = 0.75$; $p < 0.001$). Further analyses indicated that cover was consistently lower at Rapid Creek up to 1984 (ANOVA: $F = 9.71$; df = 1, 32; $p < 0.04$).

Factors affecting the rate of recovery

Light

The numbers of seedlings in the different plots at the start of the experiment varied quite considerably, so results were analysed in terms of the percentage change from the number initially present. There was gradual mortality of seedlings from the start of
FIGURE 1 Regrowth of mangrove canopy at Ludmilla Creek, following disturbance by Cyclone Tracy, and at Rapid Creek, after manual clearing.

FIGURE 2 Effects of canopy removal on abundance of seedlings (number per m²).
the experiment in August through to November with the rate being similar in the two treatments \((t = 1.20; \text{df} = 4; \ p = 0.30)\). The numbers of seedlings increased over the November to February seed-fall period in control plots but not in experimental plots, leading to a significant difference between the treatments \((t = 4.04; \text{df} = 4; \ p = 0.02)\). The rate of mortality from February through to the final sampling time was again similar in the two treatments \((t = -0.14; \text{df} = 4; \ p = 0.89)\). These results suggest that survival was not affected by the presence of adults but recruitment was.

**Responses of animals to disturbance**

The results of the surveys were quite straightforward (Fig 3): *Cerithidea* was consistently most abundant in the fringe zone between the disturbed patch and the forest. There was considerable variation in abundance in and around the different patches, particularly at Ludmilla Creek, but this does not obscure the overall pattern.

**Discussion**

Some of the work presented here is of a preliminary nature, but the results still suggest some important points. First, the recolonisation of disturbed areas by mangroves was relatively rapid. Following Cyclone Tracy, the canopy at Ludmilla Creek had regrown substantially within 6 to 7 years. Regrowth at Rapid Creek was, however, markedly slower than at Ludmilla Creek. Inspection of the aerial photographs suggests some possible reasons for these differences. Regrowth at Rapid Creek appeared to spread from the uncleared upper reaches of the creek downstream. In contrast, regrowth at Ludmilla Creek appeared to spread patchily. This is probably because regrowth at Ludmilla Creek was from surviving adult trees and seedlings. Stocker

**Table 1: Effect of burying seedlings under debris**

<table>
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<td>26</td>
</tr>
<tr>
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<tr>
<td></td>
<td>459</td>
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</tr>
</tbody>
</table>

(a) Results are given as means (bold figures) and variances of numbers of seedlings per m² (columns 2–5), and as percentage change from initial numbers (columns 6–9). Results are given separately for seedlings <25 cm in height, and ≥25 cm. Because of great variability in the initial numbers of seedlings in plots, percentage change from original numbers was analysed. Means were compared using t-tests for equal or unequal variances, as appropriate. Significant differences are indicated by < or > signs between means for control (CONT) and buried (BURY) plots.
FIGURE 3 Abundance (number per 4 m²) of Corithidea in transects across disturbed patches at Ludmilla Creek (LC-1, LC-2) and Frances Bay (FB-1, FB-2) (a)

(a) The zones sampled were: living forest upshore (UF) and lowshore (LF) of the patch, the centre of the patch (CL) and the fringes between the centre of the patch and the upshore and lowshore zones (F).

(1976) surveyed some areas around Darwin after Cyclone Tracy and noted that adults of some species, particularly Avicennia marina, had survived. Further, many seedlings and smaller plants appeared to be covered by the tide at the time of the cyclone and were little damaged (Stocker 1976). At Rapid Creek, on the other hand, seedlings appear to have been completely removed and have had to recolonise from elsewhere.

It is important to note that these conclusions refer only to the regrowth of the canopy. Guinea (1988) observed significant changes at Rapid Creek in tree density, size and species composition between 1980 and 1987. Further, Hanley (pers. comm.) has said that the forest re-establishing in some places at Ludmilla Creek after Cyclone Tracy differs markedly from that previously extant.

The second important point is that the rate of recolonisation may be modified by a variety of factors which together affect the transportation of seedlings to an area, and influence their subsequent survival and growth. Two factors shown to be important here were the presence of adults and of debris. As noted earlier, Ceriops seedlings tend to be most abundant under adult trees (Smith 1987b; Ball & Pidley 1988; pers. obs.). The experiment here showed that this was because the recruitment and/or establishment of seedlings was enhanced under the adult canopy: the presence of the canopy had no effect on their subsequent survival. The latter result differs from observations of Smith (1987b) who found that seedlings survived and grew better in light gaps than in the shade of the forest. The difference in light intensity between the two treatments in the experiment described here was, however, probably much smaller than in Smith's (1987b) experiments; this may explain the contradictory results. The observation that recruitment is enhanced under the adult canopy is not surprising, though it does run counter to other authors' suggestions (Tomlinson 1986).

Debris also affected the survival and growth of seedlings, though the mechanisms leading to these effects are not entirely clear. The general pattern was for plots with debris to have more small seedlings and fewer large seedlings than control plots. The latter result at least is somewhat unanticipated. It is possible that the debris actually acted to trap seedlings in the plots, increasing
recruitment by reducing the number washed away and leading to greater numbers in the experimental plots. Alternatively, or perhaps additionally, the debris may have retarded the growth of seedlings, resulting in fewer large seedlings in the experimental plots. Certainly, a number of seedlings in the experimental plots shows signs of having been bent or broken.

Taken together, the results of these experiments indicate that a range of environmental factors influence the process of recolonisation at a site. The work of Smith (1987b) demonstrates that the light environment of the seedling may also affect growth and survival, though such effects were not observed in this study. It is significant that some of these factors may well differ between naturally and artificially disturbed areas. A large amount of debris — fallen trees, branches and leaves — remains after a cyclone but such materials may be collected and removed if the site is artificially cleared. Further, a cyclone is unlikely to kill all adult trees and many of the seedlings may survive, particularly if the tide is high (Stocker 1976; Bardsley 1985), but areas artificially cleared may be totally denuded (pers. obs.). The experiments and observations here indicate that these differences are likely to influence both the rate and nature of recolonisation.

The third important point is that changes in the abundance of the mangroves may influence the fauna. There is a clear and consistent relationship in local forests between the abundance of Cerithidea and canopy cover: the snail is nearly always most abundant in the fringe between areas with and without canopy cover. At this stage the reasons for this pattern can only be speculated on. The snails either suffer increased mortality in the centre of disturbed patches or avoid these areas. This may be because heat and desiccation stress are extreme in the centre of these patches (Cockcroft & Forbes 1981c). Experiments and other observations suggest that the snails choose resting sites to minimise desiccation stress (McGuinness unp. data). Further, snails experimentally restrained in the centre of clearings die within a few weeks if they are unable to find protected resting sites (McGuinness unp. data).

The decline in abundance from the fringe into the forest may result from predation. Other surveys in these forests have shown that there is a consistent increase in crab numbers, as estimated by burrow counts, from the centre of disturbed patches (where there are none at all) into the forest (McGuinness unp. data). Again, it is likely that the crabs avoid the harsh conditions in the centre of these disturbed patches. There is other evidence suggestive of predation. First, 60% of 224 snails collected at one site had evidence of past shell damage likely to have resulted from failed predation attempts. Second, there was approximately 50% mortality of snails experimentally tethered to the substratum in the forest (McGuinness unp. data). Indeed, predation by subtidal predators is the reason most widely cited to explain why these snails climb trees (Brown 1971; Cockcroft & Forbes 1981a&b) and has been shown experimentally to be important for other species (Warren 1985).

In summary, this work illustrates three important points. First, that some mangrove forests may be able to recolonise after disturbance, and do so reasonably rapidly. Second, a variety of factors are likely to affect the rate and nature of recolonisation. Further, by manipulating these factors we may be able to increase the rate of recolonisation following disturbance, and direct its path. Finally, the effects of disturbance on other organisms, and the interactions among these organisms after disturbance, may be complex. Together these three points mean that it is vital that these effects and interactions are well understood so that we can correctly and confidently manage these important ecosystems and ameliorate the adverse impacts of disturbance.

Acknowledgments

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CHAPTER 8

CONSERVING VULNERABLE HABITAT IN NORTHERN AND NORTH-WESTERN AUSTRALIA: THE RAINFOREST ARCHIPELAGO

J Russell-Smith, NL McKenzie and J CZ Woinarski

Introduction

Over the past five years substantial rainforest research programs have been undertaken both in the Northern Territory and Western Australia. While the focus of research has differed in these two regions, in common both programs have set out to document the regional distribution of rainforest patches, sample floristic and faunal composition, assess their condition, and determine whether the current network of conservation reserves encompasses their biological diversity.

Many of the findings from these programs are now, or soon will be, publicly available. For example, a comprehensive description of Western Australian rainforests, with emphasis on the distribution patterns of plants, invertebrate and vertebrate assemblages, is contained in the recently published volume, Kimberley Rainforests of Australia. The final paper of that volume (McKenzie & Belbin 1991), makes recommendations for a representative reserve system in the region, and discusses some evident management problems.

Data for the Northern Territory are contained in a number of recent and forthcoming papers. These include a floristic classification of rainforest types (Russell-Smith 1991), and tree species compositional patterns are considered further by Bowman, Wilson and McDonough (1991). Vertebrate assemblages are described in a number of papers submitted for publication by Woinarski, Gambold, Menkhorst, and co-workers (eg Menkhorst & Woinarski, in press). The conservation status of rainforest floristic types, their condition, and regional management issues, are considered by Russell-Smith and Bowman (1992). Papers documenting the ecology and conservation status of individual species and communities are in preparation also.

In this paper we summarise findings concerning the distribution, composition, and population ecology of rainforests across northern and north-western Australia. We then consider the effectiveness of the current system of National Parks and Reserves in meeting the conservation requirements of regional rainforests.

Such an assessment is timely given that fires, in conjunction with cattle (additionally water buffalo and pigs in the Northern Territory) are severely damaging rainforests throughout this region (McKenzie & Belbin 1991; Russell-Smith & Bowman, in press). Further, these data have relevance for land management practices generally, given that this problem applies equally over all major forms of land tenure: vacant crown land, pastoral leasehold, Aboriginal lands, and land set aside for conservation purposes (including Aboriginal land in the Northern Territory leased as National Park (Russell-Smith & Bowman 1992). Rainforests in only a few areas are free of stock.

Distribution

The distribution of tracts or, more commonly, small patches of rainforest through the monsoonal, woodland savannas of the Top End of the Northern Territory and the Kimberley region of Western Australia, is summarised in Figure 1. Using the same digitised map data, it is estimated that there are over 16 500 rainforest patches over the entire region, including over 1500 in Western Australia (Kay et al 1991). Patches are mostly less than a few hectares in size, ranging from the crown of a few tree crowns, to riparian strips and coastal tracts thousands of hectares in extent (McKenzie & Belbin 1991; Russell-Smith 1991). The largest patch in the Kimberley is approximately 100 ha in area, with a median between 2 and 3 ha.

As indicated in Figure 1, rainforest patches are concentrated in certain higher rainfall coastal regions. In the Kimberley, patches are concentrated in rugged terrain between the Prince Regent River and the Bougainville Peninsula (Fig 1). In the Northern Territory, rainforest is concentrated
FIGURE 1  Distribution of rainforest (km²) in northern and north-western Australia, per 30' x 30' cells

(a) Distribution of rainforest in WA after Kimber, Forster & Behn (1991); in NT after Russell-Smith & Lucas, unpubl data.
particularly in the harsh, imposing sandstone terrain of western Arnhem Land. These NT forests, comprising 41% of all rainforest in northern and north-western Australia, are dominated by a tree species restricted to that region, *Allopecurus ternata*.

In total, rainforest over this broad region covers 2750 km² (Fig 1); that is, approximately 0.4% of the planar land surface area.

**Isolation and Interdependence**

Rainforest species vary in their dispersal ability and in their degree of specialisation to rainforest habitats. These characteristics largely have determined the distribution and persistence of the regional rainforest biota.

Environmental change associated with increasing climatic seasonality through the late Cainozoic at least (about the last 15 million years), has resulted in major fragmentation of the rainforests. With restriction of rainforests to increasingly precarious refuges, surviving specialist plant and animal species have become marooned in remnant patches or adept at dispersing across intervening habitats. Population sizes of plant species in any one patch are typically very small (Russell-Smith & Lee 1992).

The status of populations varies between different taxonomic groups and between regions. For example, the monsoon rainforest estate has a rich fauna of small, endemic caenamid land snails. Forty-eight species of caenamid land snail are known only from rainforests in the Kimberley (Solem 1991). By contrast, specialist rainforest ground mammals are now absent from the monsoon rainforest archipelago, presumably because such species require the continued presence of large areas of rainforest habitat. The few ‘closed canopy’ specialist mammals that persist in the Kimberley, with its smaller and sparser patches, also utilise mangrove and/or riverine habitats: *Melomys sp, Pipistrellus westralis, Macroglossus minimus, Nyctophilus arnhemensis* and *N. bifasc* (McKenzie et al 1991). As well, only one plant species is endemic to that region, *Hibiscus peralbus* (Kenneally et al 1991).

Through extinctions of formerly connected populations, and divergence in environmental conditions after patches were isolated, the entire distributions of many sedentary rainforest specialists is now restricted to one or a few neighbouring rainforest patches. The endemic palm, *Psychosperma bleseri*, is a well-known example, with a distribution restricted to a few scattered jungle patches in the near vicinity of Darwin. Equally notable is the predominantly northern hemisphere frog family, Ranidae, known in Australia from two species: one occurs in a limited area of Cape York; the other, recently discovered, is known from two small rainforest patches in eastern Arnhem Land. The average Kimberley caenamid land snail was recorded in just three neighbouring sampled patches (Solem 1991). Such species are by no means atypical; 30% of rainforest plant species occurring in the Northern Territory were sampled at 10 or fewer patches from a sample of over 1200 patches.

A consequence of such restricted, idiosyncratic distribution patterns is that patches occupying similar ecological settings, even when adjacent, commonly support different species assemblages. As well as plant assemblages, this applies equally to reptiles (Gambold & Woinarski, forthcoming), snails (Solem & McKenzie 1991), and earthworms (McKenzie & Dyne 1991).

The ability to disperse affords a release from the prison of the rainforest patch. Many monsoon rainforest plants and non-caenamid land snails are readily dispersed by birds, bats, wind or water. The fleshy fruits of many rainforest plants are attractive to a rich guild of frugivores that includes fruit pigeons, flying foxes, and more facultative species such as trillers, orioles, honeyeaters, cuckoos, even turtles. Despite being far more extensive, the surrounding open forests and savannas contain such a relatively low abundance of fleshy-fruited plants that frugivores (and nectarivores) in the Top End and Kimberley are forced to be reliant upon the isolated patches of monsoon rainforest for at least most of the year.

Movements of vertebrate species between rainforest patches provide a means of escape for rainforest plants, enabling them to colonise other patches, maintain gene flow between isolated populations, and to expand their range in response to environmental change. This process has many scales of interdependence. Frugivores can persist only if fruit is available year-round; they need high floristic diversity within and between patches (with different species fruiting at different times of the year, or separately in different patches), phenological succession, or keystone fruiting species such as certain figs which fruit through the year. On a landscape scale, frugivores will persist only where the distance between patches is not prohibitive. Once a patch is too distant to be accessible, it is likely bound for floristic decay. As
disturbances impoverish or remove patches from the network, the abundance and diversity of dependent frugivores will inevitably decline.

Finally, the rainforest system houses not only obligate rainforest species, but is used also as seasonal, daily or occasional refuge by many animal species from surrounding vegetation. For example, rainforests on floodplain fringes in the Northern Territory are invaded by the rodent Rattus colletti when floodplains are inundated during the wet season (Friend et al. 1988); many savanna insects congregate in relatively cool, humid rainforests during the long dry season (Kikkawa et al. 1981); the Agile Wallaby, Macropus agilis, shelters in rainforests during the heat of the day; populations of many other vertebrate species take refuge in rainforests during the frequent fires that characterise tropical savannas (Friend et al. 1991). Thus, rainforests provide ecological resources important to the population dynamics of many species which utilise open forest and savanna communities for much of the year.

Conservering the rainforest archipelago

Given this biological background we can begin to address the question of whether the conservation requirements of rainforest communities in this region are met. In making this assessment we will consider first the representativeness of the present reserve system, and then other management issues associated with conserving regional rainforests.

Recent assessments of the conservation status of rainforest communities in the Northern Territory and in Western Australia have found that the current, basically ad hoc, reserve network, is deficient (Burbidge et al. 1991; McKenzie & Belbin 1991; Woinarsi, in press). This is true in the Kimberley even if 19 current reserve proposals (Burbidge et al. 1991) are added to the reserve system for this assessment. In the Northern Territory, five of 16 floristically defined rainforest types are unreserved at the present time. These include three types which occur mostly on Aboriginal land (Melville and Bathurst Islands, eastern Arnhem Land), and two other types well represented on leasehold land in the south and south-west of the Top End (Russell-Smith & Bowman 1992).

In Western Australia, 21 of 28 defined species assemblages are unreserved (McKenzie & Belbin 1991). After inclusion of proposed reserves, these authors found that 11 assemblages were still unrepresented, and additional areas have been identified. The inclusion of species groups with differing ecological characteristics and requirements in this classification afforded fine scale community definition (birds as representatives of mobile fauna; land snails for their small size and poor dispersal capacity; plants for habitat and primary resources).

Community-level representation, however, is not the only criterion of biological conservation; conservation of genetic diversity is desirable also (eg Conservation Commission of the Northern Territory 1990). Given both the level of genetic isolation apparent in the distributions of many sedentary species, and the dependence of many other species on ecological resources and/or interbreeding populations scattered through a network of patches, a strong ecological case may be made for conserving the entire rainforest archipelago. This includes protection of linking habitats or corridors, such as mangrove fringes and vegetation along watercourses, that facilitate seasonal movements between patches by birds (eg Torresian Imperial Pigeon) and fruit bats.

The daunting practicalities of attempting to reserve, let alone manage, over 16 500 patches, even given improbable political support for such a move, speaks for itself. Further, while protected area status (reservation) for rainforest patches clearly does provide tangible conservation benefits, it provides no guarantee that currently threatened populations and habitats will receive effective management (Russell-Smith & Bowman 1992). It is thus important here to distinguish between reservation and conservation.

In Western Australia and the Northern Territory data are now available to facilitate development of management priorities for rainforests both within and outside the reserve system. In some situations it is evident that fencing is required to eliminate continued disturbance from cattle and other introduced animals. An example here is fencing recently undertaken to protect rainforest habitats of the endangered palm species, *Psychotria blesseri* (cf Duff et al, chapter 9 in this volume). The costs associated with such management, including establishment and maintenance of fences, weed eradication, and implementing protective burning programs, necessitate strategic planning.

For the Northern Territory, Russell-Smith and Bowman (1992) identify five major rainforest areas likely to remain severely affected by cattle/water buffalo at the end of the current Brucellosis and Tuberculosis Eradication Program (BTIEC), by 1992. In the Kimberley, the introduction of cattle to the Mitchell Plateau in the last 10 years has led to
Conserving vulnerable habitat: the rainforest archipelago

rapid degradation of rainforest patches. Elsewhere, on pastoral leases, patches are now restricted to sites protected from both frequent fires and cattle (McKenzie & Belbin 1991). Given the destructive impacts of cattle (additionally water buffalo and pigs in the Northern Territory), and severe late dry season fires, on rainforest habitats across northern Australia, stock exclusion and fire management are clearly integral to rainforest conservation throughout this region.

Conservation of rainforest patches outside the reserve system (as most are) requires community and industry support. This process, we suggest, is best addressed through education, incentives and, where appropriate, contractual agreements or enforceable covenants.

Epilogue: the conservation of vulnerable habitat and species in a shifting and fragmented environment

We have inherited a philosophy of nature conservation management that rests largely on the precept of reservation of representative samples of major habitats. This system reinforces marked contrasts in attitudes towards, and management of, natural resources under different forms of land tenure. The system is based, in theory at least, on detailed knowledge of the distributions of individual species, and the presumption of environmental stability.

While very important, reservation alone will not protect the rainforest estate in northern and north-western Australia. This applies equally to other fragmented habitats in this region; for example, wetlands (Whitehead et al, chapter 11 in this volume), and even eucalypt woodlands (Woinarski & Tidemann 1991).

By itself, the reservation system is inadequate because it does not cater for:

a) rare habitats and species which fall outside reserve boundaries. This applies particularly to plant and animal species which are poor dispersers;

b) a capricious climate which forces vagile species to change distribution in response to seasonal and yearly variation in rainfall, or other resources — these species need to have options;

c) appropriate conservative land management practice over different forms of land tenure.

Effective conservation across northern Australia requires, therefore: expansion of the reservation system so that it is representative of major habitats; active management of vulnerable species and their habitat, both on and off reserves; a shift in current attitudes to land exploitation by both the public and industry; and greater flexibility on the part of conservation Authorities. Legislation is required both in the Northern Territory and Western Australia to meet this last need.

Notes

1. The area of rainforest per 30' cells of latitude x longitude in Figs 1a and 1b was computed from digitised rainforest maps. For the Kimberley, rainforest mapping was undertaken from Landsat Thematic Scanner images (Kay et al 1991). The area of rainforest, totalling 68 km², was calculated by summing Landsat image pixels classified as rainforest (Kimber et al 1991). Mapping of Northern Territory rainforests was undertaken visually from full aerial photo coverage of the region, at scales ranging from 1:15 000 to 1:80 000. These maps were then scanned/digitised, and subsequently compiled using the ARCINFO geographic information system.

Acknowledgments

The authors wish to acknowledge that this paper draws on substantial work undertaken by a great many people, most of whom are not given as authors in the references. Marion McCabe, Matthew Pickering and Craig Walker compiled the rainforest distribution map. Research was funded by Commonwealth, Northern Territory, and Western Australian Governments, under the auspices of the National Rainforest Conservation Program.

References


CHAPTER 9

CONSERVATION AND MANAGEMENT OF THE ENDANGERED PALM
PTYCHOSPERMA BLEESERI

Gordon Duff, Glen Wightman and Derek Eamus

Introduction

Recent research has indicated that monsoon rainforests (also called monsoon forests, monsoon vine forests or jungles) in northern Australia are under severe threat at the present time. Russell-Smith and Bowman (1992) found one-third of monsoon rainforests from 1219 sites to be severely disturbed by fire, 20% by cattle and buffalo, 10% by pigs and 22% infested by weeds. These major types of disturbance were found to apply generally across the three major forms of land tenure in the Northern Territory: Aboriginal land, Crown land and National Parks and Reserves.

Monsoon rainforests in northern Australia mostly occur as small, isolated patches less than a few hectares in extent. Russell-Smith et al (chapter 8 in this volume) described 16 floristic types of monsoon rainforest, 8 of which are found on sites with perennial moisture available, and the remaining 8 on seasonally dry, freely draining landforms. Ptychosperma bleeseri, an endangered species of rainforest palm (Briggs & Leigh 1988), occurs in only one of these forest types (Type 2 — small evergreen rainforest patches associated predominantly with springs in the higher rainfall regions of the north–west Northern Territory). Forests of this type were found to have particularly high levels of disturbance by buffalo and cattle (>70% of all forest patches surveyed), pigs (>40% of patches) and weed infestation (>50% of patches). Of these forests, >30% were also found to be severely disturbed by fire at the time of the survey (Russell-Smith & Bowman 1992).

Ptychosperma bleeseri is known to occur in seven populations, all within less than 100 km of Darwin (Fig 1). Of these populations, two are reserved and fenced in the Conservation Commission of the Northern Territory (CCNT) Black Jungle Reserve. One of the reserved and one of the unreserved populations have adult populations of Ptychosperma bleeseri in excess of 100 individuals, while the remaining five populations have between 0 and 24 adults, and varying numbers of juveniles (see Table 1). The table shows that 86% of the naturally occurring adult Ptychosperma bleeseri population occurs at two sites.

TABLE 1 Location, population size and land tenure of all known, naturally occurring populations of Ptychosperma bleeseri

<table>
<thead>
<tr>
<th>Location</th>
<th>Population Size</th>
<th>Land Tenure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adults</td>
<td>Dead Adults</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Creek</td>
<td>143</td>
<td>8</td>
</tr>
<tr>
<td>Crocodile Creek</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Banka’s Jungle</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Litchfield Creek</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Whitewood Road</td>
<td>137</td>
<td>—</td>
</tr>
<tr>
<td>7km Sth H/Stead</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>8km Sth H/Stead</td>
<td>11</td>
<td>—</td>
</tr>
<tr>
<td>TOTAL</td>
<td>326</td>
<td>42</td>
</tr>
</tbody>
</table>

Source: Wightman 1990
Evidence collected during the survey carried out in the 1990 dry season suggests that numbers of juveniles had declined from previous estimates at a number of sites. Late in 1990, a fire penetrated the Whitewood Road Jungle, and while data on adult mortality are not yet available, it is believed to be significant.

Not surprisingly, *Psychosperma bieeseri* is recorded as endangered in the 1989 rare or threatened Australian plants listing. Several of the populations are severely disturbed by feral animals, and all populations are to some extent vulnerable to local extinction, as was so graphically demonstrated by the 1990 fire at Whitewood Road.

Relatively little is known about the ecology of this species, and it was the purpose of these preliminary studies to collate further baseline data and to carry out pilot experiments to assess the feasibility of future research. Priority areas for research were identified as being:

i) Population structure and population dynamics, including dispersal;

ii) Phytosociological analysis, with a view to determining the potential extent of the distribution of the species;

iii) Population genetics; and

iv) Ecophysiology, with a view to assessing microclimatic parameters for establishment of populations.

In the short-term, management of extant natural populations will rely heavily on preventative measures such as fencing, feral animal removal and the creation of fire breaks. Long-term management, including re-introduction and maintenance of genetic diversity will rely on baseline information on the ecology of the species, which will take several years to collect. It is therefore important to initiate these studies as soon as possible.

This chapter presents a summary of a number of studies of the ecology of *Psychosperma bieeseri*, carried out by staff and students at the Northern Territory University. The chapter is divided into four sections, each describing a separate study of population structure, phytosociology, population genetics and ecophysiology.

![Map showing the distribution of known populations of Psychosperma bieeseri](image)

(a) Numbers correspond to the following jungles: 1. Black Creek; 2. Crocodile Creek; 3. Barkin's Jungle; 4. Litchfield Creek; 5. Whitewood Road; 6. 7km south of Koolpinyah Homestead; 7. 8km south of Homestead.
Population structure

Aims

The primary aim of this study was to assess the population structure of two natural populations of *Psychosperma blesseri*, and to assess the dispersal characteristics and seedling distribution of the species.

Methods

Two sites were selected for the initial studies on seedling distribution, Black Creek and Litchfield Creek. At Black Creek, three parallel N-S transects were laid through the centre of the patch, running perpendicular to the creek. The transects were 10 m apart, 5 m wide and from 120 to 150 m in length. Two 5 m wide transects were laid out at Litchfield Creek, one 240 m E-W, the other 120 m N-S. Presence, position and height class (<0.5, 0.5–2, 2–5 and >5 metres) of all *Psychosperma blesseri* individuals were recorded. Three further sites were investigated: Banka’s Jungle, Crocodile Creek and 8 km Homestead. Low densities of individuals at these sites rendered the use of transects inefficient. Instead, number and size class of randomly selected individuals of *Psychosperma blesseri* were recorded. In all cases, DBH (Diameter at Breast Height) and number of stems per individual were recorded for adult palms.

Site descriptions were also prepared on the basis of transect data. Data recorded included assessment of ground disturbance, estimates of litter cover, canopy cover and understory density. All data were recorded in the late dry season (July to October), 1990.

Analyses carried out on the data included:

1. Size class frequency distribution for all five sites.

2. Goodness of fit to a poisson distribution for dispersion of seedlings at Black Creek and Litchfield Creek.
   \[ H_0: \text{That seedlings are distributed at random with respect to one another.} \]

3. Assessment of seedling frequency with respect to distance to the nearest adult from transect data at Black Creek and Litchfield Creek. Two way ANOVA was carried out on seedling densities in 5 m x 2 m quadrats. Variable 1 was site, variable 2 was distance to nearest adult individual of *Psychosperma blesseri*. Distance was divided into five classes, <6 m, 6–12 m, 12–18 m, 18–24 m and >24 m to nearest adult along the transect.
   \[ H_0: \text{That site has no significant effect on seedling density.} \]
   \[ H_0: \text{That distance to nearest adult has no significant effect on seedling density.} \]
   \[ H_0: \text{There is no significant interaction effect of site x distance on seedling density.} \]

4. A two way ANOVA was carried out on the diameters at breast height of live and dead adults at three sites (Black Creek, Litchfield Creek and Banka’s Jungle).
   \[ H_0: \text{That site has no significant effect on adult palm DBH.} \]
   \[ H_0: \text{That there is no significant difference between the DBHs of living and dead adult palms.} \]
   \[ H_0: \text{That there is no significant interaction effect.} \]

Results and Discussion

Demographic structure of populations at the five sites are shown in Figure 2. Seeding densities were observed to be relatively low at three of the sites (Banka’s Jungle, Crocodile Creek and 8 km Homestead Jungle), and the proportion of the total population represented by seedlings is also low at these three sites compared with the other two. Severe levels of ground disturbance, presumably by feral animals and/or domestic stock, are almost certainly responsible for these low seeding densities; the other two sites (Black Creek and Litchfield Creek) support this contention. At these two sites, seedling densities and seedling numbers relative to adult numbers were relatively much higher, and the observable level of ground disturbance considerably lower. The disparity in sampling design between the former three and latter two sites could account for some of the differences, but not the order(s) of magnitude of differences found.

Figure 1 also shows a gap in the size class distribution in the 2–5 metres height class at all five sites. Two related hypotheses would most readily account for this anomalous frequency distribution.

1. At some time in the past (a time corresponding approximately to the age of individuals in the 2–5 m height class), an event or series of events has caused higher than normal levels of seedling mortality, accounting for the low membership in the 2–5 m cohort in all populations. Clearly, survival to and through this size class must have occurred, to account for the presence of adult
FIGURE 2  Height frequency distributions for *Ptychosperma bleeseri* at five jungle patches surveyed (a)
(a) Height class is given in metres. D denotes frequency of dead adults >5 m.

individuals (>5 m). Alternatively, conditions are still such that fewer than normal seedlings are surviving to reach the 2–5 m size class and beyond. The possible causative agents for this phenomenon include disturbance (fire, feral animals or domestic stock), or changes in the abiotic environment (rainfall, soil moisture/drainage etc). The latter seems less likely.

2. If the species is long lived, the low numbers of individuals in the 2–5 m size class may simply be a result of the recruitment pattern of the populations, and the numbers in this size class may represent a sufficiently large pool of recruits to replace dead adults. If this is the case, then the number of dead adults observed at all but one of the sites must indicate recently increased adult mortality, and the present pool of recruits is insufficiently large to replace them.
If either of these two hypotheses are correct, and the causative agents of increased mortality are still active, these populations are demonstrably in a state of decline. In the absence of effective management measures, it is probable that these populations will become locally extinct in the foreseeable future.

A third possibility is that recruitment in the species is highly episodic, and that such a recruitment episode has not occurred in recent years. This possibility seems less likely, and in the light of the high levels of adult mortality observed, no guarantee can be given that local extinction will not occur anyway.

Fencing of two of the sites may prevent further population decline at these sites, but it will be necessary to monitor changes in population structure to assess the effectiveness of present and future protection of populations.

The results of the goodness of fit to a poisson distribution clearly demonstrated that seedlings were non randomly distributed. \( \chi^2 = 108.22 \text{ df} = 4; \ P < 0.001 \text{ for Black Creek, } \chi^2 = 175.3 \text{ df} = 4 \ P < 0.001 \text{ for Litchfield Creek.} \) Block size to Variance analysis (Kershaw & Looney 1985) indicated a strong tendency to clumping at an area of \( \leq 10 \text{ m}^2 \).

The two way ANOVA for site x distance on seedling distribution showed only a significant effect of distance (\( F = 5.54 \text{ with } 4 \times 100 \text{ df, } P = 0.005 \)). A Sidak pairwise comparison of seedling density by distance produced two homogenous groups, one for \( < 6 \text{ m} \), the other for all other distances. The combination of these two analyses indicates that seedlings are clumped near the bases of adult palms, suggesting that seed dispersal in a significant majority of cases is by gravity alone.

Observations suggest that bird or mammal dispersal are unlikely to have major roles in the dispersal of *Psychosperma blesseri*, although further research will be needed to test this hypothesis. Flowering parts of the palm are seldom seen in the forest canopy, so seeds are far less likely to attract the attention of seed dispersing birds and bats. The implications of limited seed dispersal between jungle patches are far reaching. Local extinction in a given jungle patch may be unlikely to be followed in the short term by reestablishment from another patch, even though suitable habitat is available. Current island biogeographic theory suggests that species with poor dispersal capabilities are less likely to be found in isolated habitat islands. Where the only available habitat is broken up into small fragments, as is the case with jungle patches that support *Psychosperma blesseri*, species with poor dispersal capabilities are relatively extinction prone.

Analysis of DBH data showed no significant effect of alive versus dead on DBH, and no significant interaction, although site did have a significant effect. Mean DBHs for Black Creek, Litchfield Creek and Bank’s Jungle were 4.04, 5.20 and 4.69 cm respectively.

### Phytosociology

**Aims**

*Psychosperma blesseri* occurs in lowland, evergreen monsoon vine forests associated with perennial springs and on the margins of perennial streams (Brock 1988; Russell-Smith 1988). All but one of the jungle patches supporting *Psychosperma blesseri* occur on the margins of the Adelaide River flood plain, and the remaining one in the adjacent Howard River catchment. The jungle patches of the area are floristically, structurally and geomorphologically related, but only a small proportion of them contain *Psychosperma blesseri*. The aim of this study was to investigate patterns of floristic, structural and environmental variation within a small selection of these jungles, in relation to the distribution of *Psychosperma blesseri*.

**Materials and Methods**

Initially, four study sites were selected, two at Black Creek and two at Whitewood Road. Only two of the sites, one in each area, were known to contain *Psychosperma blesseri*. However, before the completion of the study, a major fire occurred at Whitewood Road, and data from only one of the two sites in this jungle were used, the site without *Psychosperma blesseri*. The three sites from which data are available were designated BJI (*Psychosperma blesseri* present), BJII (*Psychosperma blesseri* absent) and WR (*Psychosperma blesseri* absent). At BJI, a 150 m transect consisting of 15 contiguous 10 m x 10 m quadrats was laid out, beginning at the northern boundary and ending near the centre of the patch. A similar 150 m transect running from the northern to southern boundaries was laid out at BJII. A 100 m transect was laid out at WR, beginning at the western boundary and ending near the centre of the patch. All transects ran perpendicular to the main creek lines.
At BJII and BJIII, presence of all vascular plant species was recorded in each quadrat. At all sites, the number of adult (＞2 m height) and juvenile (＜2 m height) individuals of *Psychosperma bleeseri* were recorded.

In all quadrats, species, DBH, height estimate and density were recorded for all species ≥5 cm DBH. Basal area was calculated for each species in each quadrat. Canopy closure was estimated at the beginning, centre and end of each quadrat and assigned a value of 0 (open), 0.5 (partially closed) or 1 (closed, >50% Foliage Percent Cover).

Two soil samples were collected from each quadrat, between September and October, 1990. Field pH, texture and percentage moisture were determined for each soil sample. Texture was assessed on a scale of 1-5: 1 = sand, 2 = sandy loam, 3 = loam, 4 = clay loam, 5 = clay. Percentage moisture was determined after oven drying at 80°C. Ground elevation along the transects was measured using an clinometer.

**Results and Discussion**

Floristic data (presence/absence) for BJI and BJII were first analysed using two way indicator species analysis (TWINSPLAN), (see Hill 1979b). The first division of the data produced one group of 20 quadrats, only two of which contained *Psychosperma bleeseri*, and one group of 10 quadrats, all of which contained *Psychosperma bleeseri*. Wilcoxon rank sum tests were carried out to compare mean values of environmental variables between the two TWINSPLAN groups, and between the group of quadrats in which *Psychosperma bleeseri* was present and that in which it was absent. From this series of tests, the only significant difference observed was for soil moisture between the group of quadrats in which *Psychosperma bleeseri* was present and the group in which it was absent (P = 0.0141).

Floristic data were then ordinated using Detrended Correspondence Analysis (DECORANA), (see Hill 1979a). Results showed good agreement with TWINSPLAN results, and strong correlation with the presence/absence of *Psychosperma bleeseri*. Indirect gradient analysis was used to determine correlations with DCA1 and DCA2 and environmental variables, but no significant correlations were found.

TWINSPLAN and DECORA were carried out on presence/absence data for tree species at all three sites. TWINSPLAN resulted in 4 groups. The results of Wilcoxon rank sum tests comparing means of environmental variables showed that only mean soil texture varied significantly between groups with and without *Psychosperma bleeseri*. However, all four environmental variables had significantly different mean values in TWINSPLAN groups 0 and 1. Values for DCA1 and DCA2 were shown to be approximately normal and normal respectively, using the Shapiro Wilkes W test, so regressions of both DCA axes were carried out against environmental variables. Regressions of DCA1 on soil moisture, pH and texture, and that of DCA2 on pH, were found to be significant. Spearmans rank correlation between soil moisture and pH was found to be significant (P <0.001). Also using Spearmans rank correlation, DCA1 was found to be significantly correlated with total basal area and sapling density, but not with presence/absence of *Psychosperma bleeseri*. Presence/absence of *Psychosperma bleeseri* was not shown to be significantly correlated with any structural variables or with soil moisture.

While TWINSPLAN classification of the Black Creek site showed clear floristic distinction between quadrats with and without *Psychosperma bleeseri*, the total data set of quadrats, including Whitewood Road, showed no such distinction. Furthermore, no clear trends were evident from the distribution of *Psychosperma bleeseri* with respect to environmental variables. Similarly, ordination of the data revealed no clear pattern in the distribution of *Psychosperma bleeseri* with respect to floristic variables, although clear separation was evident between Black Creek and Whitewood Road sites. Within the sites surveyed, *Psychosperma bleeseri* appears to occupy a range of sites with differing structural, floristic and edaphic characteristics. It follows that, within the scope of this study, no variables were examined which account for the scattered distribution of populations of this species. Therefore, other factors must account for its limited distribution.

Data available to date suggest that *Psychosperma bleeseri* does not occupy the full range of sites in which it is capable of maintaining viable populations, either because (1) the species once occurred at many of these sites, but has since become locally extinct, or (2) the species has not dispersed to its full potential range.

Further phytosociological research over a wider range of sites and including a wider range of environmental variables, and seasonal variation in
Aims

This project was faced with a number of difficulties, but despite these it was felt that a feasibility study investigating population genetics was of paramount importance. *Pychosperma blesseri* is known to hybridise with a number of other species in the genus, including exotic species (Jones 1984) which occur in the Darwin area. Any management plans involving the reintroduction of the species into natural populations must take into account the protection and maintenance of genetic diversity, and baseline information about this genetic diversity is completely lacking. The project was constrained by lack of adequate funding, time to carry out a sufficient number of electrophoretic analyses, limited sample size and an absence in the literature of similar studies carried out elsewhere, particularly on the family Araceae. No information was available on breeding systems, ploidy level and suitable isoenzymes. Nor was there any reproductive material available, which is the optimum source of extracts in most cases.

The primary aim of this project was to assess the feasibility of studying population genetics in *Pychosperma blesseri* using standard gel electrophoresis techniques, and to assess the requirements of a more complete study of population genetics for the species.

Materials and Methods

Four populations were sampled, Whitewood Road, Litchfield Creek, Black Creek and Banka's Jungle. At each site, 2–3 g of the youngest available leaf material were collected from six seedlings, and snap frozen at the site in liquid Nitrogen. (Unused material is presently stored at -70°C at Myily Point Campus, Northern Territory University, if required for further analysis.)

Several extraction buffers were tried, the most successful being 16% Sucrose + 8% Sodium

Ascorbate, pH 7.5. Plant material (50 mg per 100 μl of buffer) was ground to powder under liquid Nitrogen, buffer added, vortexed and placed on ice. Samples were centrifuged to remove particulate matter before use. Electrophoresis was carried out on a Phast-gel system (Pharmacia LKB Inc) using proprietary 4–15% PAGE gradient gels. Electrophoresis was carried out for 100 volt hours at 250 volts, 20 mAmps at 7°C. Gels were then stained in 20 ml staining mixture for each of the following four enzymes. The enzymes were GDH (glutamate dehydrogenase), Malic Enzyme, IDH (isocitrate dehydrogenase) and MDH (malate dehydrogenase). MDH yielded uninterpretable results. SOD (superoxide dismutase) also stained on the gels, and the results for this enzyme are also used in the report.

Results and Discussion

The gels were scored and interpreted as single allele two loci systems, with the possible exception of the IDH gel, which had a possible 3 or 4 loci visible. In this report, IDH loci 3 and 4 were treated as one locus.

The most conservative estimate of heterozygosity yields heterozygosity rates of 2.3% (Whitewood Road), 4.7% (Litchfield Creek), 5.7% (Banka's Jungle) and 23% (Black Creek).

Most of the gels showed a heavy bias towards single allele homozygous states, with GDH and IDH1 fixed at 1 allele. However, sample size was insufficient to adequately determine whether there is significant allele variation among populations.

Using the Cavalli-Sforza and Edwards measure of genetic distance, preliminary results indicate that the populations at Whitewood Road, Litchfield Creek and Banka's Jungle are all approximately equidistant from one another, while the population at Black Creek is substantially further from all the others.

No firm conclusions can be drawn from this study because of insufficient sample sizes for robust statistical analysis. However, the study has demonstrated that future analyses along these lines are feasible, and firm conclusions could be drawn from larger sample sizes. A minimum of 50 samples form large populations and a complete sample of smaller populations is recommended, along with analysis of at least 10 alleles. More information is also required on breeding systems, ploidy and dispersal.
Ecophysiology — studies of gas exchange

Aims

Information about the ecophysiological characteristics of *Psychosperma bleezeri* will be necessary in order to make the best use of seedlings reintroduced into natural populations. In particular, an understanding of gas exchange characteristics (basically photosynthesis and respiration) and water relations will assist in the selection of optimum sites for the continued survival of untended viable populations. Water relations were not studied in this program, but a comprehensive analysis of gas exchange under field and shadehouse conditions was carried out, the aim being to assess the responses of *Psychosperma bleezeri* to a range of light regimes. The field studies were constrained to data collected late in the 1990 dry season, which was a particularly severe dry season following a relatively poor wet season.

Materials and Methods

Gas exchange characteristics were assessed using a LicoR LI 6200 portable infra-red gas analyser, chamber and data logger. Field studies were carried out at Whitewood Road, on 16 September and 21 September, 1990. Measurements of gas exchange were carried out on adult and sapling individuals of *Psychosperma bleezeri*, *Carpentaria acuminata* and *Livistona benthamii*. Number of usable observations carried out on the first two species on the first trip were 92 and 24 respectively, and on all three species on the second trip were 65, 51 and 43 respectively. In addition, observations were carried out on 80 seedlings of *Psychosperma bleezeri* grown by CCNT and transferred to four shadehouses at NTU. Twenty of the seedlings were placed in each of four experimental shadehouses, with light regimes approximating 2%, 10%, 25% and 70% full sunlight. Seedlings were watered to field capacity twice daily throughout the experiment. Two sets of 48 and 255 observations were made on these seedlings.

Results and Discussion

Light compensation point is the light level at which the respiration rate and rate of photosynthesis (CO₂ evolved versus CO₂ uptake) are equal. To maintain a positive carbon balance (ie grow), total photosynthesis must exceed total respiration. Light compensation point gives an indication of the degree to which plants are able to grow in shade — the lower the light compensation point, the more shade tolerant the plant.

Light compensation points measured on leaves (fronds) at <2 m above ground in all three palm species investigated in the field indicate relatively shade adapted leaves. Mean LCP in all three species was between 4.5 and 5.9 μmol m⁻² s⁻¹, approximately 0.3% full sunlight. Comparable observations of shadehouse grown *Psychosperma bleezeri* seedlings demonstrated an LCP of at least 3 times that observed in the field, probably because shadehouse grown seedlings had been grown under 30% full sunlight prior to the experiment, and had not fully acclimated to low light conditions in the deeper shade treatments.

Apparent Quantum Yield, Maximum Rate of Assimilation and Light Saturated Photosynthesis all indicated that *Psychosperma bleezeri* growing under field conditions at that time of year were more shade adapted than seedlings grown under shadehouse conditions. Conclusions based on these data are as follows:

1. *Psychosperma bleezeri* is shade adapted under natural conditions, when investigated in the forest understory environment. As the species seldom has leaves exposed to full sunlight except in canopy gaps, conditions of partial shade are likely to be optimal for growth of the species.

2. *Psychosperma bleezeri* is able to acclimate to higher light conditions, although some evidence exists for photoinhibition under full sunlight conditions. Recent observations of shadehouse grown seedlings indicate the maximum rate of growth has occurred in the 25% shadehouse, although seedlings grown in 70% full sunlight appear to be only marginally slower. Seedlings have survived at 2% full sunlight under a mixture of clear sky, dry season conditions and overcast wet season conditions with zero mortality for a period of 12 months to date, although little growth is evident.

3. The major limiting factor to growth under field conditions is possibly water stress during the dry season.

4. *Carpentaria acuminata* and *Livistona benthamii* are also shade tolerant, and may be successful competitors with *Psychosperma bleezeri*. Both these species consistently co-occur with *Psychosperma bleezeri*.
Conclusions

Two hypotheses were presented to account for the observed size class frequency distributions in five populations of *Pychosperma bleezeri*. If either of these two hypotheses are correct, and the causative agents of increased mortality are still active, these populations are demonstrably in a state of decline. In the absence of effective management measures, it is probable that these populations will become locally extinct in the foreseeable future. The poor dispersal capabilities of this species mean that unassisted re-establishment of the species into areas where it has become locally extinct are unlikely in the short term. It is also unlikely that new populations will become established in other monsoon rainforest sites by natural dispersal vectors such as birds or bats.

Data available to date suggest that *Pychosperma bleezeri* does not occupy the full range of sites in which it is capable of maintaining viable populations, either because: i) the species once occurred at many of these sites, but has since become locally extinct, or ii) the species has not dispersed to its full potential range.

No firm conclusions can be drawn from the study of population genetics because of insufficient sample sizes for robust statistical analysis. However, the study has demonstrated that future analyses along these lines are feasible, and firm conclusions could be drawn from larger sample sizes. A minimum of 50 samples form large populations and a complete sample of smaller populations is recommended, along with analysis of at least 10 allozymes. More information is also required on breeding systems, ploidy and dispersal.

*Pychosperma bleezeri* is shade adapted under natural conditions, when investigated in the forest understorey environment. As the species seldom has leaves exposed to full sunlight except in canopy gaps, conditions of partial shade are likely to be optimal for growth of the species. Further ecophysiological research investigating water relations of the species is considered necessary.

The fate of *Pychosperma bleezeri* is inextricably linked with that of the monsoon rainforests of northern Australia in a more general sense. The case study described herein only serves to highlight the threats to conservation of monsoon rainforest which appear to have arisen in recent decades. In particular, changes in fire use patterns, increases in numbers of feral animals, the continued spread of exotic weed species and interactions between all of these factors are making rapid inroads into this valuable and unique biological resource. Protection and conservation of natural populations of a particular species is at best a stop gap measure. The real issue is conservation of the habitat, and the case of *Pychosperma bleezeri* serves to highlight the urgency of the present situation.

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CHAPTER 10

CONSERVING TOP END WETLANDS FOR TOURISM

Richard Freeman

Introduction

Until the advent of the study of ecology in the 1950s, wetlands were traditionally thought of as soggy or damp places usually buzzing with insects. As they were not immediately attractive places, many people looked upon them as wasteland that could only be of value if drained and put to some use. Recorded world history provides evidence of the most primitive of communities through to the most sophisticated in the present day treating wetlands as a dispensable resource.

Here in the Northern Territory we are fortunate, or perhaps more enlightened, in that our vast Top End Wetlands are in virtually pristine condition with little obvious damage except from the water buffalo and invasive weeds.

Through improved education, mass media programs such as the televised 'Nature of Australia', and the debate over mining in Kakadu National Park, the public has been stimulated to come and look and learn about one of Australia's great outback experiences.

Before looking in any detail at possible tourist development of the Top End Wetlands, it is worth pausing and reviewing the history of tourism and wetlands in more developed areas.

The British example: the Wildfowl Trust

It was only after World War II that official recognition was given to the need for nature conservation and the protection of Britain's natural heritage. A driving force in this conservation movement was the formation of the Wildfowl Trust in 1946 under the leadership of Peter Scott (later Sir Peter Scott). Originally a wildfowler (shooter) himself, Peter Scott understood the relationship between his sport and the habitats on which his quarry depended. Under his guiding influence, the Trust was established to counter the threat the rapidly diminishing wetlands and ultimately ensure the survival of viable wildfowl populations (The Wildfowl Trust 1985).

The term 'wildfowl' in Britain has come to mean ducks, geese and swans. In most of the world, however, they are know as 'waterfowl', and this term is used to cover any birds such as waders whose survival depends on the existence of wetlands.

The aims of the Wildfowl Trust have been defined under four main topics.

Research To find out how to conserve wildfowl and to add to human knowledge

Conservation To conserve wildfowl and their wetland habitat for future generations

Education To help people by all available means to a greater appreciation of wildfowl, other interdependent animals and plants of wetlands and nature in general.

Recreation To enable people to enjoy living wildfowl as part of our natural heritage.

The Trust has pioneered and developed methods of display that have enabled the general public to see some waterfowl at close quarters and wild native species in their natural habitat. Originating at Slimbridge on the Severn estuary, in the west of England, the Trust has now established a total of seven Visitor Centres in England and Scotland.

Each centre is sited on a natural wetland system where native wildfowl are free to come and go. Refuges have been created so that visitors can approach unseen to the very edges of marsh and water meadow. At some refuges, screened approaches lead to covered hides enabling visitors to penetrate right into the habitat and observe birds at close range without disturbing them. Excellent
information signs are provided to inform visitors about the birds and flora and fauna with which they are associated.

At the heart of each Centre are displayed collections of tame waterfowl from all parts of the world in landscaped settings. Birds are grouped either according to their continent of origin or in flocks that are suited to similar habitat types. Rare and threatened species are usually kept in special pens. Steps are taken to assist and encourage the birds to breed successfully.

A number of species threatened with extinction have been raised in captivity and reintroduced into the wild. The most striking example is the Nene or Hawaiian Goose which had been reduced to less than 50 individuals on its home island when three individuals were sent to Slimbridge in 1951. From this stock 2000 birds have been released, with 200 being sent to Hawaii and many others sent to other centres where they have successfully bred.

The Trust has been very successful in raising the awareness of the British public to the plight of wetlands and their associated birdlife. Each year hundreds of thousands of people visit the Trust’s Centres. Particular attention is given to catering for the young and old and disabled. Signs are simple and clear, often using colour graphics. In some Centres, audio information posts have been installed together with braille signs. Good quality cafeteria facilities, souvenir and book shops, provide visitors with a high level of satisfaction.

To reinforce and assist in the appreciation of the conservation issues, an excellent education and information service provides for schools and other groups on planned visits. Over 100,000 school children a year, attend illustrated talks and guided walks.

Over the last 40 years, the Trust has emerged as a highly successful and profitable business enterprise, with an international reputation for excellence.

The Australian experience

Unlike Britain, where man has been substantially changing the landscape for over 8000 years, European influence has had little more than 200 years to develop and ‘improve’ the Australian landscape. In that time, however, CSIRO has estimated that more than 60 per cent of the coastal wetlands in southern and eastern Australia have been lost (CSIRO 1990).

The recently published report, The Injured Coastline: Protection of the Coastal Environment (HORSCERA 1991, 47) states that:

Wetlands have commonly been cleared or filled for the purposes of tourism or urbanisation. However, the cumulative effect of the many separate decisions by local governments to agree to proposals for new canal estates or tourism resorts is a severe reduction of wetland habitats in the coastal regions with negative economic consequences for commercial fisheries.

The report adds:

This tyranny of small decisions can have a substantial impact on land use or lifestyle without a conscious decision by Governments to reduce the amount of wetlands.

It appears we have learned little from the experience of others! Or have we?

Shortlands

One of the most interesting and innovative examples of changing community attitudes towards wetlands can be found in the suburb of Shortlands on the outskirts of Newcastle. Located on the edge of the 2500 ha Hexham Swamp, part of the Hunter River estuary, the area has been identified as being particularly important as a waterfowl habitat.

The Shortlands Wetlands Centre was established in 1985 as a Bicentennial Project by the Hunter Wetlands Trust. The Centre is the headquarters of the Hunter Wetlands Trust Inc., a community organisation formed in 1984 to promote education, research, conservation and passive recreation in wetland settings (pers. comm. from Shortlands Wetlands Centre 1991)

Originally linked to the Hunter River, the freshwater lagoons of the Swamp were gradually filled as part of Newcastle City Council’s garbage dump, and other areas were filled for sports fields whilst drainage and flood mitigation works in the 1960s and 1970s affected yet more areas. In the early 1980s, only 8.3 ha of lagoons remained when dumping ceased at the Council’s garbage tip. In 1981, four species of egrets established a breeding colony in the paperback swamp and Professor Max Maddocks began studying the breeding biology of the birds.
With the threatened proposal to re-open the garbage tip and develop a major road through the area, the public and the Trust were galvanised into action. As a result of two public meetings, plans were established to take over the former garbage dump, sports fields and associated derelict clubhouse and establish a Wetlands Reserve. The Trust was set up in July 1984 and by February 1985 membership had grown to 1000. A design and management study was carried out by consultants to establish the form and funding of the Centre. The study was well received and was instrumental in gaining funding from BHP for $100,000 to help purchase the land and buildings. The Newcastle City Council provided a similar amount, with the NSW Bicentennial Council donating $300,000 immediately with a possible $100,000 for further site development.

The proposals for establishing a Wetlands Reserve were accepted by the Newcastle City Council and, in November 1985, the Hunter Wetlands Trust began operating in the converted sports clubhouse.

The Trust was fortunate in obtaining the services of Brian Gillingham from the NSW Department of Education, and a part-time assistant, to carry out educational programs from the Centre. Later Brian Gillingham was appointed Director, responsible for the day to day operations of the Centre and its conservation, education, research and recreation programs. The Centre was registered with the NSW Corporate Affairs Commission as non-profit company and members of the Trust Council became members of the company. A Board of Directors was then appointed to run the company.

Following the initial establishment of the Centre, valuable wetland areas were purchased, including important egret nesting and ibis roosting habitats. A section of a local creek was also purchased which enabled links to be established to other wetlands including Hexham Swamp and the Koongang Island Nature Reserve. This enabled canoe exploration of the wetlands.

During 1986-88 the field study centre was established with meeting facilities, office space, a small library and audio visual equipment installed. The Centre began to run lectures, and seminars, and cater for study group visits and tourists. A kiosk was set up to sell books, posters, tourist souvenirs and refreshments to help the Centre become financially self-supporting.

As a visitor attraction, the disused sports field directly in front of the Centre was converted into a pond with a daily feeding program to attract birds. This enabled the elderly and physically handicapped to easily observe the more common bird species frequenting the wetlands.

Access to the wetlands was carefully zoned to restrict general visitors to less sensitive areas. Ornithologists, researchers and study groups were allowed under permit to visit the breeding and roosting areas. Walking paths have been built leading to observation towers, and fencing erected to keep out predatory animals and control public access.

To 1988 funding of $1.3 million dollars had been achieved with over 75 per cent coming from Federal, State or Local Governments and, significantly, over 20 per cent coming from private sponsorship and donations.

Community involvement has been a major factor in assisting the staff to undertake a wide variety of tasks ranging from the initial cleaning up and landscaping of the site to library cataloguing, serving in the shop, conducting guided tours and general maintenance.

The Centre now serves as a venue for conferences, a meeting place for environmental organisations and for in-service teacher training. A formal education program caters for all groups, from infants to higher degrees at university, while a non-formal program caters for a wide range of community groups such as service clubs, church groups, scouts and guides.

The Centre is active in research and undertakes consultancy work for the government and private sector. Facilities are provided for passive recreation such as canoeing, walking and bird-watching. Picnicking is on the increase and organised activities such as 'Breakfast with the Birds' and 'Twilight Walks' are being developed.

The Centre's successful planning, development and operation was realised when the Centre was awarded the NSW Branch of the Royal Australian Planning Institute's State Award of Excellence for Rural Planning in 1989 and the National Award for Community Planning 1990.

A high public profile is maintained by the Centre using both local ABC radio and regular articles in the Newcastle Herald to raise awareness of its objectives.

A wide ranging education program has been established, dealing with environmental issues. In 1991 the Centre was staffed by two full-time teachers and a part-time clerical assistant provided
by the NSW Department of Education. Over 1000 pupils a month, from all over NSW now pass through the Centre.

The centre has proved so successful that it has become something of a model for environmental centres in other States and Territories.

**Top End wetlands**

In contrast to the earlier examples of wetlands in Britain and New South Wales, the Top End Wetlands are extensive and relatively undisturbed. For the purpose of this chapter, the Top End Wetlands extend east from the Howard River to the boundary of Kakadu National Park and occupy approximately 10 500 km² (see Fig 1).

As in Britain, the Top End Wetlands are relatively recent in origin. Formed in the poorly drained flood plains of the northernly flowing Howard, Adelaide and Mary Rivers, the wetlands as we see them today, would only have begun to form some 5500 years ago. Due to the shallow gradient in lower sections of these rivers and the large tidal range of about 6 m, tidal influence can extend 100 km upstream.

The monsoonal climate of the Top End results in a pronounced inundation of the flood plains during the Wet Season, making access difficult unless using a boat or helicopter. During the Dry Season, flood waters gradually recede and numerous lakes, waterholes and swamps emerge in the floodplain and on the alluvial plains near the sea.

These wetlands form part of the largest freshwater swamplands in Australia. To date, exploitation of the wetlands has been limited to extensive pastoralism and small scale ventures such as rice growing. Largely unmodified, the wetlands support a range of plant communities ranging from eucalypt forest on the higher areas, to monsoon vine forest in the wetter areas, to melaleuca swamps in seasonally inundated areas, to grass and sedge lands adjacent to the river.

The coastal wetlands provide habitat for a rich assemblage of wildlife including spectacular avifauna (Finlayson et al 1990; Morton & Brennan 1991). With the marked seasonal variations between 'Wet' and 'Dry', there is a shift in distribution of waterfowl. The most spectacular example of this process is the congregation of up to 2 million magpie geese (*Anseranas semipalmata*) on the adjacent flood plains of the South and East Alligator Rivers.

Recognition of the importance the natural fauna and flora play in attracting tourist to the region was given in *Towards Year 2000: Northern Territory Tourism Development Plan*, which identified six 'zones of opportunity' for the development of attractions, tourist facilities and infrastructure. The Top End Wetlands were identified as the second priority area for tourist development (Petar Marwick Hungerfords 1989).

Based on this recommendation, the Conservation Commission has devised a Top End Wetlands Conservation and Recreation Strategy that identifies where visitor facilities should be developed whilst at the same time identifying areas requiring special protection or management (CCNT 1990).

The eastern boundary of the Top End Wetlands abuts Kakadu National Park. Since the proclamation of the Stage 1 of the Park in 1979, visitor numbers have risen rapidly. This has been paralleled by the development of infrastructure and a range of visitor facilities. With this recent experience, it is worth reviewing some of the information provided in the recently published *Kakadu National Park Plan of Management (ANPWS 1991)*, to provide a context for possible future development in the *Wetlands*.

**Kakadu National Park**

The Plan highlights the dramatic growth in visitor numbers to the Park from 46 000 visitors in 1982 to about 240 000 in 1990. This is an annual growth rate of 24% but with a significant levelling off since 1987. Approximately 20% of visitors are from overseas and, together with inter-state visitors, make up an increasing proportion of the visitors. A majority of visitors, approximately 80%, visit the Park in the drier months of the year between May and October, with only 48 000 people visiting the park during 'wet' or 'green' season. Private visitors to Kakadu stay on average four days while those on tours stay less than two days.

Surveys indicate that there is an increasing interest in observing and understanding natural and cultural values, rather than traditional activities such as boating and fishing. This may account for the success of the Yellow Waters boat cruises.

Recent studies of tourism (Knapman, Lea & Stanley 1990) suggest that Kakadu National Park accounts for 25% of tourism expenditure in the Northern Territory.
It appears obvious from the above information that the increasing visitor levels cannot be sustained without significant overcrowding and resultant environmental degradation. Alternative attractions are required to assist in dispersing visitors and/or visitation patterns need to be expanded into the 'green' season to reduce periods of overcrowding.

FIGURE 1 Location of Wetlands Study Area
Development strategy

In preparing the Development Strategy for the Top End Wetlands, the Commission has identified the conservation and recreation values of the Wetlands and assessed their relative importance and demand. Based on this assessment, priority areas for conservation and recreation have been identified.

A Strategic Zoning Plan has been prepared that provides a basis for managing activities within defined areas so that people’s activities do not conflict with the conservation values of the area.

The development concept includes the following seven management zones.

1. Development Zone
2. Tourism Facility Zone
3. Sightseeing Zone
4. Adventure Activities Zone
5. Nature-based Recreation Zone
6. Isolated Activities Zone
7. Protection Zone

The concept’s strategic objective relies on conservation of the significant species, habitats, ecosystems or other conservation values of the Wetlands whilst at the same time providing for a range of recreation activities in a variety of unique natural settings.

Rather than elaborate on the Development Strategy, this chapter will focus on one of the key development proposals.

Fogg Dam

Fogg Dam Conservation Reserve is identified in the Top End Wetlands Development Strategy as a Development and Nature Based Recreation Zone that could provide a quality experience for interstate and overseas tourists’ (CCNT 1990, 35).

Located within an easy one hour drive from Darwin and close to the Arnhem Highway, Fogg Dam is accessible in both the ‘Dry’ and ‘Wet’ season.

The dam was built in 1956/57 as part of the Humpty Doo rice growing scheme which included the present low dam, drains, channels and sluices. Constructed as a joint project by Utah Australia Ltd and Royal Australian Air Force engineers, the dam was intended to control water for rice paddies and increase productivity. Utah’s Managing Director, Mr JD Fogg, gave his name to the project.

The birdlife in the adjacent wetlands, particularly the magpie goose, which were partly to blame for the scheme’s failure because they fed on the rice, were to become its ultimate beneficiaries. The dam was made a Bird Protection District in 1959 and has since become an increasingly valuable wildlife habitat.

Fogg Dam Conservation Reserve covers 1569 ha. Located on the western fringes of the Adelaide River floodplain, it is part of an extensive wetland system that includes Lambell’s Lagoon, Black Jungle Swamp and Harrison Dam. Access to the dam is along Anzac Parade on the low lateritic ridge that forms Middle Point.

A diverse natural flora existed in the Reserve prior to the construction of the dam. It included isolated pockets of monsoon forest, through open scrubland, melaleuca woodland to closed eucalypt forest. The Reserve displays a variety of important ecosystems and stands of interesting plants such as Livistonia benthamii. Sedges, grasses, pandanus and water lilies are a feature in the seasonally inundated area.

The dam lake, where extensive areas of lotus lily and floating islands of grass are a particular feature, has added to habitat diversity (see Fig 2).

With this diversity of habitats around Fogg Dam, it is perhaps not surprising that significant numbers of birds, reptiles, mammals and marsupials populate the Reserve. However, it is the year-round presence of water birds that has brought fame and visitors to the Reserve. The most commonly observed species include: magpie goose (Anseranas semipalmata), great egret (Ardea alba), comb-crested jacana (Irediparra gallinacea), little pied cormorant (Phalacrocorax melanoleucos), glossy ibis (Plegadis falcinellus) and Burdekin duck (Tadorna radjah) (Tideman 1987).

In addition, Fogg Dam is important for supporting a breeding population of green pygmy geese (Nettapus pulchellus) and of particular note in Workshop Jungle is the largest known breeding population of rainbow pintail (Pitta iris) in the world. Other animals commonly seen in the Reserve include agile wallabies, goannas, monitor lizards, water pythons and, during night spotting, estuarine crocodiles. Figures 3 and 4 provide a general impression of the faunal distribution in the ‘Dry’ and ‘Wet’ seasons.

With a wide variety of wildlife easily observed throughout the year, it is understandable that Fogg Dam has developed a widespread reputation and a steady stream of visitors. It is estimated about 25,000 people visit the reserve each year.
Of interest is the high level of interstate (72%) and overseas (9%) visitors, compared with locals (11%). Waterbird viewing is obviously the major attraction, but, viewing of the sunrise and sunset over the wetlands, photography and picnicking, are also popular.

In 1989, the need to develop and manage the Reserve to achieve its potential, was recognised. The Commission began preparing a Masterplan to guide future action.

FIGURE 2 Fogg Dam landscape masterplan: vegetation
Source: Clouston 1990
Using landscape architecture consultants Clouston, a plan has been prepared that seeks to address the needs of the Development Strategy, together with a number of management issues (Clouston 1990). These include:

1. Water Management — problems have developed in the catchment with erosion resulting in siltation, pollution from chemicals and nutrients, and potential instability of the dam wall during periods of flooding.

2. Encroaching Development — the integrity of the Reserve needs to be protected from the impacts of encroaching development including vegetation clearance, weed infestation, soil erosion, illegal dumping and use of agricultural chemicals.

3. Visitor Facilities and Impact — increasing numbers of visitors will need to be catered for with improved access and parking. Conflict between pedestrians and vehicles needs to be resolved. Toilets and other basic amenities need

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**FIGURE 3** Fogg Dam landscape masterplan: generalised dry season faunal distribution

Source: Clouston 1990
to be provided. Interpretative and information facilities need to be established to encourage visitors to explore and learn about the Reserve, with a degree of ease and comfort.

4. Noxious Weed Control — a number of noxious weeds which have become established in the Reserve including Water Hyacinth, Hyptis and Water Lettuce, need to be eliminated.

5. Exotic Animal Control — a number of exotic animals including pigs, buffalo and cats are adversely impacting on the Reserve and need to be eradicated or removed.

6. Conservation of Vegetation — the diversity and habitat value of the Reserve need to be protected particularly from the adverse impacts of wild fires.

7. Reserve Management and Administration — to effectively manage the physical resources and service the increasing number of visitors to the Reserve, an appropriate management system has to be put in place.

**FIGURE 4** Fogg Dam landscape masterplan: generalised wet season faunal distribution

*Source: Clowston 1990*
FIGURE 5  Fogg Dam landscape masterplan: window on the wetlands concept
Source: Clouston 1990
The concept developed in the Fogg Dam Masterplan proposes a bold departure from the current minimalist approach that has evolved to date. The proposal is to build on the assets of Fogg Dam including its proximity to Darwin, easy year-round access, diverse and robust character and spectacular wildlife, and develop a major visitor attraction with the theme 'Window on the Wetlands'.

The Masterplan anticipates a potential growth in visitors from five to ten-fold in the medium term. To cater for these additional visitors, it is proposed to provide a new main access directly off the Arnhem Highway on the western side of the dam to a visitor Centre overlooking the Adelaide River floodplain. Ultimately to be a sealed road, it will provide access for most car and coach visitors. In addition to its primary access function, the road would double as a fire break and serve as an interception for surface run-off from development to the west of the Reserve. In the future, the road could be extended to provide access to other parts of the wetland system. The existing road in to the Reserve from Middle Point would be sealed and terminated at a car park on the eastern side of the dam (see Fig 5).

The dam wall is proposed as a pedestrian zone and a service road for maintenance vehicles. Should demand warrant it, a shuttle train could provide access across the dam wall.

A major Visitor Centre is proposed on the low slopes above the western end of the dam wall. The Centre would serve as the headquarters for the Reserve's management and the focus of interpretive programs.

From the Visitor Centre an elevated boardwalk would lead visitors across the western spillway to the pandanus knoll with its panoramic views of the floodplains. Walks would then lead to bird hides overlooking the magpie goose breeding areas, the dam wall and the western shoreline of the lake. On the eastern side of the dam, a carpark and picnic facilities would be provided in the woodland area. A network of interpretive walking tracks and boardwalks would provide year round access to the various habitats.

Upgrading of the dam and lake would be undertaken to improve water management and public amenity. A sluice gate is required to improve regulation of water flow. In the longer term, modification to the lake edge could be undertaken to create islands and improve the habitat value.

Implementation of the Masterplan is likely to take many years and will depend on available funds. However, a start has been made with a grant of $100 000 through the National Rainforest Conservation Program.

These funds have been matched by a similar amount from the Territory Government and will be used to construct a walking track and boardwalk through a transect of the different habitats to the monsoon vine forest and melaleuca woodland on the eastern side of the dam. As visitor numbers increase private enterprise will be encouraged to take up commercial opportunities once the necessary infrastructure is in place.

Acknowledgments

Assistance with the preparation of this chapter has been received from Wetlands Centre, Shortlands, and in particular Brian Gillingham. Information relating to Fogg Dam has been obtained from the Fogg Dam Landscape Masterplan prepared by Clouston, and this source is duly acknowledged.

References


CHAPTER 11

MANAGING THE MAGPIE GOOSE IN THE NORTHERN TERRITORY: APPROACHES TO CONSERVATION OF MOBILE FAUNA IN A PATCHY ENVIRONMENT

Peter J Whitehead, BA Wilson and K Saalfeld

Introduction

The Magpie Goose has been described as the bird that typifies the Australian tropics (Frith 1982). The species dominates the seasonal wetlands of subcoastal Northern Territory, gathering in huge flocks to feed on shallow sedgelands during the dry season (May to November), and forming equally spectacular breeding colonies during the December–April wet season (Frith & Davies 1961; Bayliss & Yeomans 1990).

Favoured breeding and feeding sites may be widely separated in space (Whitehead et al 1987), so that Magpie Goose populations display great seasonal mobility. Moreover, habitats appear to vary in quality from year to year under the influence of an erratic rainfall regime. Seasonal movements within and between river systems are therefore superimposed on longer term shifts in distribution and relative abundance (Whitehead et al 1990).

Other aspects of the dynamics of Magpie Goose populations are also affected by rainfall variation. Mortality rises in the late dry season if rainfalls are delayed (Taylor & Tulloch 1985). Fecundity — as measured by nest density — improves with early and sustained heavy rainfalls (Corbett 1988; Bayliss 1989).

Here we consider the implications of these life history characteristics for effective conservation of the Magpie Goose in the Northern Territory. In particular, we (i) evaluate data on Magpie Goose distribution and abundance gathered since 1984 by broad scale aerial survey; and (ii) provide a preliminary analysis of these data in relation to rainfall and to vegetation patterning. We then employ this information to assess a range of management options for long-term maintenance of populations.

Methods

Magpie Goose distribution and abundance

Since 1983 broad-scale aerial survey has been employed to describe distribution and provide regional population estimates for the Magpie Goose in major wetland habitats in the western Top End of the Northern Territory (Fig 1). Methods are described in detail in Bayliss & Yeomans (1989a, 1989b, 1990) and Saalfeld (1990). In general, surveys were carried out during February and March, and invariably completed before the end of April.

Initially survey design incorporated large areas of woodland in which feral animals were also counted. Since 1990 the survey area has been reduced to floodplains and their margins. Despite the change, a sampling design that superimposed transects on the two survey grids has permitted direct comparisons among years.

In each of the wet seasons between 1984 and 1991, counts within the survey areas shown in Figure 1 were used to derive population estimates (N) and associated error terms (Caughley & Grigg 1981). Population change between consecutive years is expressed in terms of r, the annual exponential rate of increase calculated as log_e(N/N_{t-1}). Spatial variation in Magpie Goose density during the 1990 survey is described by subdividing transects into cells (1.5' of longitude = approximately 2.7 km) and assigning counts to these cells. Counts were assigned to cells by reference to flight time elapsed since the beginning of the transect. Origins and ends of transects were accurately fixed with an on-board Global Positioning System and average velocity calculated from total time taken to complete the transect.
FIGURE 1  The floodplain sites surveyed annually (a)
(a) The lines show aerial survey transects used to derive estimates of regional and total Magpie Goose populations in 1990. In prior surveys transects were spaced more widely (5.4 km rather than 2.7) and positioned so that alternate transects overlapped those shown.

Vegetation patterning
In March/April 1990 the grid employed for Magpie Goose surveys was described floristically by Wilson et al (1991). Cells 1.5° of latitude and 1.5° of longitude (approximately 2.7 x 2.7 km) encompassing the entire floodplain domain in the survey area were assigned to 1 of 25 vegetation classes derived from the floristic description. Assignments were based on the spatially dominant community determined from ground survey and aerial photographs taken during the survey.

Regionalisation
The total survey area was divided into seven catchment zones as defined in the Northern Territory Hydrological Catalogue (Water Resources Division 1986). A separate population estimate was generated for each of these areas. Because these boundaries differ slightly from the survey design used elsewhere, our regional population estimates are not directly comparable with those of Whitehead et al (1987), Bayliss and Yeomans (1990) and Saatfield (1990).
Rainfall statistics were taken from 4 stations that provided complete records for the survey period: Darwin (used in analyses relating to the Finniss River catchment and to the total survey area); Daly River Mission (Moyle and Daly River catchments); Coastal Plains Research Station (Adelaide, Mary and Wildman River catchments); and Gunbalanybah (South and East Alligator catchments). Daily rainfall records were used to derive a number of rainfall parameters for each site:

1. Annual rainfall (ANNRAIN): total rainfall for the 12 months ending in the June preceding the survey.
2. Current wet (CWET): total rainfall in the 3 months December–February preceding the wet season survey.
3. Preceding wet (PWET): total rainfall in the months December to April for the wet season preceding the year of survey.
4. Preceding dry (PDRY): total rainfall in the dry season (May to November) preceding the wet season survey.
5. Quarterly rains (PQ1–PQ4): total falls for each of the quarters of the calendar year preceding the survey.
6. Monthly rains: total rainfalls for each individual month for the calendar year preceding the survey, as well as the January and February falls immediately preceding the survey.
7. Cumulative falls: elapsed time in days between the date on which the year's post July rainfall first exceeded 100, 200, 300, 500 or 750 mm and the following 28 February when surveys generally began.

In addition, among-year variation in the temporal pattern of falls from 1869/70 to 1990/91 at Darwin was examined by Detrended Correspondence Analysis (Hill & Gauch 1980). Daily rainfall were aggregated into 73 equal (5-day) segments, and rainfalls (mm) during the 5-day periods scored into 1 of 7 classes (0 to 6 inclusive) under the following scheme: class 0, 0–5 mm; class 1, 6–20 mm; class 2, 21–50 mm; class 3, 51–100 mm; class 4, 101–200 mm; class 5, 201–500 mm and class 6, > 500 mm. Falls occurring on 29 February in leap years were omitted from the analysis. In the terminology of Belbin (1988), years were treated as objects and the transformed rainfalls as attributes. Years with incomplete daily records (1870/71, 1871/72, 1884/85, 1917/1918, 1926/27, 1940/41, 1968/69) were also excluded from the analysis.

Statistical treatment

Relationships among population estimates (N), rates of population change (r) and rainfall parameters were examined by stepwise multiple regression, analysis of covariance (ANCOVA using Procedure GLM) and Pearson product-moment correlation (R) analysis as implemented in SAS (SAS Institute 1988). All proportions or percentages were arcsine transformed (Zar 1974) before analysis. Given the preliminary nature of our analysis and the limited sample size imposed by the relatively short period (8 years) over which surveys have been conducted, we have regarded a probability level of 0.10 as sufficiently robust to justify rejection of the null hypotheses of no significant relationship between population parameters, rainfall and catchment characteristics.

Results

Total population of the survey area

Estimated total Magpie Goose populations in the whole of the survey area have fluctuated markedly, with the 1991 estimate being 43.3% of the 1984 wet season figure. The pattern of abundance is dominated by population crashes during 1987 and 1990 (Fig 2). Rates of population change (r) between consecutive years are summarised in Table 1.

Relation to rainfalls

The mean annual rainfall at Darwin (July to June) during the period 1982/83 to 1989/90 was slightly above the long-term average (survey period 1 662.8 ± 299.1 mm; long term 1615 mm). However, the survey period included two extreme events: the very dry 1989/90 wet season and the unusually wet 1990/91 season). Within-year patterns in the timing of rainfall during the period of survey are displayed in the three dimensional ordination at Figure 3. The survey years span much of the range of variation, but several years lie at the periphery of the ordination space, suggesting that the survey period includes a high proportion of years with unusual temporal patterning of falls.

Rates of between-year population change for the whole survey area were not significantly correlated with any of the rainfall parameters aggregating falls over periods of more than one month (P > 0.10). However, rates of population change could be related to individual monthly rainfalls in the period

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FIGURE 2 Variation in population estimates (line joins means ± 1 SE) for the Magpie Goose in the survey area over the period 1984–1991 and annual rainfall (July to June) at Darwin for the years 1982/3 to 1989/90 (hatched bars)

FIGURE 3 Three dimensional ordination (Detrended Correspondence Analysis) of annual rainfall patterns at Darwin broken into 5-day segments*(a)

(a) See text for a full description of methods. None of these axes is significantly correlated with total annual rainfalls; the ordination summarises variation in temporal patterns of rainfall rather than total falls. Timing of significant rainfall events during the years of survey (pillars) often diverged from the most common pattern.
between surveys (Fig 4). Specifically, $r_{tot}$ could be predicted from intervening March (INTMAR: partial $R^2 = 0.74$, $F = 14.2$, $P = 0.013$) and October rainfalls (INTOCT: partial $R^2 = 0.15$, $F = 5.4$, $P = 0.081$):

$$r_{tot} = 0.0022 \text{(INTMAR)} + 0.0021 \text{(INTOCT)} - 0.91$$  \hspace{1cm} \text{(equation 1)}

**Regional populations**

Rates of population change were not spatially uniform: in some catchments populations increased in years that saw substantial declines elsewhere (Table 1: Fig 5).

**Relation to rainfalls**

Relationships between rainfalls and Magpie Goose population parameters varied idiosyncratically among catchments. The limited duration of the survey period and resultant small sample size, together with a requirement to use rainfall records for sites some distance from the floodplains, inhibit rigorous statistical analysis. Nonetheless, we can illustrate the range of responses with a few examples.

First, observations of within-catchment rates of population change pooled across all catchments and years of survey were significantly and negatively correlated (Fig 6; $R = -0.37$, $P < 0.001$, $n = 56$) with wet season rain to the time of survey (CWBT). However, on individual catchments the relationship ranged through strongly negative, uncorrelated, to strongly positive correlations (Fig 7a).

Second, pooled within-catchment $r$ values were positively correlated with intervening March rainfalls ($R = 0.36$, $P < 0.006$, $n = 56$). On individual catchments the relationship varied from significantly positive to neutral (Fig 7b). There were no significant negative correlations.

**Magpie Goose distribution and abundance in relation to the 1990 vegetation pattern**

**Catchment Scale**: Results of the 1990 vegetation survey were used to derive a number of broad catchment descriptors: FPAREA — the area of cells dominated by wetland vegetation; SALT — the proportion of the cells classified as saline; SEMISALT — the proportion of cells classified as semi-saline; WET — the proportion of cells supporting wetter floodplain communities; and RICE — the proportion of cells classified as a vegetation type in which wild rice, *Oryza rufipogon*, was a major component (vegetation classes 16, 17, 18 and 23 of Wilson *et al* 1991; Table 2). A catchment area to floodplain area ratio was also calculated.

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**FIGURE 4** Variation in the intrinsic rate of increase ($r_{tot}$) of Magpie Goose populations with the intervening March rainfall at Darwin between consecutive surveys ($\bullet$)

(a) Populations tended to increase in years with above average falls, and decrease in drier years.
TABLE 1 Variation of annual exponential rates of increase (r) of Magpie Goose populations between years over the period 1984–1991(a)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Moyle</th>
<th>Daly</th>
<th>Finnis</th>
<th>Adelaide</th>
<th>Mary</th>
<th>Wildman/West Alligator</th>
<th>South Alligator</th>
<th>East Alligator</th>
<th>Total Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>0.11</td>
<td>0.03</td>
<td>0.32</td>
<td>-0.11</td>
<td>0.30</td>
<td>-0.44</td>
<td>0.12</td>
<td>-1.20</td>
<td>-0.10</td>
</tr>
<tr>
<td>1985</td>
<td>-0.01</td>
<td>-0.42</td>
<td>-0.54</td>
<td>-0.21</td>
<td>-0.12</td>
<td>-0.51</td>
<td>-0.42</td>
<td>0.51</td>
<td>-0.23</td>
</tr>
<tr>
<td>1986</td>
<td>0.56</td>
<td>-0.20</td>
<td>-0.65</td>
<td>0.23</td>
<td>0.33</td>
<td>-0.37</td>
<td>0.31</td>
<td>0.43</td>
<td>0.18</td>
</tr>
<tr>
<td>1987</td>
<td>-0.93</td>
<td>0.18</td>
<td>-0.16</td>
<td>-1.60</td>
<td>-1.22</td>
<td>-0.62</td>
<td>-1.11</td>
<td>-0.72</td>
<td>-0.56</td>
</tr>
<tr>
<td>1988</td>
<td>0.29</td>
<td>-0.26</td>
<td>-0.04</td>
<td>0.88</td>
<td>0.41</td>
<td>0.75</td>
<td>0.56</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>1989</td>
<td>1.22</td>
<td>-0.38</td>
<td>0.47</td>
<td>0.09</td>
<td>-0.60</td>
<td>1.05</td>
<td>0.59</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>1990</td>
<td>-1.50</td>
<td>0.31</td>
<td>-0.58</td>
<td>-0.33</td>
<td>0.44</td>
<td>-1.14</td>
<td>-0.53</td>
<td>-0.79</td>
<td>-0.62</td>
</tr>
<tr>
<td>1991</td>
<td>Mean</td>
<td>0.037</td>
<td>0.405</td>
<td>0.167</td>
<td>-0.150</td>
<td>0.064</td>
<td>0.183</td>
<td>-0.068</td>
<td>-0.168</td>
</tr>
<tr>
<td></td>
<td>(±SE)</td>
<td>0.345</td>
<td>0.107</td>
<td>0.169</td>
<td>0.284</td>
<td>0.239</td>
<td>0.297</td>
<td>0.239</td>
<td>0.271</td>
</tr>
</tbody>
</table>

(a) Separate values have been calculated for the different catchments, and the population as a whole.

FIGURE 5 Among-catchment variation in Magpie Goose populations during the period 1984–1991
FIGURE 6 Variation in rates of population change (r) with current wet season rainfall at the rainfall station nearest the catchment area \(^{(a)}\)

\(^{(a)}\) The line is the least-squares regression of best fit. The plot pools all of the within-catchment values summarised in Table 1.

FIGURE 7a Examples of variation in relationships between current wet season rainfall and within catchment rates of change in Magpie Goose populations \(^{(a)}\)

FIGURE 7b Examples of variation in relationships between intervening March rainfall (INTMAR) and within-catchment rates of change in Magpie Goose populations \(^{(b)}\)

\(^{(a)}\) Different catchments displayed a wide range of responses, eg Finnis, R = -0.74, P = 0.055; Daly, R = 0.84, P = 0.017; Moyle, R = 0.80, P = 0.031. \(^{(b)}\) Finnis, R = 0.68, P = 0.091; Daly, R = 0.23, P = 0.64; Moyle, R = 0.53, P = 0.21. Within-catchment trends were often weaker than those with current wet season rains, but were consistently positive or neutral. There were no negative correlations between INTMAR and rates of change in Magpie Goose populations.
The mean N on each catchment over the whole survey period was not significantly correlated with any of these catchment features, (P > 0.37). However, there was a significant relationship with a measure of the year to year variability of populations. Mean within-catchment annual rate of population change (mean r) for the survey period was positively correlated (Fig 8: R = 0.69, P = 0.056, n = 8) with RICE. Catchments with larger proportions of their floodplains dominated by wild rice averaged lower rates of decline over the survey period. We found no significant correlation between the mean N or mean r on individual catchments and the proportion of cells having Para Grass Brachiaura mutica or Mimosa pigra present (P > 0.30).

Survey cells: During the 1990 aerial survey Magpie Goose were sighted in 444 of 1477 cells (2.7 x 2.7 km). There was a weak association between the spatially dominant vegetation of a cell and the relative frequency of Magpie Goose sightings (Table 2: Cochran-Mantel-Haenszel test, CMH = 135.4, df = 24, P < 0.0001). Magpie Goose were most likely to be sighted in cells dominated by wetter communities and were least often encountered in dry, saline communities (Table 3: CMH = 92.9, df = 3, P < 0.0001). Frequency of sightings also varied with vegetation diversity within cells (Table 4: CMH = 35.8, P < 0.0001). Magpie Goose were more frequently sighted in cells in which two or more vegetation types were recognised during survey.

TABLE 2 Sighting frequencies and relative densities (number of geese sighted/cell corrected for visibility bias as described by Saafield 1990) in floodplain survey cells classified according to the dominant floristic type(a)

<table>
<thead>
<tr>
<th>FLORISTIC GROUP</th>
<th>Unsighted</th>
<th>MAGPIE GEESE Sighted</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant/Indicator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schoenoplectus litoralis</td>
<td>1</td>
<td>0(0)</td>
<td></td>
</tr>
<tr>
<td>Mangrove/mudflats</td>
<td>144</td>
<td>17(0.11)</td>
<td>195±61</td>
</tr>
<tr>
<td>Eriachne burkittii</td>
<td>182</td>
<td>38(0.17)</td>
<td>282±69</td>
</tr>
<tr>
<td>Paspalum distichum</td>
<td>1</td>
<td>0(0)</td>
<td></td>
</tr>
<tr>
<td>Diplachne parviflora</td>
<td>8</td>
<td>2(0.20)</td>
<td>2172±1054</td>
</tr>
<tr>
<td>Eleocharis dulcis</td>
<td>38</td>
<td>19(0.33)</td>
<td>667±188</td>
</tr>
<tr>
<td>Phragmites karka</td>
<td>7</td>
<td>8(0.53)</td>
<td>97±32</td>
</tr>
<tr>
<td>Hymenachne acutigluma</td>
<td>35</td>
<td>27(0.44)</td>
<td>284±103</td>
</tr>
<tr>
<td>Ludwigia ascrescens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scleria poaeformis</td>
<td>8</td>
<td>6(0.43)</td>
<td>89±45</td>
</tr>
<tr>
<td>Malachra fasciata</td>
<td>96</td>
<td>22(0.19)</td>
<td>233±79</td>
</tr>
<tr>
<td>Ludwigia perennis</td>
<td>53</td>
<td>44(0.45)</td>
<td>238±62</td>
</tr>
<tr>
<td>Xerochloa imberbis</td>
<td>9</td>
<td>2(0.18)</td>
<td>178±168</td>
</tr>
<tr>
<td>Sporobolus viriginicus</td>
<td>11</td>
<td>4(0.27)</td>
<td>2000±1975</td>
</tr>
<tr>
<td>Ptilia striatius</td>
<td>4</td>
<td>3(0.43)</td>
<td>63±28</td>
</tr>
<tr>
<td>Leersia hexandra</td>
<td>3</td>
<td>4(0.57)</td>
<td>182±103</td>
</tr>
<tr>
<td>Melaleuca leucadendra</td>
<td>10</td>
<td>4(0.29)</td>
<td>308±61</td>
</tr>
<tr>
<td>Oryza rufipogon (wet)</td>
<td>101</td>
<td>62(0.38)</td>
<td>550±118</td>
</tr>
<tr>
<td>Pseudoraphis spiniscens</td>
<td>13</td>
<td>12(0.48)</td>
<td>63±24</td>
</tr>
<tr>
<td>Oryza rufipogon (dry)</td>
<td>118</td>
<td>103(0.47)</td>
<td>885±145</td>
</tr>
<tr>
<td>Brachiaura muica</td>
<td>12</td>
<td>5(0.29)</td>
<td>150±96</td>
</tr>
<tr>
<td>Cyperus scariosus</td>
<td>121</td>
<td>29(0.19)</td>
<td>480±154</td>
</tr>
<tr>
<td>Eleocharis spiralis</td>
<td>13</td>
<td>2(0.13)</td>
<td>510±450</td>
</tr>
<tr>
<td>Eleocharis sphacelata</td>
<td>12</td>
<td>12(0.50)</td>
<td>1366±994</td>
</tr>
<tr>
<td>Hymenachne acutigluma</td>
<td>30</td>
<td>19(0.39)</td>
<td>614±177</td>
</tr>
<tr>
<td>Oryza rufipogon</td>
<td></td>
<td>0(0)</td>
<td></td>
</tr>
</tbody>
</table>

(a) Figures in parentheses are the fraction of cells of each vegetation type in which Magpie Goose were sighted. Mean densities (±SE) are given only for those cells in which geese were present.

97
FIGURE 8 Among-catchment variation in mean rates of population change with the proportion of the floodplain dominated by vegetation types containing wild rice (4)

(4) Magpie Goose populations in catchments with large continuous areas of wild rice tended to increase more in drier years so that the average rate of change was higher.

In cells in which Magpie Geese were sighted, their densities varied significantly but erratically with the dominant vegetation type (FLORGP) (Table 2: ANOVA, factor FLORGP $F_{21,341} = 2.1, P = 0.0003$) and among catchments (factor CATCH $F_{7,341} = 4.35, P < 0.0001$). There are few clear trends, but mean density was significantly higher ($F_{1,442}, P = 0.007$) in wet communities than in drier cells. Density varied weakly among salinity classes ($F_{2,441} = 2.4, P = 0.09$), tending to be higher in freshwater communities, but did not vary with vegetation diversity ($P > 0.10$).

Patterns of variation in Magpie Goose densities with floristic group were not consistent between catchments (ANOVA; CATCH x FLORGP interaction term, $F_{7,341} = 1.8, P < 0.0001$). These catchment differences were sustained in broader comparisons, for example between wet and dry communities (factor MOIST) (MOIST x CATCH interaction, $F_{14,428} = 3.5, P < 0.0001$). In combination these results suggest that among-catchment variation in Magpie Goose density is not exclusively a response to differences in the relative abundance of different vegetation types on the various floodplain systems.

Discussion

Population change

The capricious rainfall regime of the Top End engenders equally erratic variation in the total Magpie Goose population of the floodplains. Our surveys summarise the net impact of year to year environmental change on recruitment, mortality, and dispersal processes. Although trends are often weak, our analyses expose a number of relationships between rainfalls and population responses which appear to involve all of these processes.

Recruitment

The erratically variable timing and distribution of rainstorms in the dry-wet transition (Taylor & Tulloch 1985) determine food availability in newly germinated or resprouting grasses. Early localised shallow flooding encourages blooms of prolifically-seeding annuals like Echinochloa elliptica that are an important element of pre-nesting diets (Frith & Davies 1961). The enhanced food availability that accompanies early rains near the end of the harsh dry season improves the nutritional condition of birds as they enter the reproductive season.
### TABLE 3 Frequency of sightings of Magpie Geese among survey cells (a)

<table>
<thead>
<tr>
<th></th>
<th>Magpie Geese</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sighted</td>
<td>Unsighted</td>
</tr>
<tr>
<td>Dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saline</td>
<td>23 (0.12)</td>
<td>168</td>
</tr>
<tr>
<td>Semi-saline</td>
<td>135 (0.23)</td>
<td>465</td>
</tr>
<tr>
<td>Wet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-saline</td>
<td>21 (0.31)</td>
<td>47</td>
</tr>
<tr>
<td>Fresh</td>
<td>265 (0.43)</td>
<td>356</td>
</tr>
</tbody>
</table>

(a) Classified according to Wilson et al.'s (1991) broad categorisation of floodplain vegetation communities.

Condition of reproductive birds may be reflected in annual variation in clutch size (Dexter 1988; Whitehead & Tschirmer 1990a) or failure of many birds to nest at all in unusually dry years (Whitehead et al. 1987). Corbett (1988) showed in one colony that nest densities were greatly reduced in years when cumulative rainfalls in the 3 months preceding nesting were less than 750 mm. Heavy falls occurring after the peak of nesting may drown many nests on some floodplains (Whitehead & Tschirmer 1990b).

### TABLE 4 Variation in frequency of sighting of Magpie Geese with number of floristic groups recognised in survey cells

<table>
<thead>
<tr>
<th></th>
<th>Magpie Geese</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sighted</td>
<td>Unsighted</td>
</tr>
<tr>
<td>No. of floristic groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>215 (0.24)</td>
<td>670</td>
</tr>
<tr>
<td>2</td>
<td>190 (0.40)</td>
<td>289</td>
</tr>
<tr>
<td>3</td>
<td>36 (0.33)</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td>3 (0.38)</td>
<td>5</td>
</tr>
</tbody>
</table>

Survival of young is strongly dependent on rainfalls. As in domestic Oryza strains, density and seed set of wild rice — perhaps the most important food for rapidly growing goslings — are likely to be strongly influenced by rates, depths and duration of inundation, which are obviously dependent on rainfall patterns. Seasonal breeding swamps dry more quickly when wet season falls are below average, and young geese may perish in large numbers if drying occurs before fledging (Frith & Davies 1961). We interpret the relationship between March rainfalls and subsequent population change (equation 1; Fig 4) as a recruitment-related process.

**Mortality**

Post-fledging mortalities are also influenced by rainfall patterns. Birds die in large numbers when poor wet season falls are followed by extended dry seasons (Tulloch & McKean 1983; Taylor & Tulloch 1985). We interpret the weak positive partial correlation between October rainfalls and subsequent population estimates (equation 1) as a response to reduced dry season mortalities if significant rainfall occurs late in the dry season.

**Dispersal**

In 2 consecutive years Bayliss & Yeomans (1990) conducted broad-scale aerial surveys of the entire Top End (north of the 15th parallel). They concluded that about 95% of the Magpie Goose population occurred in the coastal floodplains that are covered by our current survey grid. In addition, limited banding returns summarised by Frith (1977) implied that, despite considerable seasonal shifts, birds were most often recovered close to the site of banding. Consequently, in his examination of population dynamics in relation to rainfall, Bayliss (1989) explicitly incorporated neither among-catchment dispersal processes, nor the potential for estimates to be influenced by significant shifts to or from the survey area.

Our analyses, based on a larger data set, suggest that there may be major weather-related redistributions of populations among the various catchments, especially in unusually dry years (Fig 5). The most parsimonious explanation for opposing trends with current wet season rains on adjacent catchments (Fig 7a) invokes movement rather than differential mortality or fecundity. Similarly, the negative correlation of rates of population change (observations pooled over all catchments) with current wet season rainfall suggests that some birds may leave the survey area in unusually wet years, and concentrate in the wet coastal fringe in drier years. Such movements may have contributed to the extraordinary population response (Fig 2) to the conjunction of an unusually dry year (1990) with an unusually wet year (1991). Failure of breeding in the 1989/90 wet season (Seafold 1990) undoubtedly contributed to the 1991 slump. However, environmentally mediated annual mortality
approaching 50% appears unusually high for a large, long-lived bird (banding returns exceeding 15 years are relatively common: Frith 1977; Tulloch 1985).

The net response of Magpie Goose populations to rainfall-driven environmental change is a product of interactions among all of these life history parameters and both the annual temporal pattern and quantity of rain. Given the likely complexity of these responses, improved understanding of population dynamics will require a considerably longer survey baseline as well as information on movement patterns under a range of weather conditions.

Vegetation pattern

During the 1990 survey Magpie Geese were recorded in survey cells dominated by a wide range of vegetation types (Table 2). However, these results must be interpreted with regard for the scale at which the observations were made. Cells most often contained more than one vegetation class, and comparisons based on dominant vegetation may obscure the features sought by Magpie Geese. Moreover, our surveys record distributions associated with a wide range of activities including nest attendance, feeding, bathing, and loafing at dry roost sites, which may also influence apparent habitat associations based on vegetation classes.

As surveys were conducted to a consistent methodology over similar daily time spans, these factors are unlikely to be implicated in among-catchment variation in the association between Magpie Goose density and vegetation type. Variation in Magpie Goose populations among catchments does not appear to be entirely attributable to differences in the relative representation of vegetation types, whether considered in terms of floristic classes or broader categorisations. Water depth is a significant determinant of waterbird assemblage patterns on the floodplains of Kakadu National Park (S Morton, pers comm). Fine-scale floodplain topography may interact with vegetation type to influence habitat selection during our wet season aerial surveys.

While population estimates for individual catchments were not clearly related to broad habitat descriptors, measures of average population change for the whole of the survey period were correlated with the proportion of floodplain area dominated by Oryza communities. On average, populations declined less over the survey period on catchments with much wild rice. In the absence of major anthropogenic disturbance, changes in the distribution of such broadly defined communities are likely to be slow. The 1990 distribution of Oryza communities described by Wilson et al (1991) does not appear to diverge markedly from 1984 results reported by Bayliss & Yeomans (1990) employing a broader-scale aerial survey technique.

However, within such communities plant density and seed set is highly variable in both space and time (pers. obs.). We speculate that birds tend to move to sites with larger, less patchy, Oryza grasslands when rainfalls are poor. The sheer area of these grasslands may guarantee an exploitable food supply even when seed production of individual plants is depressed.

Management implications

Whatever the stimuli, it is clear that Magpie Geese exploit available habitat in a flexible, indeed opportunistic, manner. They move among coastal river catchments as they respond to local environmental change driven by erratic rainfall, adopt reproductive strategies that are sensitive to habitat quality, and under some conditions a part of the population may abandon the core habitat of the coastal fringe for the capriciously variable ephemeral wetlands of the inland (M Fleming, unpubl. data). The extent to which this pattern may be altered by changed weather conditions associated with global warming cannot be reliably predicted from available data.

A static, site-based management regime cannot hope to cope with this ecology even under current weather patterns. If we are to maintain populations long term at or near existing levels, then management strategies must aim to preserve the full range of habitat options.

Management options

Here we consider three broad approaches to management that could contribute to the maintenance of spatial and temporal diversity of Magpie Goose habitat:

1) Extend the floodplain reserve system.
2) Manage existing reserves to optimise suitability for Magpie Goose.
3) Achieve management of unreserved (especially pastoral) land for conservation of the Magpie Goose.

Extending the reserve system

The existing reserve system incorporates 28% of our floodplain survey area (Wilson et al 1991). Yet the extraordinary mobility of the Magpie Goose means that reserves provide long-term protection for a considerably smaller proportion of the population.
For example, part of the dry season population of Kakadu National Park breeds outside the Park (Whitehead 1987, unpub. data). The proportion of the wet season population in Kakadu also fluctuates markedly from year to year. Few birds nest on Wildman River Station Reserve, yet many thousands of family groups from nearby breeding colonies congregate on the reserve areas to rear their broods (Whitehead, unpub. data).

Criteria for selection of additions to the reserve system on the coastal floodplains are problematic. For example, a Moyle River reserve would support up to 25% of the wet season population when rainfalls are below average, but less than 3% in most years. Further complications are added by the possibility that habitats outside the floodplain system are used by substantial proportions of the population in some years. Given that many other important wildlife habitats in the Northern Territory remain almost entirely unreserved (Whitehead et al. 1992) and many wildlife species occur only outside reserves (Woinarski, unpub. data), substantial additions to the floodplain estate may not be the highest priority.

But more important than difficulties of selection are problems of effective management for conservation. As pointed out by Russell-Smith et al. (see chapter 8 in this volume) reservation does not in itself guarantee appropriate management. In the case of the floodplains the management challenges are immense. Control of Mimosas, regulation of saline intrusion in the face of rising sea levels, and management of fire over such large areas require resources that are unlikely to be available to the public sector alone, or require diversion of funds from other urgent conservation problems. Moreover, methods to halt saline intrusion and restore degraded freshwater wetlands are still under development. Research on fire management strategies for seasonal wetlands has yet to begin.

Improved management of existing reserves

The impact of natural or anthropogenic environmental perturbations on Magpie Goose populations might be mitigated by active regulation of habitat features on reserves. For example, manipulation of water regimes might be employed to provide suitable year-round habitat in a relatively small area, reducing the pressures for Magpie Goose to disperse in search of favourable sites. Development of techniques will require a great deal more information on Magpie Goose ecology and the response of floodplain systems to variation in inundation and drawdown regimes. Such approaches are also likely to be expensive and may conflict with other management objectives and their underlying conservation philosophy. For example, the Plan of Management for Kakadu National Park calls for the 'protection of the natural diversity of plant communities' and restoration of 'areas damaged in the past by feral animals ... to a condition approaching that resulting from the interplay of natural processes' (ANPWS 1991).

Despite the difficulties, investment in such interventionist strategies is justified, because they will provide the technical capacity to cope with the long-term effects of climate change (Pittock 1988).

Conservation management of unreserved lands

Pastoralism is the major land use outside the reserve system (Whitehead et al. 1990). The peak wet season Magpie Goose population estimate was recorded in 1984 (the first year of our surveys) when feral water buffalo populations were also very high (Bayliss & Yeomans 1990). The decline in Magpie Goose populations to 1991 has coincided with implementation of the Brucellosis and Tuberculosis Eradication Program (BTEC). BTEC has all but eliminated feral stock from the survey area and seen managed herds maintained at historically depressed levels. Tulloch and McKean (1983) recorded a strong growth in Magpie Goose populations during a period (1972–80) when feral buffalo populations were effectively uncontrolled. These data provide no support for the view that regulated grazing of floodplains conflicts with continued abundance of the Magpie Goose. Indeed grazing may be a useful management tool for maintaining diversity of vegetation and habitat on the floodplains.

Annual grasses including O. rufipogon tend to be replaced by perennials like Hymenachne acutigluma when grazing pressure is removed (Corbett 1988). The tendency for Magpie Geese to seek larger areas of Oryza in drier conditions suggests that contraction of this resource may prejudice the resilience of populations under adverse conditions.

Some emerging pastoral practices do, however, conflict with conservation aims (see Whitehead et al. 1990). For example, replacement of native pastures with the exotic Para Grass, Brachiaria mativa, is being actively promoted by Government advisors to primary industry. This weed of waterways (Holm et al. 1977) now occurs in about 17% of our floodplain survey cells, and its distribution (Wilson et al. 1991) suggests that it has been spread primarily by cultivation. This species has broad ecological tolerances which overlap with the environmental niche occupied by Oryza (Wilson et al. 1991), and
has the capacity to entirely displace native vegetation types (Cowie & Werner 1989). Because it seeds infrequently (Holm et al 1977) Para Grass does not provide a substitute for the native annuals that sustain Magpie Geese and other fauna. To date its impact may have been limited by the relatively small proportion of the total floodplain area on which it is the dominant plant.

At other sites levees are being constructed by pastoralists to retain water longer and so promote the growth of such perennials. Interruption of natural inundation and drawdown cycles over large areas may reduce diversity and productivity (eg Greening & Gerritsen 1987).

These and other conflicts can be overcome. Negotiation with one landholder has led to formal agreement under the Territory Parks and Wildlife Conservation Act 1980 to exclude such practices from a large area of pastoral land, and efforts are currently being made to reach further agreements.

Harnessing resources for conservation management

The advantages flowing from integration of conservation practice with management for pastoral or other production are obvious. But in our situation the benefits extend well beyond exclusion of adverse practices from a larger area of wildlife habitat. Two of the greatest conservation threats to the floodplain ecosystem — saltwater intrusion and Mimosa — also threaten all other users.

Pastoralists and recreational hunters are controlling Mimosa on lands in which they have an interest. The desire of Aboriginal landholders to actively manage their land and preserve wildlife values has been instrumental in the allocation of Federal funds to fight Mimosa infestations in western Arnhem Land near Oenpelli, and on the Finiss River at Wagait. Government and pastoralists have worked together to prevent further saltwater intrusion in parts of the Mary and Adelaide River wetlands that support breeding colonies of the Magpie Goose, and to restore degraded areas (see Sterling, chapter 12 in this volume). The individual interests of recreational fishermen, tour operators, and conservationists have also been served by these activities, increasing the level of support for the investment of public funds. No single element of this diverse group acting alone could command the resources needed to cope with these intractable problems.

Conclusions

Superficially, the Northern Territory's seasonal wetlands and monsoon forest 'archipelago' discussed by Russell-Smith et al (this volume) would appear to have little in common. The contrasts between a recent and highly dynamic geomorphic oddity (Chappell & Woodroffe 1985) and an ancient, remnant vegetation that in general is static or retreating (Russell-Smith et al, this volume) are more obvious than similarities. Nonetheless, the conservation challenges they raise converge because both environments are patchily distributed.

While the broad geographic spread of these habitats reduces the potential for catastrophic loss to one or a few major developments, it leaves them vulnerable to a diffuse, incremental degradation (eg Whitehead 1991). Neither formal regulatory structures nor the less formal processes of non-government conservation organisations are geared towards such threats. With some exceptions, involving for example, rare species or assemblages, it is difficult to attribute special significance to individual elements of the mosaic that might provide a discrete focus for public attention or bureaucratic intervention. Indeed it may be counterproductive to emphasise the significance of particular sites: success in protecting one or a few 'special' patches may dissipate the public support needed to sustain the integrity of the whole.

If we are to provide long-term protection to such patchy environments and the mobile fauna that depend on and sustain them, we must find alternatives to the site-oriented approaches to management that may be appropriate in more developed areas. In tandem with design and implementation of an improved reserve system that straddles the Northern Territory's long ecological gradient (Whitehead et al 1992) and research to improve technical capacity to manage vulnerable habitats, efforts must be made to broaden public participation in land management for conservation.

Many landholders are increasingly willing to adopt management practices that take account of conservation aims, despite short term reductions in returns (eg Curry & Hacker 1990: Sterling, chapter 12 in this volume). But especially in our coastal wetlands such restraint may conflict with production of the income needed to meet high management costs. The solution to this conundrum is to compensate for reduced pastoral production. We do not suggest direct Government subsidy, but rather encourage a more diverse land use that is dependent
on protection of habitat diversity. In some cases this may involve active promotion of the consumptive utilisation of wildlife (eg CCNT 1989; Whitehead et al 1988), or non-consumptive exploitation such as tourism, perhaps accompanied by habitat manipulations that defy traditional attitudes to conservation in this country.

Extension of conservation aims to unreserved lands will sometimes require landholders to abandon cherished management 'traditions'. The evolving Landcare programs are built on participants' willingness to compromise, to adapt practice to local circumstances, and to focus on long-term benefits. These characteristics must also be displayed by those with a genuine commitment to wildlife conservation in the Northern Territory.

Acknowledgments

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CHAPTER 12

THE LOWER MARY RIVER:
A WORKING EXAMPLE OF MULTIPLE LAND USE

Libby Sterling

Introduction

The Mary River is located approximately 100 kilometres east of Darwin (Fig 1) and borders the western boundary of Kakadu National Park. The Mary River floodplains are recognised as having high aesthetic, conservation and recreation value as well as representing some of the most productive pastoral land in the Northern Territory (Applegate 1990, 4.29). Arising from this, the floodplains currently support a wide range of land use, endorsing the Territory Government's concept of multiple land use.

Multiple land use is a concept that has been considered for over 20 years and refers to an approach of utilising natural resources in an area in a sustained way (ie using methods that avoid causing degradation) (Nurse 1989). Through sensible management, a variety of land uses can co-exist in one area, leading to an efficient use of the natural resources. This designated area is usually a catchment, as it is more effective to manage natural resources within natural boundaries as opposed to cadastral ones. This leads to the term Integrated or Total Catchment Management (see Nurse 1989, 45).

Integrated Catchment Management is currently being adopted within the Lower Mary River area. The baseline information for this ICM is being compiled through the development of Property Management Planning (PMP). Landholders in conjunction with government agencies are developing PMP for their properties. PMP involves the mapping of fixed physical features of the property such as soils, landform and vegetation on a cadastral basis. Proven management principles are then applied to these mapped units according to their ability to sustain the desired use. With all landholders adopting this process they can effectively work together in solving land degradation problems on a catchment basis.

The Lower Mary River has been identified as having three major land degradation problems: salt water intrusion, woody weed infestation and feral animal activity. All three have led to severe degradation of the catchment.

Regional setting

The Mary River catchment itself is quite unique amongst catchments in the Top End with its unconnected billabongs, rather than a continuous channel to the sea, diversity of native flora and fauna of international significance and tourism potential due to its close proximity to a capital city.

The Mary River is one of a series of north Australian rivers flanking Van Dieman Gulf that are seasonally inundated coastal estuarine flood plains containing freshwater wetlands dominated by grasses and sedges and broad areas of swamp dominated by paperbark trees (Melaleuca spp) (Knighton, Mills & Woodroffe 1991).

The climate of the region is described as tropical monsoon and is characterised by two distinct seasons. Uniform high temperatures, with a hot wet season, extend from November to April (Wet Season). Average annual rainfall is approximately 1200 to 1400 mm with 90% of this occurring between January and March. The second is a hot dry season with mean daily temperatures remaining constant. Temperatures above 40°C or below 16°C are uncommon.

The Mary River catchment covers approximately 8200 km². Of this 1000 km² or 13% of the catchment area comprises coastal and estuarine plains discharging into Chambers Bay (Woodroffe et al 1990, 3).
These plains can be further divided into 3 broad categories:

i) the Coastal Plain which is primarily influenced by marine processes;

ii) the Deltaic-Estuarine Plain which is influenced by both tidal and fluvial processes; and

iii) the Alluvial Plain, which occurs beyond the tidal limit of each river and has developed under the influence of fluvial processes (Woodroffe et al 1990, 3).

The Mary contrasts with other seasonal rivers in the Top End in several respects. Unlike other rivers in the region, the channel is basically non-tidal. Two major creeks on the coast, Sampan Creek and Tommeycut Creek, are tidal and are dramatically increasing their influence over the Lower Mary River plains. The majority of the wet season freshwater flow remains on the plains and is lost through evaporation' (Woodroffe et al 1990, 4). The Mary River plains are at present still dominated by fluvial processes despite an increasing tidal network dissecting the plains within 30 km of the coast.

The coastal wetlands of the Mary River are essentially freshwater back swamps that are below high tide levels. These swamps are protected from tidal influences by cheniers (old beach ridges) and tidal creek levees. These levees consist of marine mud deposited during the dry season tidal inflow.

These same creek levees are host to an ever increasing expanse of mangroves. The mangrove ecosystem has also expanded rapidly over the past few years. The species Sonneratia lanceolata in particular is now growing vigorously along much of the banks of Sampan Creek several kilometres beyond its limits of two years ago (Woodroffe, pers comm). These mangroves will play an intimate role in stabilising the banks of this traditionally dynamic network, and will be an area of further intensive study.

Along with an extensive area of mangroves along the coast and flanking the major and minor tidal drainage lines, exist paperbark forests of national significance. The back swamps within the Lower Mary system that have remained uncontaminated by
Tidal influences are host to Melaleuca species such as *M. leucadendra*, *M. viridiflora* and *M. cajuputi*. Ground cover includes a myriad of grass and sedge species important in retention of freshwater and stabilisation of the plains.

The dryer uplands are characterised by eucalypt forests (*E. tetradonta*, *E. miniata*, *Erythrophleum chlorostachys* and *Acacia* species), with a native grassy understorey. Frequent fires and low nutrient soils have combined to produce these forests. Pockets of monsoon forests, occur in many areas that have a reliable supply of moisture throughout the dry season and are also protected from the influence of fire.

The diversity in vegetation and retention of freshwater has led to the wetlands providing a breeding and dry season refuge of international significance. Chambers Bay supports the largest egret rookery in the Northern Territory. The wetlands support a large community of the world renowned magpie goose (*Anseranas semipalmata*) which is the focus of major research by the Conservation Commission of the Northern Territory (CCNT). The wetlands also support large populations of other avifauna such as white bellied sea eagles (*Haliaeetus leucogaster*), Burdekin ducks (*Tadorna radja*), darters (*Anhinga melanogaster*), cormorants (*Phalacrocorax* spp), cattle egrets (*Ardea ibis*), great egret (*Ardea alba*), brolgas (*Grus rubicundus*), black necked stork (*Ephippiorhynchus asiaticus*) and the pelican (*Pelecanus conspicillatus*).

The saltwater crocodile (*Crocodylus porosus*) is increasing in numbers and breeding successfully in the area. The wetlands are also host to an increasingly diverse reptile population. In addition to the ‘salty’, the billabong network is also home to freshwater crocodiles (*Crocodylus johnstoni*). Other reptile species include the snake necked turtle (*Chelodina rugosa*), water monitors (*Varanus* spp), file snakes (*Acrochordus* spp) and the protected olive python (*Liasis olivaceus*).

Recent geomorphic evolution

The last forty years have seen a series of dramatic changes in the geomorphology of the floodplain. The nature and rate of these changes have been described by Woodroffe *et al* (1991), although the causative mechanisms still remain unclear.

Aerial photography taken of the area in 1940 shows the floodplain was separated from Chambers Bay by a series of cheniers running parallel to the coastline. These cheniers acted as a natural barrier to the sea, preventing the intrusion of salt water and retained freshwater at the end of the wet season. At that time the Mary River existed as a series of unconnected freshwater billabongs which only flowed through the wet season when the surrounding floodplains were also inundated. Unlike other Top End rivers, the Mary River has no single distinct channel through the coastal plains to the sea.

The majority of wet season floods evaporated from the plains, with several small tidal channels being the outflows of the system to the sea. Two of these channels, Tommycut and Sampan Creeks, have in recent times become sites of preferential tidal creek extension. The 1940 aerial photography shows these creeks to extend approximately five kilometres inland. These same tidal channels have since progressed to nearly thirty kilometres inland. Formerly independent billabongs have become linked as their levees have eroded, allowing saltwater to intrude, and increasing the reach of the tidal channel network. Figure 2 is a representation of the expanding tidal/creek network as presented by Woodroffe *et al* in 1990.

It has been generally accepted that large numbers of uncontrolled grazing animals caused serious modification to the geomorphology of the Mary River system. The buffalo have been pinpointed as the initiating factor responsible for massive erosion of the natural levees and beach ridges. The opening of the area to the general public in the early 1980s has also been highlighted as a cause of accelerated stream bank erosion through power boat activity. Power boats have been responsible for the linking of tidal creeks and billabongs during wet season usage. These actions, along with feral animals, drastically accelerated the natural growth and senescence of the channels. Feral animals cannot be solely responsible for the acceleration. There is also speculation that major storm activity, combined with high tide levels, may also have played a hand in triggering major changes to the systems. Thus a combination of factors with the natural dynamics of the system lead to discussion of the first threat to the multiple land use of the Lower Mary River.

Feral animals

During early settlement attempts in the late 1820s small herds of water buffalo were introduced to the Top End. These herds increased in number at an alarming rate. Feral animal surveys conducted in the 1970s identified a population of over 280 000 animals (Finlayson *et al* 1988). Permanent freshwater hosted the largest populations of beasts,
with the Mary River area being one of the most densely populated (Calder 1981). The general consensus is that these large concentrations of uncontrolled buffalo were largely responsible for the severe modification of the Mary River floodplains (Nurse 1989, 51).

The buffalo camp on high ground during the wet season. This 'high ground' was often the cheniers along the coast and small islands of land two to three metres above the surrounding plains, eg Floodmark and Firedreaming Islands situated on Opium Creek Station (Fig 3). During the day, the

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**FIGURE 2** Tidal creek extension of the Lower Mary River

*Source: Woodroffe et al 1990*
buffalo move off the high ground to feed on the flooded plains, thus initiating swim channels. These channels are still visible on the plains as distinct drainage lines radiating from the high ground. These same swim channels also linked many of the billabongs and tidal creeks. The introduction of the Brucellosis and Tuberculosis Eradication Campaign (BTEC) has removed the majority of feral buffalo across the Top End. The extensive areas of degraded land were a constant reminder of their reign on the Mary River.

Now in the early 1990s the floodplains have rapidly recovered, only to be threatened by salt water intrusion, *Mimosa pigra* and feral pig activity. Pigs are a major problem throughout the Top End and large concentrations are found in the Lower Mary. The pig foraging habit disturbs the land surface, causes damage to vegetation and creates a hazard for vehicles and stockmen. This habit has also been responsible for the failure of earthen barrages and the acceleration of tidal creek networks. Intensive control programs have been attempted in the past with limited success. Research is presently being undertaken into alternative means of pig control. At present control is limited to the actions of Rangers and landholders.

Feral cats are also recognised as a problem, but as yet no effective control methods have been implemented.

FIGURE 3  Buffalo swim channels — Opium Creek
Salt water Intrusion

Salt water intrusion has been highlighted as having caused severe degradation to a large proportion of the Mary River wetlands. This intrusion has been the result of a combination of factors: rapid tidal network expansion; activities of large numbers of uncontrolled feral animals; increased power boat activity; and the natural dynamics of this floodplain system.

Rapid expansion of the tidal network has occurred since 1943 (Fig 2). The catalyst for this expansion is still unclear. The process initiates through the surface invasion of saltwater during exceptionally high tides that overtop the natural creek levees. The tidal action then scour the central area and an initially diffuse flow becomes increasingly concentrated to give a more efficient drainage through channels (Knighton et al 1991, 177). This process, once started, is self perpetuating. Freshwater floods during the wet season inundation of the plains also accelerate this process causing rapid headward extension of creeks and tributaries. The large tidal range of up to 8 m in the area also lead to rapid channel cutting due to high tidal velocities. The small elevational differences along allow rapid invasion by salt water into the back swamps and floodplain areas. These swamps and the majority of floodplains are actually below sea level and are only protected from the sea by the cheniers and creek levees. Former channels (palaecochannels) are in many cases on the Mary incompletely filled with sediment and susceptible to invasion by the tide. Sampan Creek is an example of the incomplete infilling of a palaecochannel, tidal activity has been concentrated in a small area leading to the formation of the dense dendritic network (see Fig 2).

Large numbers of uncontrolled feral buffalo grazing on the floodplains were responsible for massive erosion of the barrier cheniers and tidal creek levees allowing the entry of salt water on to the plains. The swim channels created by their wet season activity also lead to the joining of previously unconnected billabongs and creek channels. Swim channels create linear depressions which were preferentially filled by tidal activity further resulting in an increase in the tidal network.

This network has been the pathway for the entry of salt water into the previously freshwater floodplains causing major degradation of the back swamps and grass plains. By 1988, 6000 hectares of Melaleuca swamp and 11 000 hectares of grassland representing 19% of the entire floodplain had been lost to salt water intrusion with a further 30-40% under immediate threat.

The mechanism causing the death of the vegetation is thought to be a combination of factors, thus saltwater intrusion was possibly not the sole cause. Saltwater intrusion in conjunction with the reduction in freshwater retention and capillary rise of salt in the dry season from underlying saline muds are all thought to be contributing factors. This had vast ramifications for both the flora and fauna indigenous to the area. Landholders were aware of the seriousness of the problem and began initiating their own barrier systems on a small scale prior to intervention by the CCNT.

In 1987 the CCNT recognising the seriousness of this threat initiated a major restoration program to prevent further salt water intrusion and rehabilitate affected areas. This has involved the construction of a series of barrages across tidal channels. These works are jointly funded by the CCNT and the National Soil Conservation Program (NSCP).

The majority of barrages consist of simple earthen walls across the smaller tidal channels. They are constructed to a height of approximately 800 mm above the surrounding floodplain and after their first wet season usually settle to around 500 mm above surroundings. The width of the barrages is variable but usually a minimum width of 3-4 m is adhered to. This serves a dual purpose of allowing vehicular access across channels and makes them less likely to fail due to the freshwater influence at the end of the wet season. The material used in construction is taken from the floodplains (black cracking clays) which introduces its own design problems. The cracking clays are often saturated with salts and are naturally dispersive. The nature of the floodplains and finances inhibit the use of more suitable material. This makes construction of stable barrages difficult. They are also designed to allow freshwater to flow over them. This is necessary as although it is desirable to increase freshwater retention to its original level, landholders do require the use of the floodplains for grazing at the end of the wet. Thus a very delicate balance is required to allow the continuation of multiple land use on the plains.

The massive flow of freshwater to the sea during the wet season puts considerable pressure on these barrages and has caused the failure of several structures. A combination of log and rock armouring will be used to strengthen the barrages. The 1991-92 field season will also include a vegetation planting program. Melaleuca and native
grass species will also be used in the stabilisation of these earthen walls.

Figure 4 shows the location of the majority of barrages constructed in the Mary River Conservation Reserve. Note the series of barrages along the eastern boundary of the palaeochannel to protect it from the invasion of tidal waters. If saltwater was to gain access to this channel it would accelerate the tidal network again, resulting in further loss of thousands of hectares of Melaleuca swamp and highly productive floodplain grasses.

One major concrete and rock structure was constructed on the natural rock bar at Shady Camp. This is a well publicised structure and has successfully halted the entry of salt water into the upper reaches of the Shady Camp billabong which was previously showing signs of salt stress.

The barrages play a multiple role in combating the land degradation problem on the floodplain. They have promoted infilling and stabilisation within tidal channels. They prevent the entry of salt water onto the plains in the dry season and aid retention of freshwater at the end of the wet. This last function has two advantages, the prevention of premature drainage and the flushing of salts from the soil system.

Many areas previously showing signs of salt stress are now lushly vegetated and returning to their previous freshwater state. The 17,000 hectares of severely degraded lands are in small areas showing signs of regeneration. Many of the Melaleucas are reshooting from their buttress roots. Large areas of salt affected grassland are gradually being colonised by native salt tolerant grasses such as Sporobolus virginicus and Paspalum distichum although it is pertinent to note that these are not highly productive grasses suitable for cattle production. A major rehabilitation program is required to accelerate this natural process of succession.

Even though there has been success with this program, the situation is still critical and will require major funding by government and landholders to keep on the winning side. A further threat which threatens the Lower Mary is woody weed infestation.

**Woody weed Infestation**

* Mimosa pigra is a prickly perennial shrub, native to Mexico, Central and South America. Its point of entry into Australia was Darwin, probably in the late 1800s (Miller & Lonsdale 1987, 140). At present the distribution of mimosa stretches in an area across 450 km of the NT, from near the Fitzmaurice River in the west to Arnhem Land in the east (Schultz 1990, 1).

Mimosa forms dense monospecific stands with closed canopies which are virtually impenetrable. The plants shade out natural vegetation and reduce the number of potential breeding sites for native fauna, such as the salt water crocodile and the Magpie Goose. Mimosa thrives beside billabongs and rivers, blocking off access to irrigation, stock watering points, and recreation areas.

These infestations are a major threat to the Lower Mary River floodplain and approximately 2000 hectares have already been infested. Joint control programs are currently underway between the CCNT, the Department of Primary Industry and Fisheries (DPIF) and landholders in a concerted effort to halt if not reduce the area affected.

CCNT and DPIF have officers dedicated solely to the control and eradication of mimosa in the Top End. Much of their effort is concentrated in the Mary River floodplains. Their program includes aerial and land based wet and dry season spraying. Individual landholders are responsible for the control of mimosa on their own properties. Government and landholders work together in the control programs.

The 1991 dry season has seen the initiation of a series of trials, funded by the National Soil Conservation Program (NSCP) to ascertain the best method of treatment for the Lower Mary. These trials are run by the landholders as a function of the Lower Mary River Landcare Group. This work is in addition to the programs run by the DPIF Weeds Section. The DPIF, CCNT and landholders are joining forces to eradicate mimosa.

DPIF have been funding extensive research by CSIRO into suitable biological control methods. Various seed, stem, leaf and bark feeding beetles and moths have been released since 1983 with minimal impact. Research into a suitable biological control method is still continuing.

Major funding and manpower are required to prevent ongoing damage to the pastoral, conservation and recreation values of the floodplain. A combination of current methods such as the use of herbicides and planting of grass species to compete with seedlings is considered to be one alternative to effective control and management.
FIGURE 4 Mary River flora and fauna reserve barrage location
Pastoral activities

The Lower Mary River floodplain is characterised by highly productive floodplain grasses such as Hymenachne acutigluma. Para grass (Brachiaria muicca), an introduced species, also covers extensive plains in the Lower Mary and is considered a valuable pasture for animal production (Applegate 1990, 4.32).

The floodplains currently host a successful pastoral industry of both cattle and buffalo (Fig 5). A significant proportion of the catchment is under pastoral lease with four leases currently supporting buffalo herds. All the pastoral leases in the area rely heavily on the grazing of hymenachne during the dry season. The wet season grazing of hymenachne is discouraged as it has damaging effects on the production of feed for the following dry season and causes physical damage to the floodplains through wallowing and the creation of swim channels. These channels have the potential to increase the already extensive tidal network. Wet season grazing is restricted to the dryer upland country which contains native and some improved pastures.

Research is currently underway to improve the wet season grazing potential. The fringe areas between upland and floodplain are grazed in the intermediate seasons between the wet and the dry.

The landholders all wish to maintain sustainable productivity as well as achieving sustainable utilisation of their land. On a major initiative the landholders united to combat their land degradation problems and enforce sustainable management in their area. In 1989 they formed the Lower Mary River Landcare Group. 'As a group they feel they can access government advice and assistance with increased assurance and encourage the targeting of additional resources into combating their problems' (Applegate 1990, 4.31). The group is currently drafting a series of guidelines for the Lower Mary incorporating Integrated Catchment Management and Property Management Planning (PMP).

Two landholders have already begun the process of PMP. This system integrates all the natural resource information available in a series of overlays. Land units, land capability and existing infrastructure overlays are supplied by CCNT and Department of Lands and Housing. A further set of overlays are then developed by the landholder with the aid of the relevant government extension officer. DPIF, Water Resources, Bushfires Council and CCNT Soil Conservation officers all play an integral role in the development of a Property Management Plan.

This Property Management Plan has many uses: day to day management of paddocks, stocking rates and BTEC ratings. Monthly planning of work schedules and records of work achieved. They can also be useful in financial planning, from calculating fencing requirements to a method of planning for financial assistance and tax concessions. The plan is basically a method of recording on a map or series of overlays the processes that a landholder usually does instinctively.

The plans need to take into consideration:

- sustainable stocking levels to avoid pasture deterioration;
- flexibility in stocking rates to accommodate seasonal and year to year variability;
- careful assessment of sensitive areas that are of high conservation value; and
- clearance of upland areas within their capability, to avoid soil erosion and/or change in hydrological conditions (Nurze 1989, 55–6).

These Property Management Plans will form the basis of sustainable utilisation in the future. Integrated catchment management involves this coordinated use and management of land, water, vegetation and other natural resources on a catchment basis. The Lower Mary River Landcare Group are well on their way to achieving this.

Conservation

In the not so distant past, conservation and pastoralism were seen as mutually exclusive. In the Lower Mary River landholders have taken a very different view.

In an attempt to protect the large areas of Melaleuca swamps in the Mary River Conservation Reserve, and magpie goose breeding areas outside the Reserve, adjoining landholders entered into a cooperative arrangement with the CCNT. They aid in the maintenance of the barrages on their land as well as the areas adjoining their leases. In return, the landholders are able to access extensive para grass plains within the Reserve and graze these areas at a stocking rate determined by the CCNT.

The landholders also fenced these introduced pastures which in turn protects the native hymenachne and Melaleuca swamps from grazing pressures. This has had the added benefit of controlling grazing pressure on native pastures suitable for wildfowl breeding outside of the Reserve' (Applegate 1990, 4.32).
Landholders through their Property Management Planning are able to identify areas of conservation value (monsoonal vine forests, Melaleuca swamps, goose breeding areas) and apply for funding to fence these, to exclude or regulate cattle. These areas may also be available for tourism and recreation with careful management.

The landholders in the area appreciate that management for conservation does not necessarily mean other uses are excluded, in fact they can coexist and be mutually beneficial (Fig 6).

FIGURE 5 Pastoral activities in the Lower Mary River plains
Tourism and recreation

Tourism is the second largest industry in the Northern Territory (Finlayson et al. 1988). A large proportion of interstate and overseas tourists visit the Darwin and Kakadu regions. Tourism in the Territory tends to focus on specific experiences, with freshwater wetlands being a popular destination. Recreational fishing, wildlife observation and wildfowl hunting are all popular (Whitehead et al. 1989, 105). The Lower Mary River therefore is an area of high national tourism potential (Fig 6).

The Lower Mary River wetlands are fast becoming a popular tourist destination due to their close proximity to Darwin. Barramundi fishing and saltwater crocodile viewing are the two major attractions. Several areas in the Lower Mary are renowned for barramundi fishing. Shady Camp,
Corroboree Billabong and Rockhole are all popular destinations for the amateur angler. Other popular pastimes include bird watching, photography, camping, pleasure boating and sightseeing.

The majority of activities are restricted to billabongs and major creeks and channels. Access to most of the wetlands is limited for much of the year to specialised vehicles such as airboats, helicopters and quad bikes. Public access is also restricted in areas held under pastoral lease.

The CCNT recently employed the services of consultants to investigate the possibilities of opening up areas in the Lower Mary River to low impact tourist development. These management concepts were developed in conjunction with all members of the Lower Mary River Landcare Group. A series of developments have been proposed and were made available for public comment. This integrated approach to tourism development is a vast improvement on previous methods. Financial, emotive and conservation constraints were all analysed during the planning process. Again the landholders played a major role in the decision and planning process within their catchment.

Conclusion

The future of the Mary River Wetlands is in the hands of the Landcare group (Applegate 1990). As the current land managers, they are responsible for initiating the response to any land management problems that may arise. The government also has a responsibility to support and compliment this group. They too are landholders in the Lower Mary. The government hand in hand with the landholders must take an active and supportive role in the management of the area. No single landholder is simply responsible for his lease or property but is responsible for the area as a whole. With increasing pressure on the area from a wide range of land use, integrated catchment management can provide a long term solution to sustainable utilisation' (Applegate 1990, 4.33).

The Lower Mary River wetlands are a true example of multiple land use. The coexistence between conservation, recreation and pastoral activities enforce this. Although fraught with degradation and management problems, the landholders have united to help form a formidable group to enforce sustainable management in their area.

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CHAPTER 13

BURNING FOR CONSERVATION OF THE TOP END'S SAVANNAS

Alan N Andersen and Richard W Braithwaite

Introduction

Fire is very much a prominent part of the Top End environment, with about 70% of the savanna woodlands and open forests which dominate the landscape being burnt each year (Braithwaite & Estbergs 1985; Day 1985). The fires are lit almost exclusively by people, and are generally restricted to the dry season between May and October, but may occur from March to December (Haynes 1985; Braithwaite 1991). Throughout this period there is almost always some part of the countryside ablaze, such that the dry season is often also referred to as the 'smokey' season.

Fire management is a contentious issue throughout the world's tropical savannas (Gillon 1983; Stott 1986), but is especially controversial in areas set aside for nature conservation, such as in the Top End's Kakadu National Park. Fire management in Kakadu inflames the passions of both locals and tourists alike, most of whom believe that too much of the land is burnt too often. There is also considerable debate amongst scientists over the ecological effects of fire (Duff & Braithwaite 1990; Lonsdale & Braithwaite 1991).

In this chapter we aim to take a step back from all the hype surrounding fire management in the Top End, and crystallise what we consider to be the important issues. The spirit of the paper is one of seeking answers, rather than giving them. In particular, we try to separate fact from fanciful story, because the bottom line is that despite the strong views held by so many protagonists in the fire debate, no-one really knows much about the ecological effects of fire in the Top End's savannas.

The first thing to point out is that fire ecology in our savannas is different from that in southern Australia. Savannas are an exceptionally fire-prone vegetation type, due to high herbageous production during the wet season followed by a long and severe dry season. Moreover, the prolific herbageous growth (particularly of the annual spear grass *Sorghum intans*) that occurs each wet season means that there is sufficient fuel to carry a fire every year. Fire frequency would consequently be high even without human intervention, with ignition caused primarily by lightning strikes during the 'build-up' to the wet season. The 'burning question' therefore is not should the savannas be burnt, but how frequently should they be burnt, and at what time of the year?

Another important difference from southern Australia is that, even in the absence of fire, fuel accumulation on the ground is relatively low due to high rates of decomposition (Walker 1981). The terrain is generally flat, and the leaves of savanna eucalypts have comparatively low concentrations of volatile oils (Webb 1968). All these factors mean that the Ash Wednesday-type, crown fire holocausts of southern forests are rarely, if ever, possible in the Top End. Nevertheless, fire intensity in the Top End's savannas can be as high as 20 000 kJ/m² (compared with a possible maximum of 100 000 kJ/m² that occurred during Ash Wednesday; AM Gill, pers. comm.).

A second point to keep in mind is that conservation management is only one of several reasons why our savannas are burnt. In particular, a large proportion of the Top End is under Aboriginal ownership, and traditional fire management continues to be an important part of Aboriginal life (Jones 1969; Haynes 1985). In areas of European settlement, fire is used extensively for the protection of property. The pastoral industry, which is a major land-user in the drier savannas of northern Australia, uses fire to improve pasture management (Andrew 1986) and to increase cattle production (Winter 1987). Finally, many fires are 'unauthorised' (lit accidentally or otherwise), particularly those occurring late in the dry season, which reflects the fact that numerous people are moving through an extremely fire-prone landscape. All these considerations mean that there will inevitably be some compromise with burning purely for conservation purposes. This is particularly true for a place like Kakadu, where a quarter of a million people visit each burning season, and Aboriginal issues are such an important part of the park.
Ecological reasons given for burning

Three ecological reasons are commonly given for burning the Top End savannas: the vegetation needs it; prevention of late season fires; and re-establishment of traditional Aboriginal burning patterns.

The vegetation needs it

The notion that Top End savannas 'need' to be burnt is derived from the common knowledge that the reproductive biology of many Australian plants is dependent on fire — fire triggers seed dispersal, promotes germination, and provides suitable conditions for seedling survival (Gill 1981). Fire can therefore be seen as cleansing the system and creating an opportunity for the injection of new life — 'overmature' plants are removed, nutrients are recycled, and conditions are suitable for the establishment of new plants.

This idea may be intuitively appealing, but is not really appropriate for Top End savannas. Savannas differ from southern heathlands and woodlands in that the reproductive biology of very few of its component species is geared to fire. Savanna eucalypts, for example, shed all their seeds soon after flowering, rather than retain them inside persistent capsules that open after fire, as occurs in most southern eucalypts. Most perennial plant species in savannas regenerate vegetatively following fire, and are therefore not replaced by 'fresh' cohorts.

Moreover, even if savannas did contain many fire-dependent species, they certainly would not need to be burnt every year (see Gill 1977). The notion that fire is 'good' for vegetation hardly leads to the conclusion that the more frequently it is burnt the better! In short, most savanna plants are well-adapted to cope with frequent burning, but they are unlikely to 'need' fires of the frequency prevailing under current management.

Prevention of late season fires

The rationale here is that early dry season burning imposes a firebreak mosaic on the landscape, thus preventing large-scale devastation by high intensity fires later in the season (ANPWS 1991). Early dry season fires tend to be light and patchy because the vegetation is still moist, and such fires are considered to have minimal effect on the biota.

However intuitively attractive this argument may be, there is very little evidence to support it. It is based on the unsubstantiated assumption that frequent, low intensity burning is better ecologically than less frequent but more intense burning. The ecological effects of neither regime have been satisfactorily documented. Indeed, the little evidence that is available suggests that the 'devastation' caused by late-season fires is more superficial than real. For example, Lonsdale & Braithwaite (1991) found that a particularly intense late dry season fire in Kakadu actually led to increased habitat diversity. A critical point that must also be borne in mind is that the contemporary biota evolved before people started lighting fires early in the dry season, and therefore presumably under a higher intensity, lower frequency, late dry season fire regime.

It is clear, however, that certain fire-sensitive vegetation types embedded within the savanna landscape, particularly monsoon rainforests and stands of Callicrisis (Bowman 1988; Bowman & Fensham 1991; Russell-Smith 1991), are deleteriously affected by high-intensity fires. The maintenance of these habitats requires their protection from frequent, late-season burning. Many of them occur in areas offering natural fire protection, such as in rocky gorges, but there is evidence that others are suffering from apparently recent increases in the frequency of late season fires (Russell-Smith, pers comm).

Another problem with the 'early burning' argument is that it is not an optimum fire regime for nature conservation per se. Rather, it is compromised by the (realistic) expectation of unauthorised burning later in the season. It is therefore an argument based on doing 'least harm' rather than 'most good'. Similarly, the argument that early burning of savannas is required to protect fire-sensitive vegetation such as monsoon and Callicrisis forests is a compromise with issues other than nature conservation in savanna vegetation.

Re-establishment of traditional Aboriginal burning patterns

According to this argument, Aborigines have been in the Top End so long that the savannas have become adapted to their traditional burning practices. The optimal fire regime is therefore one that mimics these practices.

Again, this argument is appealing but not well-substantiated. It is indisputable that Aborigines have profoundly influenced the fire history of Australia (Pyne 1991). As Pyne so evocatively puts it: 'The constant rubbing of nomadic tribes against a tindered Australia was ... an environmental firedrill that littered the landscape with smouldering
ignitions' (p 91), which 'set to boil the whole biological billy that was Old Australia' (p 8). However, the extent to which Aboriginal burning shaped the savanna biota, which already had a long history of high frequency fire, is not clear. One effect of Aboriginal burning might have been to change the relative abundances or performances of different species — but, without any evolutionary response, these species cannot be claimed to be 'adapted' to Aboriginal burning practices.

It is difficult enough to find evidence that Aboriginal burning has influenced the current distribution and abundance of plants and animals in Top End savannas, let alone their evolutionary history. One example of the former case appears to be Callitris intratropica, a fire-sensitive tree capable of growing in savannas but now mostly restricted to rocky habitats offering shelter from fire (Bowman 1988). However, there is no evidence whatsoever that either the flora or fauna, or any components of it, have adapted in an evolutionary sense to Aboriginal burning practices.

Moreover, Aboriginal burning was conducted for utilitarian reasons (such as for hunting, ease of travel, protection of edible plants, and signalling), which makes the relevance of Aboriginal burning to nature conservation goals even less certain. There are also practical problems with management prescriptions based on traditional Aboriginal burning practices. In the first place, no-one is really sure exactly what these practices were. Little information is available on the spatial distribution of Aboriginal fires across the landscape, and, in particular, on their overall extent. It is a difficult enough task to document the spatial patterns of contemporary Aboriginal burning regimes (Head et al., Chapter 15 in this volume), let alone those occurring prior to European settlement. The seasonal patterns of burning are becoming increasingly well documented, and they are clearly far more complex than the simplistic characterisation of 'early season burning' (Haynes 1985; Braithwaite 1991). Second, whatever traditional Aboriginal burning practices were, they were the result of many people moving through different parts of the landscape at different times of the year — a labour-intensive exercise impossible to mimic by contemporary land managers.

In summary then, the ecological reasons commonly given for burning are either logically suspect, based more on intuition than on data, or are aimed at protecting vegetation types other than savannas. In any case, they inspire little confidence as a basis for current fire management in our savannas. Rather, they are grist for the mill of public controversy.

Ecological effects of fire

What exactly is known about the ecological effects of fire in savannas of the Top End? We actually know a fair bit about the short term effects of individual fires. In most cases, few trees are killed directly by fire, with most resprouting as soon as moisture is available, either from ground water, from plant reserves or from rainfall (Gill et al. 1990). Animals vary in their response to fire, with fires of different intensities and different times of the year favouring different species (Braithwaite 1987, unpublished data). The result is that any particular fire will benefit some species, and disadvantage others (although the overall balance of 'winners' and 'losers' is unknown). Some animals are favoured by fires whenever they occur — for example, black kites (Milvus migrans) exploit fire fronts by feeding on fleeing insects and small vertebrates (Braithwaite & Estberg 1987).

However, little is known about the longer term effects of particular fire regimes — that is, what happens when an area is consistently burned in a particular way? We might know, for example, something about the response of the biota to an early dry season fire, but we do not know what happens if an area is burnt that way every year over a long period of time.

We do know that the long-term exclusion of fire has a dramatic effect on vegetation structure, leading to pronounced mid-storey development (Bowman et al. 1988) and in some cases to the establishment of rainforest species (Fensham 1990). These changes lead to parallel changes in faunistic composition (Woinarski 1990; Andersen 1991). However, any large-scale, long-term exclusion of fire is probably just an artefact of human intervention, because of the high likelihood of ignition by lightning. Long-term, fire exclusion on a landscape scale is therefore not a viable management option. As mentioned previously, the critical issue is not whether the savannas should be burnt at all, but how frequently they should be burnt and at what time(s) of the year.

An understanding of the ecological effects of different fire regimes (as opposed to different fires) requires a rigorous, experimental approach, and cannot be obtained from anecdotal evidence or ad hoc observations. Such an experimental approach has been attempted at Mumbarlany in the north of Kakadu National Park, where a series of replicated fire-treatment plots (each 1 ha) were established in 1972 jointly by CSIRO and the Conservation Commission of the Northern Territory (Hoare et al. 1980). This experiment has yielded some valuable results (Bowman et al. 1988; Woinarski 1990;
Andersen 1991; Cook 1991), but methodological deficiencies limit its usefulness. Unfortunately, no data were collected on the plots prior to treatment, and plots were burnt in a way likely to minimise any seasonal effects of fire (Lonsdale & Braithwaite 1991).

However, the biggest limitation of the Muninary experiment lies in the problem of using results obtained from small plots to address large scale issues. The securing of small plots with fire-breaks disrupts many important ecological processes that operate on a landscape scale, such as surface hydrology, nutrient flow, and faunal movements. Moreover, fire behaviour in small plots differs significantly from that in large areas, and in small plots it is impossible to study the effects of fire on animals with large home ranges. The study of the ecological effects of different fire regimes therefore requires a landscape-scale experiment.

The Kapalga fire experiment

The CSIRO Division of Wildlife and Ecology has embarked upon a landscape-scale fire experiment at Kapalga research station (approx 650 km²) in Stage Two of Kakadu National Park. The savannas of Kapalga are typical of those occurring throughout the sub-coastal, higher rainfall areas of northwestern Australia (e.g. Wilson et al 1990). It is envisaged that the generality of results obtained from comprehensive studies at Kapalga can be checked by smaller scale studies in other savanna landscapes.

Kapalga has been divided into a series of compartments (10–20 km²), each representing a catchment based on seasonal creeklines which drain either westward into the West Alligator River, or eastward into the South Alligator River. These creeklines often support permanent pools or semi-permanent seeps, which appear to be critical foci for small mammals and granivorous birds, many of which are endangered or locally extinct elsewhere in Australia (Braithwaite 1990).

Each compartment is burnt according to one of four treatments, together representing a range of fire regimes occurring in the Top End:

1. 'Early' — annual fires lit early during the dry season (May/June), which is the predominant management regime occurring elsewhere in the coastal and sub-coastal region;
2. 'Late' — annual fires lit late in the dry season (Sept/Oct), as also occurs extensively (as 'wildfires') elsewhere in the region;
3. 'Progressive' — annual fires lit progressively through the dry season, such that different parts of the landscape are burnt as they dry out. This is thought to approximate traditional Aboriginal burning practices.
4. 'Natural' — no human interference, with fires restricted to those caused by lightning strikes, predominately during the build-up to the wet season (Nov/Dec). The frequency of such fires, however, is likely to be limited by isolating the compartments with fire-breaks.

Each treatment is replicated three times, in a randomised block design modified according to topographic and security constraints. The experiment commenced in 1988, with the first two years devoted to the collection of baseline data prior to the establishment of the experimental fire regimes. Work is concentrated on transects running from creeklines to adjacent ridges (about 500–750 m away), so as to capture the full moisture gradient, and associated gradients in soil and vegetation, occurring in the savanna landscape.

An important feature of the Kapalga experiment is the detailed measurement of fire intensity and behaviour. Such measurements are crucial for interpreting biotic responses. We have already found, for example, that although early dry season fires are generally less intense than those occurring later, this pattern can be reversed by prevailing weather conditions.

Another notable feature of the experiment is its multidisciplinary approach. The CSIRO Division of Wildlife and Ecology has five scientists and their assistants based in Darwin and dedicated to the project. These scientists comprise specialists in the ecology of soils, vegetation, insects, small mammals, and vertebrate predators. They are also involved with numerous collaborative projects related to the experiment, involving research students and scientists from universities and elsewhere in CSIRO. The experiment receives valuable logistic support from the Australian National Parks and Wildlife Service, the managers of Kakadu National Park, and some financial support from WWF Australia.

This multidisciplinary approach, combined with the scale of the experiment, enables the critical ecosystem-level issues to be addressed. Key questions include: Do frequent fires cause a gradual loss of soil nutrients or increase soil erosion? Do frequent fires prevent the recruitment of seedlings into the canopy? How does fire influence the seasonal phenology of plants? Are the fires
significant contributors of greenhouse gases to the atmosphere? How does fire influence soil invertebrates and therefore rates of nutrient cycling? Do fires cause eruptions of defoliating insects? How do the fires influence the survival of rare and endangered mammals? Does fire influence the pattern of predation by large vertebrates?

The answers to questions such as these will presumably vary with the different fire regimes. From the results of the Kapalga experiment it should be possible to produce a fire management plan, probably encompassing a mosaic of different fire types, to satisfy the specific goals of land management authorities. It is hoped that the results of the Kapalga experiment will provide a sound scientific basis for the conservation management of savannas in the Top End.

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CHAPTER 14

THE EFFECTS OF FIRE ON NUTRIENT LOSSES FROM TOP END SAVANNAS

GD Cook

Introduction

Historically, fire has been used as a management tool by humans in the Top End for thousands of years. The timing of burning by Aborigines has been investigated (Braithwaite & Estberg 1985), but it is more difficult to determine the past extent of their activities across the landscape. It probably varied greatly between districts and years. Currently in the Top End, fires occur on any given piece of land in two out of three years on average (Braithwaite & Estberg 1985). Fire will remain the cheapest tool for land management in the Top End for the foreseeable future. This is because of the extensive patterns of land use which dominate the pastoral properties, national parks, and Aboriginal lands of this region. Therefore fire management is an important issue for all who work in savanna lands.

The consequences of nutrient losses caused by combustion of biomass during fires in the Top End has received little consideration despite the frequency of fires in this region being among the highest in the world. If the transfer of nutrients to the atmosphere each year exceeds the inputs from outside the system then nutrient rundown is occurring. The growth of both introduced and native plants in the Top End is already limited to varying degrees by the low levels of soil nutrients such as N, P, S, Zn, and possibly Cu (Calder & Day 1982; Cameron et al. 1982; Day et al. 1983; Rance et al. 1982). Hence, any management strategy which decreases nutrient availability further will have important ramifications for both nature conservation and the pastoral industry in the Top End.

In this chapter, the determinants of nutrient losses and gains in the savannas of the Top End of the Northern Territory are reviewed. The results from CSIRO’s Fire and Water experiment at Kapalga in Kakadu National Park are then used to model the effects of fire frequency on nutrient losses. The implications of the nutrient budget for ecological processes and fire management are discussed.

What factors determine nutrient losses during and after fires?

Fire characteristics

The magnitude of nutrient losses due to fire is determined by the fire intensity, flame dimensions and temperature profiles, the spatial pattern of these properties across the landscape, and the recurrence interval of particular fire patterns. These characteristics of fires in northern Australia have been discussed by Gill et al. (1990). Briefly, early dry season fires result in fine grained patchiness due to the variety of moisture contents of the grassy fuels and the uncertainty of the weather. Fires usually go out at night, and cannot burn the wetter vegetation of lower topographic zones. Later in the year, leaf fall from trees and shrubs (Fig 1) has increased the fuel load, and desiccation of the grasses is more uniform (Fig 2). Fires at this time are more intense, more extensive, and flame heights are greater (Braithwaite & Estberg 1985).

FIGURE 1 Leaf fall from unburnt savannas at Kapalga, from 8.9.89 to 29.3.91

Litter fall (g m\(^{-2}\) d\(^{-1}\))

Date

xii.89 vi.90 vii.90 xii.90 vi.91

123
The soil temperatures during fires in savannas are relatively low due to the low intensity of the fires and their rapid consumption of available fuel. During a fire in a Brazilian cerrado, the maximum temperature at the soil surface was 74 °C while at a depth of 1 cm, the maximum was 47 °C (Coutinho 1990). Hence the potential losses of nutrients from combustion of soil organic matter are low. Furthermore, the build up of organic matter at the soil surface in unburnt savannas in Australia is restricted by rapid microbial decomposition of organic matter each wet season and consumption by termites (Holt & Coventry 1990).

**Nutrient content of the fuel**

There is little published information on the nutrient content of the understorey of the savannas in the Top End. At Katherine, Norman and Wetscher (1960) determined that 5 kg N ha⁻¹ would be lost during grass fires. They considered that this loss was negligible compared with the total store of N in the soil. However, Cook and Andrew (1991) point out that an annual loss of this magnitude is substantial when compared with the doubling of dry matter yields of native grasses which can result from the application of 38 kg N ha⁻¹ as fertilizer (Norman 1962).

At Thorak near Darwin, the biomass of the fuel in the understorey was up to 3.1 t ha⁻¹ (Cook & Andrew 1991). The amounts of macronutrients in this biomass were up to (in kg ha⁻¹), N: 12.3, P: 1.1, K: 13.0, S: 2.5, Ca: 11.8, Mg: 5.7. Generally, the amounts of nutrients in the fuel will be greater if the biomass of the understorey is greater. Thus the potential for nutrient losses will also be greater if the biomass is greater. In Table 1, the understorey biomass is given for a range of sites in the Top End. It can be seen that the biomass can vary greatly. In the Darwin region, the invasion of introduced perennial grasses such as Andropogon gayanus can increase the fuel load more than five times that of the native grass Sorghum intrans. Thus the potential for nutrient rundown under an annual fire regime is also increased. In the Katherine district, heavy grazing alters the grass species and reduces the fuel load, which should decrease the risk of nutrient losses due to fires, but other considerations make such changes undesirable.

**TABLE 1 Biomass and dominant grass species of the understorey at a range of sites in the Top End of the NT**

<table>
<thead>
<tr>
<th>Site</th>
<th>Dominant species</th>
<th>Biomass (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darwin region</td>
<td>Sorghum intrans</td>
<td>2.6-3.0</td>
</tr>
<tr>
<td>Darwin region</td>
<td>Andropogon gayanus</td>
<td>17</td>
</tr>
<tr>
<td>Willeroo ungrazed</td>
<td>Sorghum timorensi</td>
<td>14.2</td>
</tr>
<tr>
<td>Willeroo grazed</td>
<td>Themostachys sp</td>
<td>3.6</td>
</tr>
<tr>
<td>Mambulloo ungrazed</td>
<td>Themeda triandra</td>
<td>3.5</td>
</tr>
<tr>
<td>Mambulloo grazed</td>
<td>Enneapogon sp</td>
<td>1.3</td>
</tr>
</tbody>
</table>

(a) Cook & Andrew 1991

**Chemistry of nutrient elements**

It is often considered that most of the nitrogen and sulphur in the biomass is volatilised during fires, while most of the phosphorus, potassium, calcium, and magnesium is deposited in the ash. However, this generalisation is misleading because P, K, and Mg can also volatilise during fires and all elements can be transferred to the atmosphere as particulates.

Transfer to the atmosphere removed between 25% and 75% of all macronutrients (excluding S) in the fuel during low intensity understorey burns in the ACT (Table 2) (from Raison et al 1983). Further, gaseous losses accounted for substantial proportions of the transfer of P, K, and Mg as well as N (Table 2). Nitrogen has the lowest vaporization temperature of the macronutrients (Table 2), and more than 80% of the losses of this element were gaseous. In contrast, the vaporization temperature of calcium is sufficiently high to assume that Ca does not volatilise during fires and all losses occur...
TABLE 2 Vaporization temperatures of macronutrient elements, and the proportions and mechanisms of transfer to the atmosphere during controlled burns in ACT

<table>
<thead>
<tr>
<th>Element</th>
<th>Vaporization Temperature (°C)</th>
<th>Transfer to atmosphere on combustion (%)</th>
<th>Gaseous loss as a percentage of total transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>200</td>
<td>54 – 75</td>
<td>&gt;80</td>
</tr>
<tr>
<td>S</td>
<td>300</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>P</td>
<td>774 *</td>
<td>37 – 50</td>
<td>25 – 55</td>
</tr>
<tr>
<td>K</td>
<td>774</td>
<td>43 – 66</td>
<td>60 – 80</td>
</tr>
<tr>
<td>Mg</td>
<td>1107 *</td>
<td>25 – 49</td>
<td>0 – 50</td>
</tr>
<tr>
<td>Ca</td>
<td>1484</td>
<td>31 – 34</td>
<td>0</td>
</tr>
</tbody>
</table>

* lower for organically bound forms

Source: Raison et al 1985, Walker et al 1986

as particulates. The vaporization temperatures of P, K, and Mg are intermediate (Table 2) and the proportions of these elements transferred to the atmosphere were less than that of N.

The mechanism of transfer of nutrients has particular ecological importance because elements lost in gaseous forms are unlikely to be deposited on or near the site of the fires. In contrast, particulates are likely to return nearby as dry deposition. Hence the likelihood of permanent export of nutrients increases as vaporization temperature decreases (Raison et al 1985).

The residue remaining after fires is enriched in nutrients compared with the fuel because carbon is oxidised and transferred to the atmosphere to a greater extent than other elements. Hence the residue represents a supply of nutrients concentrated from the labile fraction in the understory. Therefore, the fate of the residue is critical to nutrient cycling.

The enrichment of nutrients in the residue is indicated by the ratio of nutrient concentrations in the residue after fire to the concentrations in the grass before the fire. The values of this ratio at Kapalga were positively related to the vaporization temperatures of each macronutrient (Fig 3). This indicates that the fate of the post-fire residues has greater importance for those nutrients with higher vaporization temperatures.

**Leaching**

Australian soils are generally highly leached (Hubble et al 1983), and the soils of the Top End are no exception. Extensive lateralisation (Isbell 1983) and the impact of intense rainfall on typically coarse-textured soils has removed exchangeable cations and left many soils with high levels of exchangeable acidity (Calder & Day 1982; Day et al 1983). Under these conditions, competition by plants for the remaining nutrient cations is likely to be intense. Thus plant uptake should limit further losses due to leaching. However, leaching has lead to gradual nutrient rundown on podzols in Cooloola (Walker et al 1981) which indicates that extremely low rates of leaching over long periods can cause substantial changes in vegetation.
The inflow of nutrients in seepage water may contribute to the fertility of the highly leached siliceous sands along drainage lines and depressions in the Alligator Rivers Region (Aldrick 1976). This process may cause significant losses of nutrients which were deposited as ash. However, in the savannas of Central America, leaching does not appear to cause significant nutrient losses after fire because of rapid immobilisation of nutrients (Kellman et al 1985). Further work is required to evaluate the contribution of leaching to the nutrient cycle in the Top End.

**Erosion**

Erosion of ash through water runoff was identified as a major cause of nutrient loss following fires in Central America (Kellman et al 1985). In the Top End, the critical period for such losses is during the early storms of October/November prior to the substantial growth of grasses and herbage during the wet season. The patchiness of fires early in the dry season and the subsequent resprouting of vegetation will limit soil disturbance due to raindrop impact and will reduce the rates of water flow across the soil surface. Thus erosion by water of ash deposited during early fires should be minimal unless unseasonal rain occurs. In contrast, fires late in the dry season consume the understorey almost completely and resprouting of vegetation is insufficient to prevent high rates of water runoff and removal of ash.

There are no data to show the magnitude of nutrient losses through erosion of ash by water in the Top End. Generally, the northern plains are remarkably stable and not subject to severe erosion as indicated by the widespread survival of the Cainozoic Koolipinjah Surface (Isbell 1983). Nevertheless, the reworked laterites, deposits of alluvial and colluvial materials, and the lack of deep soils on slopes steeper than about 5% (Williams 1976) demonstrate that substantial movement of soils can occur in certain landscape positions. On Kapalga, which is typical of much of the northern lateritic plains, zones of active erosion often occur about 300 m to 500 m up slope from drainage lines (Fig 4). These zones are most likely to suffer from losses of nutrients due to removal of ash.

**What are the inputs of nutrients to Top End savannas?**

**Rainfall and Dry deposition**

Nutrient accretions in rainfall and their role in nutrient cycling in Australian savannas have been briefly reviewed by Holt and Coventry (1990). They conclude that much of the nutrient content of rainfall originated from dry season fires, and suggest that the nutrient losses caused by burning are closely related to the nutrient gains by rainfall. Values for rainfall accretion are available for Jabiru, Katherine, and Groote Eylandt (Noller et al 1985; Wetselaar & Hutton 1963; Langkamp & Dalling 1983).

Dry deposition of nutrients is difficult to measure and is rarely monitored routinely (Fowler, Cape & Leith 1990). In the UK, dry deposition of sulphur exceeds wet deposition in most areas (Fowler 1984 cited by Fowler et al 1990). In tropical savannas, the settling of particulates transferred to the atmosphere during fires is likely to account for a substantial proportion of the total dry deposition.

**Weathering of primary minerals**

The great age of the soils in Australia generally and of the Top End in particular (Hubble et al 1983; Isbell 1983) means that weathering of primary minerals will not contribute significantly to the fertility of soils. This is in contrast to many other tropical regions where volcanism and active erosion frequently cause fresh unweathered material to be exposed and contribute to soil fertility. In the Top End, the widespread occurrence of coarse sedimentary rocks further restricts the supply of nutrients from weathering of material underlying the soils.

**Biological fixation**

Estimates of biological fixation of nitrogen by native species in the Top End range from 2.2 kg ha\(^{-1}\) y\(^{-1}\) in savannas at Katherine (Norman & Wetselaar 1960) to 12 kg ha\(^{-1}\) per wet season in a planted stand of *Acacia pellita* at Groote Eylandt.
(Langkamp et al 1979). Although there is a considerable range of legumes and other species with N fixing symbioses in the Top End, their density is unlikely to be above that of *A. pellita* studied at Groote Eylandt. Hence, a value of 12 kg N ha\(^{-1}\) y\(^{-1}\) probably represents a maximum rate of N fixation for this region.

**Do the losses of nutrients exceed the gains?**

The major inputs of macronutrients are through rainfall accession and dry deposition with biological fixation of N contributing less than 12 kg ha\(^{-1}\) y\(^{-1}\). The major outputs are through direct transfer of nutrients in particulate and gaseous forms while losses of ash by water erosion may be important in certain landscape positions after late fires.

The transfers of macronutrients to the atmosphere during fires at Kapalga in May 1991 are given in Table 3 along with the accession of nutrients through rainfall based on data from Jabiru (Noller et al 1985). The annual balance of each nutrient was calculated as the difference between rainfall and gaseous transfer to the atmosphere during fires. This assumes that all of the particulate loss is returned via dry deposition. The balance was calculated for four fire frequencies (every 1, 2, 3, or 4 years) under a minimum loss and a maximum loss scenario. The minimum loss scenario used the minimum transfer to the atmosphere measured at Kapalga and the minimum gaseous transfer of each nutrient recorded for understorey fires in the ACT (Table 2). The maximum loss scenario assumed maximum values of these properties. The accuracy of the predictions under these scenarios depends on the validity of the assumptions about dry deposition, the lack of leaching, and erosion losses. This will be discussed below.

The predictions indicated that under annual fires, gains of nutrients from rainfall will exceed losses of all nutrients except N (Table 3) assuming the minimum loss scenario. Under the maximum loss scenario, substantial net losses of N, K, and Mg are predicted if fires occur annually. The maximum predicted losses of N are more than double the levels of biological fixation in a pure stand of *A. pellita*, while the minimum predicted losses are equal to that fixation rate. Hence, rundown of nitrogen reserves is likely under an annual fire regime.

With decreasing fire frequency, the predicted maximum net losses of N, K, and Mg also decrease (Fig 5). Deficiencies of K and Mg are uncommon in Australian soils (Williams & Raupach 1983) and have not been reported in the Top End. Losses of K and Mg may therefore have little consequence. Nevertheless, siliceous sands are susceptible to potassium deficiency, and removal of biomass by cropping and hay making can induce deficiencies elsewhere (Williams & Raupach 1983). Hence, gradual depletion of potassium reserves may affect plant growth in the savannas of the Top End, particularly where siliceous sands occur such as along drainage lines.

The predictions of nutrient losses described above are conservative estimates. Greater nutrient losses may occur due to erosion of post-fire residues by wind and water. Deposition of wind-borne particulates is likely to be less on the western side of catchments than the eastern side because the prevailing winds are south-easterly. Deposition of particulates in the sea will increase nutrient losses.

**TABLE 3 Transfers of macronutrients to the atmosphere during fires at Kapalga in 1991\(^{(a)}\) compared with rainfall accession at Jabiru\(^{(b)}\)**

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage transfer</th>
<th>Total transfer (kg ha(^{-1}))</th>
<th>Rainfall accession (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>91 – 95</td>
<td>17 – 29</td>
<td>2</td>
</tr>
<tr>
<td>S</td>
<td>76 – 84</td>
<td>0.9 – 1.7</td>
<td>3.1</td>
</tr>
<tr>
<td>P</td>
<td>13 – 52</td>
<td>0.07 – 0.56</td>
<td>0.3</td>
</tr>
<tr>
<td>K</td>
<td>23 – 73</td>
<td>1.1 – 13</td>
<td>1.1</td>
</tr>
<tr>
<td>Mg</td>
<td>19 – 62</td>
<td>0.9 – 7</td>
<td>0.4</td>
</tr>
<tr>
<td>Ca</td>
<td>0 – 54</td>
<td>0 – 15</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Sources: (a) Cook (unpubl), (b) Based on Noller et al 1985.
FIGURE 5 The effect of fire frequency on the predicted losses of N, K and Mg from savannas at Kapalga

If the rainfall accession includes some of the particulates transferred to the atmosphere during the fires, then the total annual inputs will be overestimated. Further, if sufficient area of land is subject to reduced fire frequencies than currently prevailing, rainfall accession of nutrients is likely to decrease. This will cause the net losses of nutrients under less frequent fire regimes to be greater than those predicted.

Implications for ecological processes and land management

The small but recurring losses of K and Mg caused by frequent fires may be causing irreversible nutrient rundown of the savannas of the Top End. This may result in a slow regressive succession of vegetation similar to that demonstrated for sand dunes at Cooloola (Walker et al. 1981). These effects may already be evident, but would be difficult to prove due to the prevalence of burning in the savannas. Substantial losses of nutrients may result from fires affecting relatively nutrient rich sites such as monsoon forests in which fires have rarely occurred in the past.

The substantial losses of N caused by burning are potentially reversible if fire is excluded for several years, but this is unlikely to occur. The dominance of annual grasses such as Sorghum spp and Eucalyptus spp in the savannas of northern Australia may have resulted from the long history of burning and the resultant depletion of soil nitrogen. The biomass of the annual grasses is often low and the herbage of insufficient quality to support mammalian herbivores (Cook & Andrew 1991). Nevertheless, seeds of the annual Sorghum spp are very important as food for granivorous birds and mammals (Cook & Andrew 1991). Thus nutrient rundown does not necessarily imply that the conservation values are diminished. Similarly at Cooloola, the heathlands on the most depauperate sites are major habitats for ground parrots (Petrophila wallacei) and southern emu-wrens (Stipiturus malachurus), and fire is critical to their survival (McFarland 1988).

Annual burning by pastoralists, although useful for removing rank grass and developing green pick, may be maintaining the pasture in a state of very low productivity by preventing accumulation of nitrogen. While fire exclusion is neither practical nor desirable, a reduction in fire frequency may increase nitrogen stocks in the herbage.

Conclusions

The extremely high prevalence of fires in the savannas of the Top End raises a host of issues for land managers, and possible nutrient rundown is one of fundamental importance. Conservative estimates of nutrient losses at CSIRO's Kapalga Research Station in Kakadu National Park indicate that net losses of nitrogen, potassium and magnesium are occurring due to annual fires. The erosion of ash particularly from certain zones in the landscape may increase the rate of nutrient rundown. By excluding fires for a number of years, the magnitude of these losses should decrease. However, the greater intensity of fires following several years of fire exclusion and fuel accumulation needs to be considered for nutrient budgeting in the long term.

The development of systems of fire management on a landscape scale in northern Australia (eg Andrew 1986; Press 1988) must include consideration of nutrient dynamics if conservation values and productivity are to be maintained. The timing and frequency of fires should be selected so that net losses of nutrients do not occur in the long term. Particular consideration needs to be given to landscape positions with high susceptibility to nutrient rundown such as riparian zones with very poor sandy soils.
Acknowledgments

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References


CHAPTER 15

A COMPARISON OF ABORIGINAL AND PASTORAL FIRES IN THE NORTH-WEST NORTHERN TERRITORY

LM Head, AL O'Neill, JK Marthick and RLK Fullagar

Introduction

Lands leased for pastoralism in northern Australia (for example more than 50% of the Northern Territory) are increasingly subject to demands for multiple use as dispossessed Aboriginal groups regain living areas excised from pastoral leases. Our research shows that many of these uses, for example hunting-gathering and extensive cattle grazing, are compatible, but we focus in this paper on an area of conflict, the use of fire. We compare the way two groups, Aboriginal people and pastoralists, have used fire on the same area of land surrounding Marralam Outstation, excised from Legune Station in the far northwest of the Northern Territory. The comparison, based on field research and interviews with both groups, shows different perceptions of fire and its impact on the environment. Remote sensing and geographic information techniques provide independent description and quantification of fire types. This analysis has to date focused on spatial comparisons of different fire sources, though ways of considering ecological comparisons in the future are also discussed.

The study area

Legune Station is in the far northwest of the Territory, adjacent to the Western Australia border (Fig 1). The excision for Marralam Outstation, covering 439 ha, was handed to the Aboriginal community on 11 December 1986. This community comprises Murinpatha and Jaminjung people, many of whom had worked on Legune and neighbouring stations prior to the 1970s. The excision is bounded on the west and south by Spirit Hills Station. Excisions are not large enough to support a subsistence lifestyle, nor were they intended to provide anything more than ‘living areas’, but Aboriginal hunting and gathering access to the pastoral lands has some protection under the NT Crown Lands Act and WA Land Act. For a more detailed discussion of the background to the excisions program, see Head and Fullagar (1991).

In a classification essentially designed to assess pastoral and agricultural potential, a number of geomorphic units and land systems have been identified (CSIRO 1970) (Plate I). These can be summarised as:

1. Coastal Country, the Carpentaria Land System (C), estuarine alluvial plains where saline soils support grasses such as Xerochloa imberbis and Sporobolus sp;

2. Blue Grass Plains comprising the Legune Land System (Lg) with cracking clays supporting saline short grasses, tall grasses such as Imperata cylindrica and Blue grass (Dicanthium sp), and the Ivanhoe Land System (Lv), the cracking clays of the alluvial flood plains which also support Blue grass and tall grasses such as Aristida, Sorghum and Aristida spp with fringing forests near streams;

3. Upland Tall Grass Plains have sandy soils which support stringybark—bloodwood woodlands (Eucalyptus tetradora, E. dichromophloia, E. miniata) over tall grass communities dominated by Sorghum stipoides and Plectranche pungens in the Cockatoo Land System (Cc). The slightly more loamy sands of the Angallari Land System (Ag) support the northern box—bloodwood (E. tectifica, E. foelscheana) woodland and the sparse low woodland of silver leafed box (E. pruinosa) over tall grasses Themeda, Setaria and Chrysopogon spp;

4. Rugged Sandstone Hills of the Pinkerton Land System (Pi), and the Weaber Land System (W) also support stringybark—bloodwood woodland over tall grass communities although with considerable bare rock outcrop;

5. Low Hilly Country is typified by the small Cockburn Land System (Co). With skeletal soils and rock outcrop, this area is either treeless or has sparse, low paperbark over sparse spinifex (Plectranche pungens).
The vegetation of the whole region is typified by woodlands with grassy understoreys. Shrub layers are rare (Perry 1970).

There are similarities between these land systems and lands recognised and named by people at Marralam, for example; palarungarr (mountain ranges), ngalbunu (rocky ridges), darinmun (sandy country), darinbirr (black soil plain), punbah (salt flats), koora kalangarr (freshwater swamp country). However, Marralam Aboriginal people emphasise that these names are not as important as the place names of individual parts of these areas.

Climatically the region is semi-arid, with a warm dry monsoonal climate. Mean annual rainfall is 750 mm at Kununurra and nearly 900 m in the coastal parts of Legue, virtually all of it falling in the wet season between November and March (Slater 1970). Soil moisture is the most important factor limiting plant growth, meaning a total duration of useful pasture growth of 18.2±3.4 weeks per year at Kununurra (approximately 20 weeks at Legue), with a mean commencement date of December 14 (Slater 1970). This should be seen as a total period during which a "green pick" is available for stock rather than one in which a high growth rate can be expected (Slater 1970, 71).
Aboriginal land use

While aspects of contemporary land use have been discussed more fully elsewhere (Head & Pullagar 1991), they bear summarising here as it is our contention that the Aboriginal use of fire must be understood as an integrated aspect of a wider system of land use and resource management. Land use patterns were mapped and subsistence quantified in four field work periods covering a total of several months between 1987 and 1990, supplemented by less detailed observations during other visits.

Land use extends well beyond the excision, but is most intensive closest to it. Figure 2 shows one example of this, in the dry season of 1988. Trips tend to be vehicle-based and multipurpose, with activities undertaken including hunting, gathering, collection of raw materials for art and craft production (including wood, bark and ochre) and burning. The spatial pattern of land use reflects the presence of roads and tracks, with less frequent off-track visits to favoured locations such as the estuarine reaches of the Keep River for fishing.

Seasonal variability is seen when wet and dry season maps are compared (Head & Pullagar 1991). During the wet season the road between Legune and Kununurra is frequently cut several kilometres either side of Marralam, resulting in a much more concentrated pattern of land use, with trips on foot to locations within several kilometres of Marralam.

Aboriginal use of fire

This summary is based on observations around Marralam outstation during the 1987–1990 fieldwork periods. Aboriginal people were interviewed about their own use of fire, and their reactions to other sources of fire. Detailed mapping of fires adjacent to a 40 km stretch of road between the Keep River and the Legune Station gate was carried out, and where possible, ignition sources were attributed. In addition, fires lit on hunting and gathering trips, as well as Aboriginal use of areas burnt by others, were recorded. This combination of descriptions and recordings provides the field basis for the interpretation of the satellite images.

For example, Figure 2 shows fires attributed to Aboriginal activity for an early dry season period in 1988. Areas burnt away from the road are not mapped, except for the heavily utilised area south of the road around Sandy Creek. (Pastoral and other fires are not shown on this map.) Areas marked (a) and (b) on the diagram provide the following additional information about Aboriginal utilisation of areas burnt by the pastoralist:

a) An area several kilometres long on either side of the road had been burnt by the pastoralist within the previous several weeks. This was considered by women from Marralam to be a good goanna and blue tongue fire because a lot of sand was exposed and the diggings at burrow entrances would be easily visible.

b) During the fishing trip to the Keep River, this predominantly blacksoil with camgrass area was observed to be burnt patchily all the way to the coast. This was attributed by the Aboriginal people to pastoral burning along the road west of Sandy Creek. They had no particular use for such a fire, except that it made access and visibility somewhat easier.

From a compilation of field observations like the example above, the characteristics of contemporary fire use can be summarised as follows.

The consistent use of the term 'burning grass' for any sort of fire activity implies low intensity fires whose main role is to clear out the undergrowth. The dominant reasons for burning are to allow access (for vehicles and on foot), to increase visibility, to protect against snakes (especially children), for hunting (mainly goanna, blue tongued lizard and tortoise), cleaning up and looking after country, and collection of ashes to be mixed with chewing tobacco. Burning to encourage plant foods is not a deliberate part of the strategy, mainly because bush plants do not form a major part of the diet (Head & Pullagar 1991). But they are included in the general explanation that burning off the dead vegetation helps the new growth to come through.

Fires are lit for delayed return. They are lit at the end of a visit to an area, with an expectation of returning in several days or weeks. No on-site attempts to observe where they go have been seen, although the smoke is often monitored back at camp. Detailed monitoring of fires' progress is made by looking at smoke in the sky. This enables deliberate visits to particular areas, no matter who had set the fire in the first place.

People are certainly not averse to utilising areas burnt by the pastoralist. In the late dry season of 1990 a deliberate visit was made to a burnt area outside people's normal round, where a large fire had been observed to burn a swamp and a woodland area on the west bank of the Keep River. Two women collected seven tortoises buried under the exposed dried swamp surface, five goannas from the
FIGURE 2  Land use around Marralam, May–June 1988
sandy woodland country, and a large quantity of high quality ash to be mixed with chewing tobacco. It is not clear whether this fire was set by the pastoralist or by fishermen, but it was considered to be a good one by the hunters.

Burning is concentrated in the early dry season, and areas are burned virtually as soon as they are dry enough to carry a fire. This means that the sandy ground is burnt before the black soil areas. Fire has not been observed being used in the late dry season, when the vegetation is very open anyway. Nevertheless informants maintain that there is no reason why fires should not be lit late in the dry season, particularly in the wetter areas close to the salt water, where they argue green pick will still come back within a few days.

People who have regained community living areas are more or less accepting of the constraints of living with pastoralism. For example, Marralam people have agreed not to burn in the main bull paddock at Legune. However, they remain somewhat bemused by the zeal of the pastoralists to control fire in the area, pointing out that a bushfire broke away from a pastoral station to the southeast in late 1988 and burnt part of the main paddock anyway. There is quite a bit of sensitivity towards being seen as pyromaniacs by local white people. Aborigines are quite adamant that the real 'vandals' with fire are tourists and fishermen.

Fire use appears to be one aspect of hunting and gathering that is not legally protected by the reservation within the NT Crown Lands Act. Indeed any use of fire outside the prescribed early dry season burning-off period is technically illegal (see below).

Pastoral use of fire

Our source of evidence here was again based around interviews with the managers of Legune and Spirit Hills Stations and observations of their burning practices. Discussions with pastoralists indicate considerable variability in attitudes to and knowledge of fire. In most cases the person who makes the on-ground decisions about fire is the station manager, who is rarely also the owner of the lease. Length of service in particular areas also varies. In the early part of the study there were four managers at Spirit Hills in four years, each with slightly different fire policies. In other cases people work on the same station or within the general region for most of their working lives.

However for all of the pastoralists talked to, the rationale of the burning program was based on the protection of cattle and the maintenance of feed late into the dry season. For example, Legune Station's most vulnerable resource is a large paddock on the black soil plains that maintains good grass cover throughout the dry. It is this area that the manager did not allow the Marralam residents to burn. The major fire threat to these grass reserves comes from lightning-triggered fires in the late dry season, and tourists such as barramundi fishermen who come through Legune to the estuarine reaches of the Keep River.

In conjunction with the Bush Fires Council, aerial incendiaries are used to start control burns early in the dry season. Roads are used as natural firebreaks and areas adjacent to roads are burnt by throwing lighted matches from a moving vehicle. (The same ignition method is used by Aboriginal people.)

The sandy country is burnt quite early in the dry season, when there is still enough moisture in the soil to provide for growth of green pick, but once the soil has dried out there will not be regrowth after fire. This is the main rationale for not burning in the late dry season. Managers also emphasised the importance of managing different types of country on their own terms. For example in areas dominated by Acacia, burning can increase the rate of sapling resprout and decrease the availability of grazable land.

Hazard reduction burning

A third group relevant in this discussion of different fire practice is the Northern Territory Bush Fires Council (BFC), which has a mandate to prevent and control bushfires. Burning off without a permit is illegal between specific dates in the dry season, usually June 1 to December 31. Lewis (1985) has reviewed BFC activities. He highlights the role of the 'Protective Aerial Controlled Burning Program' which uses aerial incendiaries to mitigate fire hazards by igniting control burns early in the dry season along and within cattle station boundaries. (In Western Australia the relevant authority is the Bush Fires Board, which first developed the aerial burning program.) Pastoralists interviewed by us vary in their attitudes towards the program. Information about areas subject to aerial incendiaries during the study period was obtained from participating pastoralists and flight plans supplied by the BFC.
Summary of conflicts

We see potential and actual conflicts between Aboriginals and pastoralists on the fire question as operating at two levels. The first is the broad question of power and control over the land. Perceptions of the way the others burn, as well as general attitudes towards them, is very much influenced by the perception of the legitimacy of their occupation of the country.

It is a common perception in Australia, including among land managers, that the Aboriginal influence ceased in the eighteenth and nineteenth centuries when Aboriginals were forcibly removed from their lands. If they are using fire at present, it is seen to be not really 'traditional', and therefore something that does not have to be accommodated by official fire policies. Even in National Parks on Aboriginal land, for which there are detailed accounts of the contemporary Aboriginal use of fire (e.g. Jones 1980), Lewis (1989) has argued that there is a view that because such activities are altered by contact with Europeans, park managers have little to learn from them. This is even more the case for those large areas of northern Australia held under pastoral lease, to which Aboriginals have limited access and over which they have few rights, despite long-term occupation and demonstrated traditional links (Coombs et al. 1989; Head & Pullagar 1991). For these people, profoundly affected by the pastoral incursion, it is even more difficult to counter the prevailing non-Aboriginal view that virtually nothing remains of 'real' Aboriginal culture, including fire technology and knowledge.

The question of the extent to which contemporary Aboriginal fire use resembles the prehistoric past is complex. For the purposes of this paper it is sufficient to note that suppression of Aboriginal fire, whether deliberate or otherwise, constitutes a means by which Aboriginals continue to be denied access to land. Further it stems from a set of views about fire generally, and Aboriginal fire in particular, as destructive, widespread and a threat to the pastoral industry. These views seem to be based on little objective data. For example, it is claimed that 30% of bush fires in the Kimberley are lit by Aboriginals (Director, WA Bush Fires Board, pers comm), but there is no information on their relative extent or ecological impacts.

The second level at which conflicts can be viewed relates more specifically to the study area. Two different groups are occupying overlapping areas of land on which they are using and managing two separate suites of resources (cf Lewis 1985). The sometimes uneasy but mostly workable coexistence is at its most vulnerable late in the dry season, when pastoralists are particularly concerned with the preservation of fodder until the wet. It is in this context of differing perceptions and heightened sensitivities that we have attempted to use remotely sensed data to obtain information on the spatial and temporal distribution of fires. However, we do not see it as an all-knowing umpire in a field of competing interests. Rather it provides another tool to understand what is happening in the landscape. It relies for its interpretation on an understanding of the factors discussed above. Specifically, we aimed over a clearly defined and relatively well known area, to:

- compare known Aboriginal, Pastoral, aerial incendiary and bush fires for characteristics such as intensity, extent and frequency;
- examine and map seasonal fire patterns;
- study fire patterns in this area over three successive years to begin to build up a longer term picture;
- examine the broader potential of the method, and the possibilities of using it to understand the ecological impacts of these fires.

Spatial definition of fires using satellite imagery

Landsat Thematic Mapper imagery was selected for this project as it has a spatial resolution of 30 m which allowed delineation of small Aboriginal lit fires as well as larger control burns. The spectral resolution of Thematic Mapper data allows good definition of vegetation communities and soil moisture conditions (Kay et al. 1990). Spectral data was available in 6 bands from the visible blue band 1 (0.43-0.52 μm) to the short wave infrared band 7 (2.08-2.35 μm).

End of dry season imagery was obtained for September 1988, November 1989 and September 1990. The microBRIAN image analysis software was used for all digital processing of satellite data. The data were registered to the Australian map grid and resampled using the nearest neighbour procedure retaining the 30 m pixel size. Copies of false colour images for field verification were printed at 1:100 000 and 1:50 000 scale.

Digital transformations of the data were performed in order to obtain the best definition between different types of fire scars on different land systems as well as to enhance differences between
vegetation communities. A number of complex variables are involved in obtaining signatures from surface types on Landsat imagery and attempting to characterise burn types by radiance values. Soil type, soil moisture, vegetation community and terrain are all interrelated and each influences the radiance as measured on the satellite. Spectral transects across a number of burns of different intensity as well as unburnt vegetation (Fig 3) were used to help categorise burn types. The other fire related variables were, time since burn, intensity of burn and time of year of burn. Transformations such as band ratios, vegetation indices and principal component analysis were trialled. The principal components analysis of bands 3 (0.63-0.69 µm), 4 (0.76-0.9 µm), 5 (1.55-1.75 µm) and 7 (2.08-2.35 µm) was found to be the most useful. The image produced from the third principal component (PCA3), combined with the near-infrared band 4 and the mid-infrared band 7 proved to be the most discriminating of burn types and enhanced details of variation within a fire scar. Bands 4, 7 and PCA3 were used to produce a false colour image on which to interpret fire patterns and delineate training areas for the classification of the area.

A supervised classification using a 'minimum distance to means' algorithm with two iterations to migrate the means, was used to allocate pixels to classes. Approximately 50 training classes were used for each image classification. The statistics of the resultant classes were examined for between and within class variation using canonical variate analysis and cluster analysis. Together with field data for spatial analysis, these were used as the decision factors for merging classes. The final 11 classes were labelled as follows: saline coastal grasslands, river and floodplains, rock outcrop and bare soils, grassland on clay soils, grassland on sandy soils, woodland over tall grasses on sandy soils, sparse woodlands on sandy soils, type 1 burn, type 2 burn, type 3 burn and dry lakes and scalds. The burns were labelled as above (Table 1) as it was difficult to differentiate between early season burns which had had five or six months to revegetate and a very light burn somewhat later in the season (type 1). Type 2 burns were either mid-season burns with some regeneration or late season moderate burns. Type 3 burns were either late season burns, recent in relation to the date of the imagery or high intensity burns from earlier in the season. Some of the aerial incendiary burns from late April were in this category as were the late season bushfires. The results of the classification procedures are shown in plates 3, 4 and 5.

**Fire frequency and change analysis using a geographic information system**

A modal filter was used to smooth each classified image before the data were exported to the geographic information system (GIS) for further change analysis. The SPAtial ANalysis System (SPANS), a raster based geographic information system, was used for the spatial analysis of the

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**FIGURE 3** Spectral transect across burns of different intensity and unburnt vegetation, on Cockatoo Land System east of Sandy Creek

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PLATE 1  Digitised land systems of the study area
(a) Pinkerton (P) – rugged sandstone hills; Weaber (W) – sandstone hills; Cockburn (Co) – low hills; Cockatoo (Cc) – woodland, tall grass plains; Angallali (Ag) – woodland, tall grass plains; Ivanhoe (Iv) – blue grass plains; Legune (Lg) – saline and tall grass plains; Carpentaria (C) – estuarine alluvial plains.

PLATE 2  Fire frequency in the study area showing the spatial distribution of areas burnt once, twice and three times in three years
PLATE 3  1988 LANDSAT Thematic Mapper computer classified image of the study area

PLATE 4  1989 LANDSAT Thematic Mapper computer classified image of the study area

PLATE 5  1990 LANDSAT Thematic Mapper computer classified image of the study area
TABLE 1 Characteristics and likely sources of burn types

<table>
<thead>
<tr>
<th>Burn type</th>
<th>Spectral characteristics</th>
<th>Field characteristics</th>
<th>Likely ignition sources*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image.png" alt="Image" /></td>
<td>early season light-mod with revegetation or light late season</td>
<td>Aboriginal, Pastoral</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>mid-season light-mod with regeneration or late season moderate</td>
<td>Aboriginal, Pastoral</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>early season high intensity or late season</td>
<td>Aerial incendiary, Bushfires</td>
</tr>
</tbody>
</table>

* Based on field observations

multidate images together with other data layers. Roads, land system boundaries, the Maralalum outstation and the Lagune homestead were digitised and added to the geographic information system.

**Single map analysis**

The GIS simplified the task of analysing the area of each land cover in the images. An area analysis of burn types on each classified image is shown in Table 2. In 1988, 27.7% (264.5 km²) of the area was burnt compared with 10.6% and 12.6% in the following two years. Two thirds of the burning in 1988 took place in the earlier part of the dry season though severe bushfires late in the season were responsible for the majority of the 44 km² labelled as type 3 burn.

**Area cross tabulation**

Area cross tabulation allows the information contained in two different maps to be correlated. Using this technique, fire types on different landsystems over the three years can be analysed. Figure 4 shows the percentage of each burn type which occurs on each land system over three years.

TABLE 2 Area burnt by each burn type 1988–1990(a)

<table>
<thead>
<tr>
<th>Burn type</th>
<th>September 1988 km²</th>
<th>November 1989 km²</th>
<th>September 1990 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>Type 1</td>
<td>104.4 (10.9)</td>
<td>62.0 (6.5)</td>
<td>40.7 (4.2)</td>
</tr>
<tr>
<td>Type 2</td>
<td>116.2 (12.2)</td>
<td>27.1 (2.8)</td>
<td>50.9 (5.3)</td>
</tr>
<tr>
<td>Type 3</td>
<td>43.9 (4.6)</td>
<td>12.7 (1.3)</td>
<td>30.1 (3.1)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>264.5 (27.7)</td>
<td>101.8 (10.6)</td>
<td>121.7 (12.6)</td>
</tr>
</tbody>
</table>

(a) The percentage of the study area burnt for each category is shown in brackets
FIGURE 4  Comparison of burn types on Land Systems over three years: 1988, 1989 and 1990 (a)  
(a) Pi — Pinkerton, W — Weaber, Co — Cockburn, Cc — Cockatoo, Ag — Angallari, Iv — Ivanhoe, Lg — Laguna and C — Carpentaria.
It shows that the largest area of type 1 burns in 1989 occurred on the Ivanhoe land system, which also sustained the largest area of type 2 burns in 1989 and 1990 and the largest area of type 3 burns in 1989 and 1990. The Ivanhoe land system occurs in the study area between the Keep River and Sandy Creek. The area is mainly tall grasslands on clay soils and, as can be seen on Plate 3, in 1988 there were a series of small intense burns where aerial incendiaries had been dropped though fires had not spread. In 1989 and 1990 (Plates 4 & 5), fires in the same area were initiated by aerial incendiaries but due to better burning conditions they burned larger areas.

**Effect of the Aboriginal outstation on fire distribution and area burnt**

**Fires along the road**

During the 1987 and 1988 field seasons it was shown that many fires are initiated along the road from the Keep River to the Legune station gate (Head & Fullagar 1991). In order to analyse the fire patterns adjacent to the road, and compare these hand ignitions from moving vehicles (both Aboriginal and pastoral) with the wider pattern, buffer zones were created in the geographic information system. Buffers 0 to 2 km and 2 to 5 km were examined. The percentage area burnt was calculated and is shown in Table 3. The percentage area burnt within 5 km of the road each year shows a similar pattern to the whole area though percentage burnt within the road buffers is actually somewhat less than for the whole.

**Fires around Marral ram**

In order to see whether the area of most intensive Aboriginal usage around Marralam experienced a higher percentage of fires than either the total area or buffer regions along roads, the same buffering procedure was used. This time it was centred on a point — Marralam outstation — exclusive circles 0 to 2 km, 2 to 5 km and 5 to 10 km were set up on the GIS (Plate 2).

The results of this analysis (Table 4) show that in 1988 there was a higher percentage of the area within a 10 km radius of the outstation burnt than either of the following years and that most of these fires were type 1 burns. The percentage area burnt around Marralam was slightly higher than the average for the area that year (29.5% compared with 27.7%). This contrasts with the patterns for the following years. In 1989 only 6.1% of the area within a 10 km radius of Marralam was burnt compared with the average of 10.6% for the whole area, and in 1990 it was 8.6% compared with 12.7% for the whole area.

**Fire frequency**

Ecologically, the frequency with which a vegetation type is burnt is significant (Braithwaite & Listsbergs 1985, Bowman & Wilson 1988, Fansham 1990, Lonsdale & Braithwaite 1991). In order to examine which particular vegetation type was experiencing high fire frequency, a unique criteria map was produced. A unique criteria map is obtained by overlaying all available information so that each different combination of input classes produces a new class which is characterised by a unique combination of features. An extract from the report on the unique criteria map shows that 25.6% of the study area was burnt once over the three years, 3.3% was burnt twice and 0.1% was burnt three times. The spatial distribution of these fire frequency classes is shown on Plate 5.

**Discussion**

While it is not possible to spectrally distinguish fires from different ignition sources, we have demonstrated some broad differences between the less intense fires ignited by hand, and the more intense burns started by aerial incendiaries. Hand ignitions by both Aborigines and pastoralists, such as those lit along the road, are very similar in terms of spectral signatures. This concurs with observational evidence that Aborigines hunt and gather on areas burnt by pastoralists, suggesting that the ecological impacts of the two types of fires, at least on food plants and animals, are not very different. Detailed monitoring through a single season is necessary to fully separate regeneration effects from those induced by fire intensity and time of ignition.

The total areas burnt annually in the study site are low by comparison with other areas where figures are available. For example, Day (1985 in Walker et al 1985; see also Bowman et al 1990) examined the Kakadu region for 1980–2, and found that on average 62% of lowland areas and 33% of the Arnhem Land plateau was burnt each year. Most of the latter was from late dry season fires. It may be that the incidence of intense late fires is lower in the Marralam area because of lower fuel loads and/or more frequent early season burns. From the three years monitored in this study, 1988 stands out as a fire prone year with 27.7% of the area being burnt.
TABLE 3 Percentage of buffer area burnt each side of the main road from Legune Homestead to the Keep River

<table>
<thead>
<tr>
<th>Buffer (km)</th>
<th>Type 1 burn (%)</th>
<th>Type 2 burn (%)</th>
<th>Type 3 burn (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1988</td>
<td>0–2 11.3</td>
<td>9.2</td>
<td>1.8</td>
<td>22.3</td>
</tr>
<tr>
<td></td>
<td>2–5 11.8</td>
<td>11.7</td>
<td>6.8</td>
<td>30.3</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–5 11.6</td>
<td>10.6</td>
<td>4.5</td>
<td>26.7(*27.7)</td>
</tr>
<tr>
<td>November 1989</td>
<td>0–2 2.1</td>
<td>0.4</td>
<td>0.7</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>2–5 9.1</td>
<td>2.5</td>
<td>0.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–5 6.0</td>
<td>1.6</td>
<td>0.5</td>
<td>8.1(*10.6)</td>
</tr>
<tr>
<td>September 1990</td>
<td>0–2 5.5</td>
<td>3.2</td>
<td>1.6</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>2–5 4.2</td>
<td>8.0</td>
<td>3.7</td>
<td>15.9</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–5 4.8</td>
<td>5.8</td>
<td>2.8</td>
<td>13.4(*12.6)</td>
</tr>
</tbody>
</table>

* percentage of the total study area burnt

TABLE 4 Percentage of buffer area burnt 0 to 10 km around Marralam Outstation

<table>
<thead>
<tr>
<th>Buffer (km)</th>
<th>Type 1 burn (%)</th>
<th>Type 2 burn (%)</th>
<th>Type 3 burn (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 1988</td>
<td>0–2 15.9</td>
<td>3.6</td>
<td>0.1</td>
<td>19.6</td>
</tr>
<tr>
<td></td>
<td>2–5 20.9</td>
<td>7.0</td>
<td>0.3</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td>5–10 14.7</td>
<td>12.4</td>
<td>3.9</td>
<td>31.0</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–10 16.08</td>
<td>10.6</td>
<td>2.8</td>
<td>29.5(*27.7)</td>
</tr>
<tr>
<td>November 1989</td>
<td>0–2 4.4</td>
<td>0.3</td>
<td>0.0</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>2–5 2.1</td>
<td>0.3</td>
<td>0.0</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>5–10 6.5</td>
<td>1.1</td>
<td>0.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–10 5.3</td>
<td>0.8</td>
<td>0.0</td>
<td>6.1(*10.6)</td>
</tr>
<tr>
<td>September 1990</td>
<td>0–2 2.6</td>
<td>0.7</td>
<td>0.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>2–5 5.8</td>
<td>1.0</td>
<td>0.6</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>5–10 2.9</td>
<td>3.4</td>
<td>3.0</td>
<td>9.3</td>
</tr>
<tr>
<td>Total Area burnt as % of buffer area</td>
<td>0–10 3.6</td>
<td>2.7</td>
<td>2.3</td>
<td>8.6(*12.6)</td>
</tr>
</tbody>
</table>

* percentage of the total study area burnt
compared with 10.6% and 12.6% the following years. We emphasise however that three years is a totally inadequate time frame from which to draw any conclusions about climatic, vegetation or fire patterns. This glimpse into a fascinating and complex pattern serves to emphasise the need for long term monitoring.

The breakdown of fire types along the road and within 10 km of Marralam reflects the distribution of fire types for the area as a whole. The Marralam figures are slightly higher than for the total area in 1988, though considerably less than the total for 1989 and 1990. Even the high 1988 figures are overwhelmingly the less intense type 1 and 2 burns. It is possible that the intense burning in 1988, and the subsequent reduction in total area burnt around Marralam in the following years, indicates a re-establishment effect following permanent resettlement in late 1986, but this needs to be followed up.

The comparison of the frequency and intensity of burns on different land systems has shown that the Ivanhoe land system (grasslands on clay) is burnt most frequently, has the highest percentage of its area burnt each year and also sustains the most intense fires. The differential effect of fire on different landsystems is discussed in more detail elsewhere (O'Neill et al 1992), but it is important to note here that the method provides for high resolution comparisons of fire frequency and intensity on these different systems. The use of satellite imagery to periodically update land cover maps and the integration of these data with detailed field information in a geographic information system will allow for a better understanding of the role of fire in the ecology of the region.

Conclusions

Opportunities for Aborigines to burn, because of reduced access to land, have been severely curtailed in the last two decades, and it is highly likely that the removal of Aboriginal influences increased the possibility of the more destructive large area, infrequent, high intensity fires.

Although the re-establishment of Aboriginal fire regimes with renewal of access requires further analysis, perceptions of Aboriginal burning as widespread and destructive are demonstrably unfounded in the context of a small residential group like that at Marralam. The process of accommodation with pastoralists which has developed in the four years since the excision was granted seems to represent a more positive future scenario over much of northern Australia.

Aboriginal foraging over areas burnt by the pastoralist suggests that, at least in this type of environment, the two types of fires may not be very different in terms of outcome and desirability for hunting and gathering.

However, the new coexistence is unlikely to be easy, since it essentially involves competition between land users and Aboriginal use of fire appears to have no explicit statutory protection. The extent to which Aboriginal activities are constrained by a lack of land tenure needs to be explored. There is a need for Aborigines to be recognised by governments as legitimate land users, and to have a voice in fire policy. Application of analytical tools like those used in this study have an important role in the monitoring of this issue over time and space.

Acknowledgments

We are indebted to the Marralam Community, various managers of Legune and Spirit Hills Stations, Phil Pisani, Elizabeth Telford and Richard Miller for their assistance with this study. The NT Bush Fires Council made flight plans available. Funding was provided by the Australian Institute of Aboriginal and Torres Strait Islander Studies and the Quaternary Environmental Change Program of the University of Wollongong.

References


CHAPTER 16

INCREASED ATMOSPHERIC CARBON DIOXIDE LEVELS AND VEGETATION RESPONSES IN THE TROPICS

Derek Eamus and Gordon Duff

Introduction

Several lines of evidence support the view that atmospheric CO₂ levels (\([CO_2]_a\)) have been increasing since the advent of the industrial revolution. These include measurements of \([CO_2]_a\) at Mauna Loa in Hawaii (Crane 1985); measurements of \([CO_2]_a\) of air trapped in ice (Pearman et al. 1986); inferences based on dendrochronology (Hamburg & Cogbill 1988) and modelling based on fossil fuel consumption and the airborne CO₂ fraction (Keeping et al. 1986). Two major causes of this increase are burning of fossil fuels and deforestation. Much of the evidence for increased \([CO_2]_a\) has been reviewed (Bolin et al. 1989). It is taken as axiomatic in this review that \([CO_2]_a\) will continue to increase for the next century and that by the end of the 21st century \([CO_2]_a\) will approximate to 600–700 µL L⁻¹.

Carbon dioxide (CO₂) is a radiatively absorbent gas. Consequently, as \([CO_2]_a\) increase, the amount of heat retained by the atmosphere increases and thus mean global surface temperature is raised. Not all of this increase is the result of an increase in \([CO_2]_a\). Additional radiatively absorbent gases (RAGs) include methane, ozone and chlorofluorocarbons. Table 1 shows the calculated global mean temperature increase resulting from a doubling of the present level of the major RAGs. Whilst CO₂ constitutes the major contributor to increased global mean temperature, ozone and methane also contribute significantly and the proportion attributed to these additional RAGs is likely to increase during the next century.

Much public and scientific debate in recent years has focused upon the impact of climate change upon sea-levels, agronomy and vegetation. The Earth’s climate is considered to be entering a phase of rapid and extensive change, resulting from the increase in the concentration of atmospheric RAGs. Only recently has any concerted and sustained attention been made to the fact that vegetation (both ‘natural’ and commercial) is responsive to changes in \([CO_2]_a\) irrespective of any changes in climate per se.

Table 1  The effect of doubling the present nominal atmospheric concentration of some of the major radiatively absorbent gases on global mean temperatures

<table>
<thead>
<tr>
<th>Nominal Concentration (ppbv)</th>
<th>Temperature Increase °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>1700</td>
</tr>
<tr>
<td>N₂O</td>
<td>320</td>
</tr>
<tr>
<td>O₃ (tropospheric)</td>
<td>10–200*</td>
</tr>
<tr>
<td>CF₂Cl₂</td>
<td>0.2</td>
</tr>
<tr>
<td>CFCl₃</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Indicates an approximate general range of concentrations. Tropospheric ozone shows large local temporal and spatial variations in concentration.

Source: adapted from Fowler 1990.
This review focuses its attention upon vegetation responses to elevated $[CO_2]_a$ and does not deal extensively with the impact of climate change (e.g., mean temperature, rainfall) (both total annual rainfall and temporal distribution)) for the following reasons:

a) The current means of predicting climate change are based upon a range of global circulation models (GCMs). Thus CSIRO has its own GCM, as does the UK meteorological office, and many other leading laboratories/institutes. However, the spatial resolution of these models is inadequate to allow confident prediction about regional responses of climate. Consequently, in the absence of reliable regional predictions about the extent, direction and time-scale of regional responses of climate, it appears unwarranted to attempt to predict vegetation responses to climate change. If we cannot predict whether a given region will experience, on average, a change in mean summer and winter temperatures of $+2\,^oC$ or $-1\,^oC$, how can we predict the vegetation response?

b) Vegetation distribution cannot be explained solely on the basis of climate. Therefore a knowledge of climate change may not necessarily be sufficient to allow the successful prediction of changes in vegetation distribution.

c) It is often wrongly assumed that a given species assemblage (ecosystem) responds as a functional unit, with all species responding in the same way to a given change in climate. There is little evidence to suggest that it is not. Therefore the prediction of ecosystem responses to climate change are unlikely, at this stage, to be reliable.

d) The rate of change of climate is difficult to predict in view of the uncertainty in predicting future global emissions of RAGs. Thus the use of static, stable vegetation descriptions in correlations with current climate cannot characterise the transient dynamic response of forests, which are likely to persist for up to 300 years following the attainment of a new, stable climate system.

e) Correlative relationships are used between present-day vegetation distribution and climate to explain the pattern of present-day vegetation. The use of such correlative relationships to predict future vegetation distribution will be unreliable if the correlation structure among different components of climate and plant distribution are themselves altered by changes in climate. There is some evidence that this is the case.

f) We do not know how increased $[CO_2]_a$ per se influence the response of a given species to a change in climate.

g) We are confident that the global mean $[CO_2]_a$ has been increasing for the past 200 years and will continue to do so for the next century. We are also confident that by the end of the 21st century $[CO_2]_a$ will approximate to 600–700 $\mu L$L$^{-1}$. We also know that vegetation does respond to a change in $[CO_2]_a$ of this magnitude. Therefore it appears warranted to focus attention upon vegetation responses to changes in $[CO_2]_a$ until we can reliably predict climate change at the regional scale.

h) Vegetation distribution is influenced substantially by the occurrence of extreme events (floods, gales, fires, extreme frosts, prolonged droughts). Whilst there are early indications that the frequency and intensity of such extreme events may increase in the future, reliable regional predictions are unavailable.

We do not wish to imply that climate change per se will not have a significant impact upon plant growth and distribution. However, with the limitations outlined above, we feel it more productive to focus attention upon detailing the responses of plants to an increase in $[CO_2]_a$. Furthermore there is far more effort being directed to climate change research per se than vegetation responses to elevated $[CO_2]_a$ and we are attempting to address this imbalance.

Rapid, small-scale responses of plants to increased $[CO_2]_a$

Small-scale (cellular, leaf, rapid (hours, days)) responses of plants to increased $[CO_2]_a$ have been investigated in a range of annual and perennial plants. These data have been extensively reviewed recently (Eamus & Jarvis 1989; Eamus 1991b; Long 1991). Consequently only a brief overview will be presented, with emphasis given to the some of the most recent data.

The study of plant responses to elevated $[CO_2]_a$ at the small-scale have focused largely on four areas, namely, carbohydrate status, assimilation rate, stomatal conductance, and respiration.
Carbohydrate status

In an early study, Delucia, Sasek and Strain (1985) showed that cotton plants grown at 675 or 1000 μL L⁻¹ had 72% and 115% more dry weight respectively than plants grown at 350 μL L⁻¹. This increase was partially attributed to increased starch accumulation in plants grown under elevated [CO₂]ₐ. The diurnal pattern of starch accumulation and loss was also altered. Such accumulation of starch by plants grown at elevated [CO₂]ₐ has been frequently observed (Ehret & Jolliffe 1985a, b) and has been proposed as a major cause of decreased assimilation rate under conditions of elevated [CO₂]ₐ. The accumulation of starch in leaves has been taken by some to reflect conditions of source strength exceeding sink demand, for photoassimilate (Ehret & Jolliffe 1985b; Eamus & Jarvis 1989).

More recently, Rowland-Bamford et al (1990) investigated the response of carbohydrate status and partitioning of carbon in response to elevated [CO₂]ₐ in rice. They observed that during vegetative growth leaf sucrose and starch concentrations increased with increasing [CO₂]ₐ up to 500 μL L⁻¹ and then reached a plateau. The ratio of starch to sucrose concentration was positively correlated with [CO₂]ₐ. At maturity, increasing [CO₂]ₐ resulted in an increase in non-structural carbohydrate concentration in leaf blades, leaf sheaths and culms, but there was no effect on the carbohydrate concentration in the grain at maturity. Interestingly, increased starch accumulation in leaves was not associated with a decline in leaf assimilation rate, possibly due to enhanced export from the leaf. It would appear that elevated [CO₂]ₐ need not always result in starch accumulation with a concomitant negative impact upon assimilation.

Wong (1990) has provided a detailed analysis of growth and carbohydrate accumulation for cotton grown under conditions of elevated [CO₂]ₐ at different levels of nitrogen nutrition. He observed that non-structural carbohydrate accumulation (mostly starch) increased with increased [CO₂]ₐ, and that this accumulation increased at low levels of nitrogen nutrition. He makes the important point that different interpretation can be given of dry weight changes in response to elevated [CO₂]ₐ depending on whether total dry weight or structural dry weight is used. When structural dry weight was used the enhancement of dry matter yield by elevated [CO₂]ₐ was reduced. Elevated [CO₂]ₐ was also found to alter the pattern of carbon partitioning, such that at ambient [CO₂]ₐ shoot-root ratios decreased with plant age, whilst the ratio increased for plants grown with elevated [CO₂]ₐ.

A more detailed analysis of the impact of elevated [CO₂]ₐ upon carbohydrate pool sizes, fluxes and regulation, is required if we wish to understand the mechanisms underlying plant growth responses.

Assimilation responses

The assimilation rate (Pn) of an individual leaf is given by:

\[ Pn = \frac{g_{s} (C_{a} - C_{i}) - (C_{i} + C_{a}) E}{2} \]

where \( g_{s} \) = stomatal conductance to CO₂,
\( C_{a} \) = [CO₂]ₐ,
\( C_{i} \) = CO₂ concentration inside the leaf,
\( E \) = transpiration rate

Thus as \( C_{a} \) increase the gradient of CO₂ concentration between the inside and outside of the leaf is increased. Diffusion of CO₂ into the leaf increases and so Pn increases, despite a general decrease in stomatal conductance (see below).

In most cases studied, Pn increased in response to increased [CO₂]ₐ in annual crops and tree species. For crop species, the range of increase in Pn is approximately 30 to 100% (Cure & Acock 1986; Lawlor & Mitchell 1991) whilst for tree species the mean is approximately 25% with a range from 0 to 210% (Eamus & Jarvis 1989). However these means do hide the fact that for both tree and annual crop species, several studies have reported a significant decrease in Pn. Thus Phaseolus vulgaris (Ehret & Jolliffe 1983), cotton (Delucia et al 1985), Populus euramericana (Gaudiiere & Moussseau 1989) and Ochroma lagopus (Oertbauer et al 1985) have shown a decline in Pn following growth at elevated [CO₂]ₐ.

It has been observed in some studies that the magnitude of the stimulation of Pn resulting from growth at elevated [CO₂]ₐ declines with time. Thus, the weighted average short-term stimulation of carbon exchange rate for a range of C₃ crop species was found to be 52%, whilst for acclimated plants the stimulation was 29% (Cure & Acock 1986). Similarly Tolley and Strain (1984a,b) have shown that the rate of net assimilation of Liquidambar styraciflua and Pinus taeda declined as the duration of the experiment increased, particularly at high photon flux densities. The results from such longer-term studies may indicate problems with experimental protocol or may reflect the existence of real feed-back mechanisms that operate to limit assimilation rate in the long-term.
The increase in Pn is generally ascribed to several causes. First, elevated [CO$_2$]$_a$ results in an increase in substrate concentration for ribulose bisphosphate carboxylase-oxygenase (Rubisco), the primary carboxylating enzyme involved in the C$_3$ photosynthetic pathway. Second, a decrease in photorespiratory loss of carbon due to the increased CO$_2$:O$_2$ ratio resulting from increased C$_1$. Finally, the activation state of Rubisco may be enhanced by elevated [CO$_2$]$_a$. However, in a recent detailed study of five crop species, the activation state of Rubisco was found to decline following transfer to elevated [CO$_2$]$_a$ in all five species (Sage et al 1989). Interestingly, Besford et al (1990) have found that growth of tomato at 1000 μL·L$^{-1}$ did not alter the amount or activity of Rubisco, but did accelerate the normal ontogenetic decline in these parameters. Vu, Allen and Bowes (1987) observed that growth of soybean under elevated [CO$_2$]$_a$ resulted in a reduction in the total extractable Rubisco activity. Reductions in total Rubisco content of leaves under conditions of elevated [CO$_2$]$_a$ may reflect the occurrence of adjustment of allocation of nitrogen away from the CO$_2$ fixation enzyme towards ribulose bisphosphate regeneration and/or light capture and electron transport processes, i.e. the allocation of a limited resource (nitrogen) to the steps in the assimilatory pathway that limit the rate of carbon assimilation.

Several explanations for the decline in Pn observed in some studies have been proposed. Thus the accumulation of starch that has been observed in some species (Delucia et al 1985; Ehret & Jolliffe 1985; Wong 1990) has been proposed as a major cause of reduced Pn under conditions of elevated [CO$_2$]$_a$. In extreme cases the accumulation of starch has been observed to cause physical disruption of the chloroplasts (Wulff & Strain 1982). The observed decline in Rubisco content and/or activity (see above) may contribute to a decline in Pn. Finally, increased sequestration of phosphate in sugar phosphates or an inability of the Calvin cycle to regenerate ribulose bisphosphate have been proposed as possible causes of the decline in Pn (Eamus & Jarvis 1989).

**Stomatal conductance responses**

Stomatal conductance responses to elevated [CO$_2$]$_a$ are generally less variable than the response of assimilation. In a series of reviews, conductance has been shown to decline by 10–60% in a range of tropical and temperate tree species (Eamus & Jarvis 1989), and 20–80% in a range of C$_3$ crop plants (Cure & Acock 1986). For a recent review of stomatal responses to [CO$_2$]$_a$, the reader is referred to Mott (1990).

The mechanism by which [CO$_2$]$_a$ influences stomatal conductance remains debated. At least four mechanisms have been postulated in recent years. Raschke (1977) proposes that [CO$_2$]$_a$ determines the amount of malate in stomatal guard cells (fixed via phospho-enol pyruvate carboxylase) which in turn determines guard cell pH and the rate of ion leakage from the guard cells. In the absence of detailed knowledge of the carbon metabolism of guard cells it is difficult to evaluate this hypothesis (Mansfield et al 1990).

Edwards and Bowling (1985) have proposed that CO$_2$ acts directly upon the H$^+$ pump of the guard cells. However after a detailed analysis of guard cell membrane potential changes induced by changing [CO$_2$]$_a$, Blatt (1987) was unable to substantiate this view. Blatt (1987) concluded that [CO$_2$]$_a$ may act via changes in guard cell apoplastic pH.

Zeiger (1983) has proposed that [CO$_2$]$_a$ acts via the modulation of rates of photophosphorylation. Such a mechanism cannot operate in the dark. However changes in [CO$_2$]$_a$ influence guard cell ATP levels via changes in oxidative phosphorylation (Shaiash et al 1989). At present it is not possible to decide whether changes in [CO$_2$]$_a$ cause a decline in stomatal conductance by one or more of these mechanisms, or via an as of yet undetermined mechanism.

It should be noted that whilst changes in [CO$_2$]$_a$ are experimentally induced, guard cells respond to the concentration of CO$_2$ inside the leaf.

Several recent studies have shown that stomatal density can change in response to increased [CO$_2$]$_a$. Thus Oberbauer et al (1985) observed a decreased stomatal density in response to elevated [CO$_2$]$_a$ for one of two tropical tree species studied. Similarly, Woodward (1987) concluded that a decline in stomatal density has occurred in a range of species over the past century in response to elevated [CO$_2$]$_a$.

**Respiration responses**

Growth is the net accumulation of dry weight by plants. A given percentage increase in assimilation rate may not necessarily result in an equal increase in growth rate since respiration and photorespiration change in response to a change in [CO$_2$]$_a$. For a recent discussion of respiration and elevated [CO$_2$]$_a$, the reader is referred to Amthor (1991).

The response of respiration to increased [CO$_2$]$_a$ is variable. It is often difficult to compare directly the
data from different studies due to specific methodological differences. For example, measurements have been made on isolated cells, individual organs, whole plants and plant communities and it is often unclear as to whether measurements are based on the dry weight of individual leaves/the entire shoot or the entire plant. Plant growth history differs in many instances and this has an impact upon respiration responses.

Plants grown at elevated \( [\text{CO}_2] \) have shown both increased respiration rates (R) (Gifford 1977; Azcon-Bieto & Osmond 1983; Gifford et al 1985; Nijs et al 1989) and decreased R (Gifford et al 1985).

The results vary according to the method of presenting the data. Thus Bunce (1990) has shown that in the short-term, the ratios of the rates of respiration, measured at 35 Pa \( [\text{CO}_2] \) versus the rate measured at 70 Pa \( [\text{CO}_2] \), was higher for 5 of the 6 combinations of 3 species x 2 \( [\text{CO}_2] \): \( \text{(Amaranthus hypochondriacus x 35 or 70 Pa \( [\text{CO}_2] \); Lycopersicon esculentum, both \( [\text{CO}_2] \); Glycine max, significant decline at 35 Pa \( [\text{CO}_2] \), only for plants grown at the lower \( [\text{CO}_2] \).}

In longer term responses, R measured at 70 Pa \( [\text{CO}_2] \) was higher for the high \( [\text{CO}_2] \) grown \( G. \ max \) but no effect was observed for the remaining two species, when \( R \) was expressed per unit leaf area (Bunce 1990). However, when \( R \) was expressed per unit dry mass, a lower \( R \) was observed for \( L. \ esculentum \), but no significant effect was observed for the other two species. When whole plant \( \text{CO}_2 \) efflux rates were calculated at the end of the dark period, all three species showed a reduction in whole plant \( R \) when grown under conditions of elevated \( [\text{CO}_2] \).

It was proposed that the enhanced \( R \) per unit leaf area for \( G. \ max \) grown under elevated \( [\text{CO}_2] \), resulted from increased leaf carbohydrate storage. The contrast between leaf and whole plant \( R \) may reflect the inhibition of whole plant \( R \), resulting from an enhanced inhibition of \( R \) of stems and roots (Bunce 1990). Much of the available data suggests that whole plant \( R \) is related to either relative growth rate or rate of assimilation (Bunce 1989). However the data presented by Bunce (1990) are not consistent with either of these relationships, possibly because the assumptions inherent in these relationships are not valid under conditions of elevated \( [\text{CO}_2] \). Thus, carbohydrate pool size may vary significantly over a 24 hour period, and plants under elevated \( [\text{CO}_2] \) may synthesise and store different carbohydrates. For a more detailed discussion of this see Bunce (1990).

Bunce and Caulfield (1991) studied the respiration rate of \( Dactylis glomerata \), \( Lolium perenne \) and \( Medicago sativa \) in controlled environment chambers and field plots. They observed that in controlled environments, \( R \) per unit biomass were 30-40% lower in elevated \( [\text{CO}_2] \) chambers for \( L. \ perenne \) and \( M. \ sativa \) at similar relative growth rates. No effect was observed for \( D. \ glomerata \). In the field \( M. \ sativa \) plots showed a 15% decline in \( R \) per unit ground area, despite the total biomass being higher in the elevated \( [\text{CO}_2] \) treatment. Field plots of \( D. \ glomerata \) had higher biomass, but no change in the rate of \( \text{CO}_2 \) efflux. Thus, in all cases studies, respiratory \( \text{CO}_2 \) efflux was reduced at elevated \( [\text{CO}_2] \), relative to the biomass accumulated. It was concluded by Bunce and Caulfield (1991) that all three species either had a higher growth conversion efficiency or lower maintenance respiration rates under conditions of elevated \( [\text{CO}_2] \).

Techniques for assessing the long-term, larger-scale response of vegetation to elevated \( [\text{CO}_2] \)

There are three major techniques available to address the question: what is the long-term, large-scale response of vegetation to elevated \( [\text{CO}_2] \)? These are (a) field fumigation facilities, including open-top chambers, closed-top chambers and chamber-less fumigation techniques; (b) branch-cuvette experiments, and (c) modelling of vegetation responses.

Field fumigation techniques and results have been recently reviewed by Lawlor and Mitchell (1991). The use of chambers lacking tops (open-top chambers — OTCs) with a high flow rate of \( \text{CO}_2 \) enriched air through them has the important advantage that temperatures within the chamber can be kept very close to ambient throughout the experimental period. This is important since growth is temperature sensitive. However, this method does suffer from the fact that the cost of \( \text{CO}_2 \) is very high due to the high flow rates of air needed. Furthermore high velocity wind continuously applied over the experimental plants does increase evaporative demand above that experienced by the rest of the crop in a field situation. However OTCs do allow the manipulation of temperature within the chambers by varying the flow rate so that the interaction of temperature and elevated \( [\text{CO}_2] \) can be studied. Such studies have recently been highlighted as an area requiring additional study (Eamus 1991). The use of climate controlled closed field chambers is cheaper in terms of \( \text{CO}_2 \) costs, but temperature and vapour pressure deficit control.
systems do require a certain level of sophistication of feed-back control. However the technology is readily available and has been applied extensively.


The use of chamber-less fumigation has only recently been attempted. Temporal and spatial control of \([\text{CO}_2]_a\) is a major problem with this technique. Essentially \(\text{CO}_2\) is injected into the atmosphere at a height appropriate for the canopy under study. \([\text{CO}_2]_a\) is monitored within the canopy and the rate of injection of \(\text{CO}_2\) into the atmosphere varied according to the degree of deviation from the set point. Spatial and temporal variation arising from changes in wind profiles and vegetation structure do pose technical difficulties but these are slowly being overcome. This technique has the benefit that there are no changes in micro-climate around the plants due to the absence of a chamber. Little work has been published to-date using this technique.

Experimental manipulation of \([\text{CO}_2]_a\) around annual crops and grasslands is considerably easier than around large trees. Wong and Dunin (1987) have shown that OTCs can be applied to trees, and recent work with ozone fumigation and forest trees has also shown the technique to be applicable.

A recent development has been that of the use of 'branch-cuvettes', where an entire branch of a mature tree is enclosed in a giant cuvette, which may or may not have associated climate control systems. This technique has several advantages over that of the use of growth rooms. First, mature tissue is available for study in the natural micro-climate of a branch in a forest. However there are questions pertaining to the extent to which an individual branch can be considered in isolation from the rest of the tree. Thus, one branch under conditions of elevated \([\text{CO}_2]_a\) with the rest of the tree under ambient conditions may be expected to have different source-sink relationships from that of entire trees under conditions of elevated \([\text{CO}_2]_a\). This is especially pertinent when it is noted that changes in source-sink relationships probably have a major impact on carbohydrate partitioning, growth and assimilation responses to elevated \([\text{CO}_2]_a\). The authors are not aware of any published work that is based upon the use of branch-cuvette techniques.

Long-term, large-scale responses of vegetation to elevated \([\text{CO}_2]_a\)

Data from large-scale, long-term studies have been reviewed recently (Jarvis 1989; Eamus 1991b; Lawlor & Mitchell 1991). Consequently only a brief consideration will be given here.

In a review of temperate tree species, Eamus and Jarvis (1989) showed that assimilation was increased, on average, by approximately 30% for young, acclimating seedlings. Exceptions were noted, however, and in some cases it was shown that stimulation of assimilation declined with time (Eamus & Jarvis 1989). Lawlor and Mitchell (1990), in a review of field studies (which typically encompass all or most of the growing season for annual crops and therefore may be considered long-term studies), show that the capacity of the photosynthetic system is sufficient to allow a significant (30-100%), rapid and sustained increase in net assimilation rate. However, there remains a substantial body of data for annual crops that show that the increase in assimilation rate declines with time of exposure to elevated \([\text{CO}_2]_a\) (Sage et al 1989; Besford et al 1990).

Ziska et al (1990) studied mono-specific communities of a \(\text{C}_3\) sedge (\(\text{Scirpus} \text{olneyi}\)) and a \(\text{C}_4\) grass (\(\text{Spartina} \text{patens}\)) in situ in a tidal marsh. They observed that the \(\text{C}_3\) sedge maintained a significant stimulation of assimilation throughout the two year experimental period, whilst the \(\text{C}_4\) grass showed an increase at the start of the second growing season only. The degree of stimulation of assimilation was increased at higher temperatures.

Growth responses to elevated \(\text{CO}_2\) have been recorded for a range of annual and perennial species. Cure and Acoc (1986), in a detailed literature survey, show that the weighted average increase in biomass accumulation in response to elevated \([\text{CO}_2]_a\) for a range of crop species was 30%, with a range from -15% to 84%. More recently, Lawlor and Mitchell (1991) refer to field trials which show that \(\text{CO}_2\) doubling increased cotton biomass by 82%. For soybean, biomass increased by 39% (Cure & Acoc 1986), 22% (Rogers et al 1986), or 78% (Rogers et al 1983).

Field results are thus highly variable, influenced as they are by soil and local biotic and abiotic factors. For trees, a similar variation in growth response is observed. The median growth response for a range of coniferous and broadleaf species is approximately 40%, with a range from 20 to 120% (Eamus & Jarvis 1989). However, for community response
considerations it is pertinent to ask the question: to what extent do experiments conducted with isolated plants grown in individual pots reflect the response of the same species in a mixed species field system? Because of this question more and more work is being conducted at the community level. This is clearly easier for short vegetation types (grasslands, tundra).

Gruiske et al (1990) have studied whole ecosystem CO₂ flux for control and elevated [CO₂]₄ environments in situ for an Alaskan Eriophorum tussock tundra. Elevated [CO₂]₄ resulted in greater carbon acquisition than control treatments (for which there was a net loss of carbon over the growing season). The initiation of a positive carbon budget for the ecosystem was brought forward and the onset of dormancy was delayed by growth with elevated [CO₂]₄. However homeostatic processes appeared to develop which greatly reduced the initial large stimulation of assimilation observed early in the season for elevated [CO₂]₄. These authors predicted that little, if any longterm stimulation of ecosystem carbon acquisition by increased atmospheric [CO₂]₄.

In a 90 day experiment the response of 2 deciduous forest tree communities was studied (Williams et al 1986) in a mixed species design. Three species from a well-drained upland forest and three species from a bottomland forest were studied with three CO₂ levels and two light regimes. Competitive interactions were influenced by increased [CO₂]₄ such that the relative proportion of biomass of each species changed, although the total community biomass was little affected. Low light conditions were particularly important in influencing the outcome of competition. Seedling competition generally occurs in many forests under conditions of limiting light flux density.

In a study of two tropical species (a pioneer species, Ochradra lagopus and a climax species (Pentaclethra macroloba), Oberbauer et al (1985) showed that a doubling of [CO₂]₄ resulted in a greater enhancement of growth of the early successional species than the climax species, a result attributed to the greater allocation of biomass to leaf tissue and a higher rate of assimilation in the pioneer species.

It is clear from the longer-term, larger-scale studies that the magnitude of the stimulation of assimilation and growth observed in the early, small-scale short-term studies has not been maintained (Eamus 1991). This may reflect the lack of maintenance of a continued sink for fixed carbon, or may reflect poor growth conditions that prevailed in the early experiments with pot grown seedlings (Eamus & Jarvis 1989). However, although the magnitude of the change may be reduced it is clear that in both mono-specific experiments and mixed species community studies, elevated [CO₂]₄ does have a rapid long term impact upon growth (both in terms of absolute growth rate and biomass partitioning between plant organs).

Modelling large scale vegetation responses

Fumigating entire trees is possible and has been undertaken (Wong & Dunin 1987). The fumigation of several trees together, whilst technically possible, is excessively expensive. The fumigation of entire stands and communities of plants will probably never be undertaken. Consequently we have to use models to address the question — what is the regional response of vegetation to elevated [CO₂]₄?

Two sets of models are currently in use. The first are models of canopy processes (assimilation, transpiration). The second are models of population dynamics, treating the community as an assemblage of individuals and/or species. Models can be further sub-divided according to whether they are 'top-down' or 'bottom-up' models (Eamus 1991b). There are several models currently being used to predict changes in vegetation distribution in response to climate change per se. For example, Solomon (1986) modelled the temporal response of forests to CO₂ induced climate change for eastern North America. He showed that a distinct dieback occurred in response to changes in monthly temperatures and precipitation. In the southern range of today's deciduous-coniferous transition forests, dieback was less pronounced and deciduous recovery was rapid. In more northerly transition areas, dieback was more pronounced and conifers suffered the most. Importantly, transient responses in species composition and carbon storage continued for up to 300 years after the simulated climate had ceased changing. For a discussion of vegetation modelling and climate change the reader is referred to Rosenzweig and Dickinson (1986).

Current state-of-the-art models of vegetation growth and population dynamics reveal the paucity of data derived from plant material acclimatised to elevated [CO₂]₄ that has been incorporated into simulations of vegetation responses to either climate change or elevated [CO₂]₄. For further discussion of this point the reader is referred to Jarvis (1989). Furthermore it is apparent that we are unable to include more than a very limited number of processes and interactions that are known to have an impact upon plant population dynamics. Thus we have few models that take into account changes in
plant architecture, biomass partitioning, plant responses to climate and regional water use efficiency induced by increased [CO$_2$]. However, on a more positive note, the output of simulation models do show that significant changes in plant biomass, ecosystem species composition and age structure. They also indicate that plants on the edge of their distribution will be more sensitive to changes in climate or [CO$_2$]. Therefore we should look to such species as indicators of change. Models also indicate that different forest types differ in their response to climate change. Interestingly, the lag phase in the response of forests to climate change can be greatly reduced and major changes in species composition can occur more rapidly if periodic disturbances occur. In the NT, periodic disturbances include fire, drought, and cyclones. We may therefore expect that the NT vegetation will undergo more rapid change than the more stable ecosystems of temperate Europe and USA.

**Conjectures on the NT vegetation response to elevated [CO$_2$]**

**A brief summary of the floristic composition and structure of the Northern Territory**

The floristic composition and structure of the vegetation of the Northern Territory (NT) is determined on a broad geographical scale by the latitudinal rainfall gradient. The northern portion of the region is characterised by strongly seasonal rainfall, with more than 90% of the annual precipitation occurring during the period October–March. The environment becomes increasingly arid towards the southern part of the region. Two floristic sub-kingdoms occur in the NT (Doig 1981). The Eucalyptus sub-kingdom north of about 18°S is represented by the Northern Savanna Region, while the Central Australian sub-kingdom in the NT includes two regions, the Mulga and Desert Regions.

The dominant vegetation types in the north of the NT are comprised of a continuum of Eucalypt dominated open forests and woodlands. This vegetation continuum has been classified by different researchers at a range of scales into a variety of different vegetation types according to structural and floristic variables (Wilson et al 1990, Duff et al, Chapter 9 in this volume). At a scale of 1:1 000 000, Wilson et al (1990) recognised six classes of Eucalypt dominated open forests, woodlands, low woodlands and low open woodlands in the lowlands and a further two classes of Eucalypt dominated communities in sandstone escarpment. Other important vegetation types in the north of the NT are Mangroves (low closed forests), Samphire (low shrubland), lowland and escarpment rainforests (closed forests), seasonal floodplains and Melaleuca forests.

Eucalypts are replaced by Acacias as the dominant taxa to the south of the territory. Whilst full climatic deserts are almost absent from Central Australia, the NT does contain substantial areas of sparsely vegetated, treeless areas consisting of sandhills, sandplains, salt lakes and gibberplains. The mulga regions to the north and west of the NT desert region are structurally and floristically more diverse. Vegetation structure varies from tussock and hummock grassland to tree and shrub deserts.

Any attempt to predict the response of the NT vegetation to elevated atmospheric [CO$_2$] is confronted by a major problem. Work on NT vegetation responses began in April 1991, with construction of a fumigation facility at the Northern Territory University in Darwin. No data is available at present. The following discussion is based on extrapolation from experiments and theory that are not directly concerned with the unique climate and flora of the NT.

Whilst we wish to focus on the impact of elevated [CO$_2$] _per se _upon NT vegetation, it is of value at this point to summarise the conclusions that have been reached about the likely climate of the NT in the year 2030. These conclusions have been reached after the Conservation Commission of the NT commissioned the CSIRO to model the climate of the NT in the 21st century. A recent annual report (Pearman & Mitchell 1990) issued by the Climate Impact Group of the CSIRO Division of Atmospheric Research has concluded that the average surface temperatures in all seasons will, by 2030, have increased relative to the 1980s by 1–2 °C in northern coastal areas, and by 2–4 °C inland. Summer rainfall is expected to increase in tropical NT by approximately 10%. Flash floodings may increase in frequency.

Global sea-levels are expected to increase in the range of 10–50 cm by 2050. El Nino-Southern Oscillation phenomena are likely to change, as is the frequency and intensity of tropical cyclones. These later considerations are perhaps the least understood phenomena and the furthest from reliable prediction. However, if we take these statements at face value we can tentatively suggest the following vegetation changes:

a) fire frequency, intensity and timing may change.

This is because (i) mean temperature has
increased, thereby increasing the likelihood of fires; (ii) increased summer rainfall may extend the period of plant growth further into the dry season due to increased soil water content, thereby increasing the total combustible material (fuel load) that is present when the first fires occur. Increased soil water availability and plant growth prolonged into the dry season may delay the onset and reduce the intensity of the first early season fires. Since it appears that fire is a major determinant of the vegetation structure of much of the NT, any change in fire regime may be expected to have a major impact upon vegetation structure and distribution. It is difficult to predict the outcome (in terms of vegetation structure) of the competing effects of a delay in the start of the dry season fires with the increased fuel load that may be present towards the end of the growing season. Furthermore, as discussed in (b) below, the change in [CO₂]₄ and water availability may lead to an increase in the proportion of biomass present as trees.

b) The vast majority (>90%) of grasses in the NT show the C₄ photosynthetic pathway. These plants do not respond to an increase in [CO₂]₄. In contrast the trees of the NT are all C₃ species and thus respond to increased [CO₂]₄. With increased rainfall and elevated [CO₂]₄, it is tentatively suggested that the present balance in the NT savannas between grasses and trees will shift towards favouring trees. Any increase in tree biomass may be accompanied by a decline in grass cover. This would be expected to reduce the intensity and possibly the duration of fires since the majority of the fuel load is grass. This will have a positive feedback effect upon the increase in tree biomass since frequent fires act to hold back growth and establishment of tree regeneration and mid storey woody species.

c) Increased sea-levels, coupled with increased rainfall will influence the major drainage systems of the NT, (for example the Adelaide, Alligator, Mary and Daly rivers). It is suggested that Mangroves will move inland, and the total area of floodplains may decrease. Increased saltwater incursions to lowlands will favour the salt tolerant Mangroves and sea grasses whilst the freshwater tolerant species will move inland or disappear.

d) Species that are on their edge of distribution should respond sooner than species in the middle of their distribution.

e) The vegetation of northern NT may undergo more rapid change than that of temperate Europe, USA, or southern Australia due to the presence of intense, periodic, wide-scale disturbance (fires, drought, floods, and cyclones).

Research priorities for the future

The following are clear research priorities for tropical Australia.

a) Investigate the response of tropical native and commercial trees to elevated [CO₂]₄;

b) Investigate the interactions between elevated [CO₂]₄, increased temperature and increased water availability upon native grass and tree growth and plant water use efficiency;

c) determine the direction, nature and extent of any changes in the competitive balance between native trees and grasses in the NT.

d) monitor seasonal and annual changes in atmospheric concentrations of ozone and methane in the NT to establish whether the NT constitutes a significant source of these radiatively absorbent gases.

These projects could be undertaken over a 5 year timescale at a cost of $350,000 per year. In view of the amount of Australia that is tropical, and in view of the paucity of data that relate to tropical vegetation in Australia and indeed world-wide, and in view of the pristine nature of much of the vegetation of the NT, this would appear a reasonable cost.

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CHAPTER 17

TOWARDS A VEGETATION MANAGEMENT STRATEGY FOR THE NORTHERN TERRITORY

FJ Van der Sommen

Introduction

The vital role that native vegetation plays in sustainable land use has wide recognition in the community at large. It is constantly raised in forums dealing with land degradation, ecologically sustainable development and biodiversity. It has given rise to a number of vegetation management support programs such as 'Save the Bush', the 'Billion Trees' program and 'Landcare' all of which recognise the need to restore and maintain native vegetation cover for both ecological and economic reasons.

The Northern Territory is fortunate to have native vegetation cover which is still extensive in both area and variety providing an opportunity for pro-active planning for the maintenance of this important resource. The type and extent of this vegetation has recently been mapped and documented by Wilson et al (1990). The major structural groups identified are summarised in Appendix 1.

Only about 2% of this vegetation has been cleared. The remainder is, however, under pressure from a wide range of disturbances associated with land use which places this vegetation under varying degrees of stress. These pressures are likely to increase as development continues and, when combined with natural forces, such as climatic change, drought or fire may, in some circumstances, contribute to localised catastrophic decline. Massive deaths of Melaleuca stands on the coastal floodplains provide a timely warning for this.

A vegetation management strategy, based on such understanding, provides the basis for facilitating the integration of vegetation with all forms of land use. Such a strategy specifically needs to recognise the role and value of vegetation and the nature, impact and consequences of natural and human induced stress on this.

The functions of vegetation

A number of intrinsic values of vegetation are recognised. These are summarised in Table 1. The formal recognition of some or all of these functions or values are integral to the formulation of management goals for vegetation management.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Value of vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCTION — of food, fodder, timber, fibre, chemicals, oils</td>
<td></td>
</tr>
<tr>
<td>CONSERVATION — of species, communities, habitats, gene pool</td>
<td></td>
</tr>
<tr>
<td>PROTECTION — from wind, water, solar radiation, for land water, biota, people</td>
<td></td>
</tr>
<tr>
<td>INFORMATION — for aesthetics, research, education</td>
<td></td>
</tr>
<tr>
<td>ASSIMILATION — of solar radiation, excess water, gases</td>
<td></td>
</tr>
</tbody>
</table>

Production value

The importance of native vegetation as a source of food and medicine for Aboriginal use in the Northern Territory is well established and documented by Barr (1988) and by further work currently being conducted by the Conservation Commission of the Northern Territory (G Wightman, pers comm).

The intrinsic value of some 180 species of native plants as a source of food and medicine for Aboriginal use has been evaluated and recorded by the Northern Territory Department of Health.
This information is recorded on the botanical data base, ALICE, within the Conservation Commission of the Northern Territory (CCNT).

Investigations are being conducted at the Northern Territory University on the more detailed chemical composition of native flora (David Penn, pers comm).

Detailed analysis of Acacia seeds by Brand and Maggiore (in press) are also significant. These indicate that on average Acacia seeds are about 23% protein, 26% available carbohydrate, 32% fibre and 9% fats. These have the potential for further development as a food source.

The potential of native plants to produce wood products ranging from firewood to timber has also been evaluated in the Northern Territory during the last 20 years. Indications are that severe limitations are imposed by poor soils, climate and termites and only a few species restricted to limited landscapes have any commercial potential. Scope however exists for further evaluation of species and appropriate silvicultural systems to overcome ecological limitations. Many of the Acacias, such as Acacia auriculiformis, as well as a number of rainforest and arid zone species are recognised to have high value as speciality timber species. Tree breeding work and the establishment of seed orchards on Melville Island jointly by the Australian Tree Seed Centre (ATSC), CCNT and Melville Forest Products are providing valuable information on the genetic potential of such native plants, particularly for seed production.

Many native grass species, herbs and perennial broadleaved plants are used as fodder for cattle and are of vital importance in maintaining this industry both in the arid zone and in the tropics. Grasses of the genera Enneapogon, Aristida, Digiaria and Enteropogon form a major part of the cattle diet in central Australia (Foran 1984).

The full genetic potential and management requirements of these well adapted species and communities to meet future demands for food, medicine, fibre, structural material and other products, which will ensure self sufficiency for Northern Territory communities, require ongoing evaluation.

Conservation value

Both communities and species of plants have intrinsic conservation values associated either with their unique status, their scarcity or because of their value as a genetic resource irrespective of the contributions made to the habitat of other species.

Many of the species growing in the Northern Territory are endemic and therefore have high conservation value requiring protection. A large number of vulnerable species such as the palm Psychosperma bleeeri occur in scattered remnant rainforests restricted by moisture and fire to favourable micro-environments. These occur in gorges, along water ways in floodplain depressions and along escarpments. Others occur in habitats where access by grazing animals is restricted or a particular set of environmental factors favour the species. These and other communities provide vital habitat, in part or in whole, for fauna increasing their conservation value. The factors threatening these species and the communities of which they are a part, have been discussed by Russell-Smith & Bowman (1991) (see also chapters 8 & 9 in this volume — eds). These highlight the need for landscape based management strategies to protect them.

Land protection value

Many of the soils and landforms constituting the landscape in the Northern Territory are sensitive to environmental perturbations associated with storms, fire and other potentially catastrophic events. In the tropics clearing of vegetation, even on slopes of low gradient, can lead to severe soil loss (M Dilushad, pers comm 1990). In the arid zone, both wind and water contribute to soil movement and associated land degradation. Native vegetation in these environments has evolved to cope with climatic, edaphic and pyric stress with adaptations to recover quickly from disturbance, providing much needed protection for soil. It is the unique adaptability and resilience of such vegetation together with its morphology which makes its retention and management on vulnerable landscapes essential.

Cover provided by vegetation also provides protection against the severity of solar radiation experienced in the Northern Territory. Such values are equally important in pastoral and urban areas.

Information value

Native vegetation has intrinsic value for the purposes of recreation, aesthetics, research and education. Its resource value is in the information it stores. This satisfies basic human needs for pleasure and curiosity, reflected in a growing recreation and tourist industry, as well as providing base line ecological data for sustainable management. The importance of the need to
establish ecological reference areas against which the impacts of intensive land use can be assessed is vital in this regard. This value of vegetation is often under rated. It is only when the value of 'information' is quantified that it will be recognised as a resource requiring management input.

Absorption and assimilation value

The role of vegetation in buffering the harmful effects of excessive solar radiation, water and carbon dioxide, is well recognised. This is strongly emphasised in the National Greenhouse Strategy (ANZEC 1990). The effectiveness of vegetation for this purpose is a function of structure, composition, vigour and successional state and general health. Specific management techniques to maintain or enhance assimilation values of vegetation may be required under some circumstances. (Much fundamental research on the response of vegetation to increased levels of CO₂ is required, see for example Eamus & Duff, chapter 16 in this volume — eds.)

Landscape ecological concepts as a basis for identifying stress and developing management programs for vegetation

In order to manage vegetation for its intrinsic values some basic concepts which form the basis for management need to be addressed.

The concepts

In dealing with the issue of vegetation management in the broader context of land use, it is important to recognise the contribution native vegetation structure, composition, spatial patterns and related processes play in landscape stability, productivity and conservation. This knowledge is important in planning for sustainable development and the maintenance of biological diversity.

In formulating a strategy it is recognised that the value of vegetation varies with the landscape or parts of the landscape in which it occurs.

A landscape ecological approach which integrates these considerations provides a useful framework for the formulation of a vegetation management strategy. The elements of such an approach are summarised in Table 2.

In using this approach it is recognised that the state of vegetation is determined by processes within ecological entities within the landscape which are in turn controlled by processes between such entities. These entities or landscape elements as well as the processes may range from natural to highly modified as a result of human activity.

The consequences of such interactions can contribute to varying degrees of stress which may contribute to a change in the health and vigour of vegetation or some change in its structure and composition with an associated loss in value or function.

TABLE 2 Landscape approach to vegetation management

1. Establish natural and cultural landscape patterns

2. Determine landscape processes within and between patterns:

   Energy transfer
   Solar: heat, light, wind
   Kinetic: wind and water movement
   Pyric: fire movement and combustion

   Matter transfer
   Water: surface and subsurface chemicals and particles
   Air: gases, particles, moisture

   Biotic movement
   Animals: vertebrate and invertebrate
   Plants: macro and microflora
   Micro organisms: bacteria, viruses
   People

3. Assess and evaluate landscape response to processes

4. Manage processes to meet desirable goals

Recognition of stress

Stress resulting from landscape processes finds expression in a number of ways. These include:

- Changes in phenotypic and genotypic diversity
- Changes in area for the maintenance of desired diversity and opportunity for reproduction and evolution
- Death without recruitment of individual plants within communities leading to changes in composition and structure
Towards a vegetation management strategy

- Changes in the composition of other trophic levels such as vertebrates, invertebrates and microbial populations reflecting altered energy fluxes and feedback mechanisms for dampening undesirable fluctuations.

- Modification of the soil structure and chemistry influencing the nutrition and moisture pool and circulation system.

- Changes in the flow and quality of both surface and subsurface water resources, and associated erosion, sedimentation, waterlogging, drought and salinisation.

- Loss of capacity to buffer toxic effects including the capacity to decompose, transfer, chelate or bind toxins within the system.

Processes contributing to stress in vegetation

A number of processes, either individually or collectively, contribute to stress influencing the condition of native vegetation in the Northern Territory. Some of these result from natural causes whereas others result from, or are influenced by, human activity. These are summarised in Table 3.

**TABLE 3 Processes causing stress to vegetation**

**FIRE** — changes in the fire regime of intensity, frequency and duration

**WATER** — changes to the hydrological regime both surface and subsurface flow and storage

**PLANTS** — invasion and colonisation by alien plants

**ANIMALS** — movement and browsing by herbivores, both feral and domesticated

**INSECTS** — predation on seed, foliage, root and stem

**CLIMATE** — changes in precipitation, radiation, wind, its direct impact on vegetation and indirect effect on other processes

**HUMAN ACTIVITY** — clearing, crushing, harvesting, poisoning and direct effect on above processes

A number of these processes are receiving attention and in some cases are being dealt with in the Northern Territory.

**Fire**

Fire regimes, possibly instituted at the time of first human habitation and/or as a result of natural causes such as lightning, appear to have had a major influence in determining the structure, composition and distribution of vegetation communities in the Northern Territory (Griffen et al. 1983; Stocker & Mott 1981). There are suggestions that alterations to fire regimes associated with changes in human attitudes and use of fire, both preventing or altering the time and intensity of burning, have changed vegetation with possible adverse consequences (Bell 1981; Braithwaite & Estberg 1985). This is particularly evident in relation to decline in *Calotis intratropica* forests in the humid tropics (DMJS Bowman, pers comm) and increased woody plants in the more arid areas (Foran 1984).

The precise long-term impact of altered fire regimes is by no means clear and is under investigation in burning trials being conducted at Munmarlasy by the Conservation Commission (Hoare et al 1980; Bowman et al 1988), at Kapalga by CSIRO and those which have been conducted jointly between CCNT and CSIRO in the arid zone (Saxon 1984). Such information is essential if fire control and the use of fire is to satisfy the needs of vegetation conservation and productive use. (See Andersen & Braithwaite, chapter 13 and Cook, chapter 14 in this volume — eds.)

**Hydrological change**

The condition and pattern of vegetation over much of the Northern Territory is to a large extent determined by the availability of water (Bowman & Dunlop 1986; Bowman & Minchin 1987). Changes in both surface and subsurface hydrology associated with climate/sea level change or changes in land forms and land use, such as dams, can, and already have, affected vegetation. This is particularly evidenced by extensive areas of dead and dying Melaleuca forest and associated grasslands on coastal floodplains in the Top End of the NT. The causes are not clear and possibly involve a combination of cyclic sea level change (Woodroffe et al. 1985) and levee damage by Buffalo (Stocker 1970). Works involving embankment construction have been initiated by the Conservation Commission and land holders on the Mary River floodplain to prevent this intrusion. The effectiveness of this has not been fully evaluated.

Changes in runoff associated with land use also have implication for riparian vegetation and are
likely to be significant in arid areas where intensive grazing has altered vegetation cover and subsequent hydrology.

**Competition from exotic plants**

Invasion and subsequent competition by exotic plants pose a constant threat to native vegetation. A recent survey of areas dedicated to conservation found 27 declared weed species and 33 exotic plants which are not weeds (van der Sommen 1991). The most widespread were Hyptis (Hyptis suaveolens), Spiney headed sida (Sida acuta), Khaki weed (Alternanthera pungens), Mossman River grass (Cenchrus echinatus), Caltrop (Tribulus terrestris) and Mimosa (Mimosa pigra). Mimosa is spread over an estimated 800 km² of floodplain and poses a serious threat to wetland ecosystems displacing sedges, riparian vegetation, paper bark forests, and monsoon forest communities (Northern Land Council 1991). Tamarisks (Tamarisk aphylla) although not as widespread, pose a similar problem in water courses in the centre with potential for displacing riparian vegetation here (Griffen et al 1989). Many invasions by plants are the consequence of other ecological disturbances which need to be addressed in the first instance.

**Browsing by herbivores**

Herbivorous native wildlife has browsed on native vegetation with minimal apparent adverse impact. More recently introduced feral animals and livestock have imposed severe stress on this native vegetation and the associated environment. This was highlighted in a report by Leuts et al (1979) who identified feral livestock including cattle, donkeys, buffalo, pigs, horses, camels, bali cattle, timor ponies and goats and introduced wild animals including rabbits and deer. The indirect effects of buffalo induced damage on levee banks and subsequent salt water encroachment destroying large areas of vegetation has been mentioned. Grazing and trampling of vegetation has caused severe soil degradation making regeneration difficult. Many such areas are also predisposed to invasion by weed species which are also transported by these animals. These represent the most widespread disturbances to native vegetation in the Northern Territory.

**Insect attack**

Hebivory by insects is widespread in the Northern Territory as it is elsewhere in Australia. Many insect plagues such as Lerps on Red gum (Eucalyptus camaldulensis) are cyclic. The effect of termites is consistent and widespread throughout the northern part of the Northern Territory and affects a wide range of species (Fox 1974). These pose little threat to the conservation and protection value of vegetation which is well adapted to cope with this form of stress. They do however provide a major obstacle to large-scale utilisation of vegetation, particularly for solid timber.

The presence and ecological function of insects need to be recognised in vegetation management.

**Pathological diseases**

Dieback has been reported in Darwin stringybark (Eucalyptus tetradonta) forests on the Gove peninsula. Studies by Weste (1983) suggest that this is due to the root disease Phytophthora cinnamomii. Subsequent isolation of this disease has proved impossible which may be linked to inherent difficulties associated with the techniques used. Dieback has also been noted at Noonamah; the cause has not been established. There are indications that the build up of pathogens may be cyclic or may be associated with ecological disturbances as well as with transport. These matters require investigation.

**Climatic factors**

Climate has a direct and indirect effect on much of the vegetation. The effects of rainfall and solar radiation on plant growth are well established. Climatic extremes such as those associated with cyclones and periods of prolonged low rainfall can place native vegetation under severe stress. Vegetation structures in parts of the cyclone belt of the Top End reflect this stress but are also a testimony to the resilience of vegetation to this. Most of the factors discussed previously are also affected by climate and will therefore alter their influence on the state of vegetation in response to climatic shifts.

**Direct human damage**

The distribution of major land uses in the Northern Territory in terms of area is illustrated in Figure 1.

Apart from grazing, conservation and Aboriginal land use, a number of other land uses exist. These occupy relatively small areas and vary in intensity of disturbance and ecological impact, and include agriculture, mining and urban development.

It is recognised that apart from natural agencies, human activities contribute to the processes described. In addition the use of land directly impinges on vegetation through such activities as cutting, harvesting, clearing, grazing, excavation and poisoning.
FIGURE 1  Land classifications of the Northern Territory
Source: Conservation Commission of the Northern Territory (unpublished).
These vary in intensity and can be arranged as a continuum in terms of the pressures these land uses place on native vegetation resources.

The intensification of land use involves not only increased *in situ* disturbance to vegetation and the growing environment, but also increased input of materials such as chemicals (fertilisers, herbicides) and pollutants such as exhaust gases, with potential side effects on native vegetation. A proposed categorisation of land uses along the intensity spectrum is shown in Table 4.

**TABLE 4 Vegetation disturbance spectrum**

<table>
<thead>
<tr>
<th>Largely undisturbed to pristine vegetation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• conservation and wilderness areas</td>
<td></td>
</tr>
<tr>
<td>• closed water catchments</td>
<td></td>
</tr>
<tr>
<td>• traditional Aboriginal land use areas</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partially disturbed vegetation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• extensive pastoralism</td>
<td></td>
</tr>
<tr>
<td>• passive recreation</td>
<td></td>
</tr>
<tr>
<td>• selective harvesting</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Partially cleared and fragmented vegetation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• rural living areas</td>
<td></td>
</tr>
<tr>
<td>• small scale agriculture/horticulture</td>
<td></td>
</tr>
<tr>
<td>• small scale mining/quarrying</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Altered vegetation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• urbanisation</td>
<td></td>
</tr>
<tr>
<td>• large-scale agriculture/horticulture</td>
<td></td>
</tr>
<tr>
<td>• large-scale mining/quarrying</td>
<td></td>
</tr>
</tbody>
</table>

It should be recognised that there are variations within these land use groups in terms of impact. This structure does however provide a useful framework for management of impact dealing with both area and intensity.

It is significant that the spatial scale of disturbance is often inversely related to intensity; large areas of vegetation generally experiencing disturbance of low intensity and vice versa.

It also needs to be remembered that these disturbances are often interactive in their effects on vegetation. For example, opening up of vegetation through partial clearance increases exposure to wind and increases transpiration. Transpiration is further exacerbated through the softening of foliage by fertiliser application. Such foliage also becomes more palatable to insects, accelerating defoliation. Similarly, selective grazing coupled with fire control or reduced fire intensity resulting from reduced fuel, can and has contributed to a significant shift in the composition of vegetation favouring woody species. This is particularly apparent following good seasons for regeneration (Foran 1984).

Appropriate management practices adopted within the strategy will depend on the extent and condition of existing vegetation as influenced by past land use. Based on the four disturbance categories listed in Table 4, four different levels of management are recommended.

1. Areas with intact, undisturbed vegetation cover

   • with potential for development in the future,
   • with no potential for development,
   • with intrinsic conservation or other values which need to be protected.

   The emphasis here is on evaluation, on a landscape basis, of the intrinsic value of such vegetation as well as its value for landscape protection, and the contribution to sustainable land use production. This involves planning for strategic clearing or retention of vegetation according to both land capability and vegetation importance criteria. It must also allow for fire protection, pest invasion and other adverse effects of damaging agencies.

2. Areas of native vegetation under partial utilisation involving grazing, harvesting or recreation.

   Monitoring the impact of human activity is important here so that the resilience and sustainability of the ecosystems affected can be determined and appropriate management guidelines can be developed. The impact of fire and pest plant and animals responding to disturbance need to be given particular attention.

3. Areas with vegetation partially or wholly cleared or left as remnants and damaged or destroyed to such an extent that rehabilitation is required.

   The aim here is to research the causes and effects of deterioration. This needs to be coupled with research and extension to achieve an effective and efficient rehabilitation program using species appropriate to the altered ecological conditions and community needs.
4. Areas dominated by exotic vegetation either by deliberate or accidental introduction.

Here the stress is on evaluation, research and monitoring of the causes and effects of such introductions to ensure that these are compatible with the environment and meet land use objectives with minimal adverse effects. Procedures for the control of undesirable landscape processes and enhancing other vegetation values will need to be developed.

The objectives are:

To evaluate and collate information on the spatial distribution, area and condition of vegetation. Emphasis will be on native and significant exotic communities of plants.

To identify, through research and monitoring, the causes of stress in vegetation, particularly the variability in time and space, resulting from both natural and human agencies.

To analyse and monitor the short and long term effects of stress, particularly on long-term productivity and other landscape values.

To utilise existing, and further develop appropriate rehabilitation techniques where vegetation has been affected by excessive exploitation, environmental degradation or invasion by exotic biota such as weeds, disease and grazing animals.

To develop appropriate sustainable management strategies to reduce actual or potential stress and maintain desirable processes.

To conduct an extension program for the implementation of management and rehabilitation technology for planners, managers and users.

To undertake monitoring programs for evaluating the effects of rehabilitation and management and feed information back into the management process.

Regional organisation for achieving the vegetation management strategy

For vegetation management to be effective it must be implemented within defined natural landscape boundaries which give expression to the processes to be managed. This combined with existing administrative and cadastral boundaries should form the geographic context for the implementation of the vegetation management strategy. In most cases, particularly in the Top End, a water catchment stratified into upland, floodplain and discharge zone should form the zones for research and management. In more arid areas such boundaries may be less appropriate but are still worth defining. Many landscape patterns and processes associated with vegetation are related to such geomorphic units. Such patterns and processes are dominated by geologic and soil characteristics interacting with vegetation.
They include not only the flow of surface and subsurface water but also such processes as fire, weed invasion and animal movement which can all be studied and managed within this natural framework.

It is recognised that natural boundaries frequently do not coincide with those used for administrative and land use purposes, for example reserves, parks, pastoral leases, Bushfires Council regions, Territory Government administrative regions, Aboriginal lands and mining leases. These boundaries can be accommodated within Geographic Information Systems as a separate overlay and can be utilised in the vegetation management program.

To be effective the strategy will need to be dealt with on a regional basis for administrative purposes and on a catchment or river basin basis for scientific investigation purposes. Catchment boundaries can be based on those identified in Water Northern Territory (1983) a report prepared by the Water Resources Division of the NT Department of Mines and Energy. A list of basins and administrative regions is presented in Appendix 2, and the basins are illustrated in Figure 2. Where parts of basins cover more than one region, cooperative management programs may need to be developed. Within this framework both broadscale and point sources of vegetation disturbance are recognised.

**Action plan for the strategy**

An action plan needs to be established to successfully meet the goals and objectives of the strategy. The framework for such a plan is summarised in Table 5.

Such a plan recognises that knowledge of landscape ecological components and processes operating within a particular land system will always be imperfect because of the dynamic nature of such systems. Management of natural resources will always be based on best possible information at the time. The management strategy must provide for changes in management practices when new information on the state of vegetation comes to light. Monitoring and feedback is vital in providing such information.

**Concluding comments**

All vegetation has some capacity to contribute to all of the values identified. The importance of any one value varies with location, species, life forms and with the nature of the environment and the demands imposed by the community. Some species or communities may not have a high production value but on some sites may more usefully serve a protection role and should therefore be managed accordingly.

It should also be recognised that in some landscapes the replacement of native by exotic vegetation may better satisfy the needs of sustainable land use and development. This needs to be carefully evaluated.

Therefore consistent with a conservation strategy for the Northern Territory, a draft of which has been released for comment (CCNT 1992), a vegetation management strategy must recognise that management of vegetation needs to ensure that all functions of vegetation in the landscape are objectively considered. This will ensure that development protects the natural resource and maintains options for its future use.

Controlling the processes and maintaining the physical environment or life support systems within which such processes occur is essential to such management.
FIGURE 2  Drainage basins of the Northern Territory
The strategy also recognises the need for maintaining pools of genetic resources in managed reservations, creating flexible opportunities for species movement through the landscape so that colonisation and evolution are not inhibited and the goal of the maintenance of diversity can be achieved.

Vegetation management on a landscape ecological basis specifically recognises these processes, providing appropriate infrastructures for desirable processes to proceed. It also provides a buffer against their adverse effects thereby sustaining the life support system essential for sustainable development.

The realisation of the objectives of the strategy must involve a range of disciplines and agencies concerned both with the analysis of vegetation patterns and processes in the landscape and the interpretation of these for human use. These need to interact with land managers, community groups and the public at large.

To a large extent activities concerned with landscape and vegetation mapping, research into vegetation patterns and processes, rehabilitation, management, extension and education and monitoring are occurring within various government and research agencies. These activities are however spasmodic and somewhat ad hoc requiring closer coordination.

Close cooperation and coordination is particularly required between landholders and managers, relevant agencies involved in land management and research and appropriate community groups using the strategy as a framework. This will lead to greater commitment and effective implementation of the strategy. This is particularly vital in the Northern Territory because of the extent of the vegetation resource and the relatively small population to deal with this. Community involvement can be harnessed through 'Landcare' and through the 'Billion Trees', 'Save the Bush' and the National Soil Conservation programs all of which need to be evaluated in the context of the strategy.

Commitment to vegetation management can be increased through financial incentives. Management of vegetation for protection can be increased if such vegetation has a commercial value. To this end the food, medicinal and other values of native plants which can be cultivated on sensitive landscapes, at least on a cost recovery basis, should be more fully explored.

The contribution that the structure, composition and spatial arrangement of vegetation, particularly remnant areas, makes to wildlife habitat needs to be further researched so that any clearing of vegetation associated with future development, or revegetation where it has been indiscriminately cleared, can be undertaken in an ecologically sensitive manner.

The spread of weeds, disease and herbivores pose constant threats to vegetation and in particular the viability of remnants. This needs to be monitored and acted upon at every opportunity. Such problems should be tackled at the earliest stage before they are out of control, often resources are provided too late.

Fire will continue to be a major land management tool for vegetation management particularly in the sparsely populated areas of the Northern Territory. Fire research leading to fire prescriptions for defined land management objectives must continue, if not increase, so that this tool is used judiciously.

The relationship between vegetation and water is also vital. Changes to local hydrology has and will continue to have severe impact on vegetation communities dependent on specific hydrological regimes. Similarly changes in vegetation cover will have hydrological implications. Catchment based planning and management to minimise adverse impacts is vital in this regard. The perception of competition for moisture and nutrients between native, 'unproductive' vegetation and more productive vegetation used for crops and pastures will pose the major pressure for land clearance. Further studies to examine the precise nature of the total interaction between native vegetation and plants and animals used in agriculture, on a landscape basis, is essential if the goals of sustainable development and the maintenance of biological diversity are to be realised.

Establishment of critical ecological indicators reflecting the state or health of vegetation, discussed previously will be vital.

In particular, determination of allowable ranges and optima, together with appropriate measures and procedures for assessment for those parameters which inhibit desirable ecological processes, will need to be established if monitoring for vegetation management is to be effective.
APPENDIX 1:

Major structural classes of vegetation in the Northern Territory

<table>
<thead>
<tr>
<th>Structural Class</th>
<th>Area (km²)</th>
<th>% Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed Forest</td>
<td>1,029</td>
<td>0.77</td>
</tr>
<tr>
<td>Eucalypts/Grass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open forest</td>
<td>60,416</td>
<td>4.50</td>
</tr>
<tr>
<td>Woodland</td>
<td>175,066</td>
<td>16.04</td>
</tr>
<tr>
<td>Low woodland</td>
<td>59,285</td>
<td>4.42</td>
</tr>
<tr>
<td>Low open woodland</td>
<td>31,980</td>
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<tr>
<td>Eucalypt/Hummock Grass</td>
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<td>A. shirleyi</td>
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<td>Grasslands</td>
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<td>Littoral Grasslands/Tidal Flats</td>
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<td>Chenopod Low Sparse Shrubland/Wetland</td>
<td>19,060</td>
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(Based on Wilson et al 1990)
APPENDIX 2:

Proposed organisational framework for the implementation of the vegetation management strategy

<table>
<thead>
<tr>
<th>Darwin Region</th>
<th>East Arnhem Region</th>
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<tbody>
<tr>
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</tr>
<tr>
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<td>Wildman River Basin</td>
<td>Koolatong River Basin</td>
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<td>Finniss River Basin</td>
<td>Walker River Basin</td>
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<td>Darwin River Basin</td>
<td>Pt Roper River Basin</td>
</tr>
<tr>
<td>South Alligator Basin</td>
<td></td>
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<tr>
<td>East Alligator Basin</td>
<td></td>
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<td>Mann River Basin</td>
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<tr>
<td>Fitzmaurice River Basin</td>
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<tr>
<td>Moyle River Basin</td>
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<td>Goomadee River Basin</td>
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<td>Liverpool River Basin</td>
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<tr>
<td>Pt Blyth River Basin</td>
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<td>Pt Daly River Basin</td>
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<table>
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</tr>
<tr>
<td>Victoria River District</td>
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<td>Pt Daly River Basin</td>
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<tr>
<td>Daly River District</td>
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<td>Katherine River Basin</td>
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<tr>
<td>Pt Roper River Basin</td>
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<tr>
<td>Katherine District</td>
<td></td>
</tr>
<tr>
<td>Gulf District</td>
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<td>Towns River Basin</td>
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<tr>
<td>Limmen Bight River Basin</td>
<td></td>
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<td>Rose River Basin</td>
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<td>McArthur River Basin</td>
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<tr>
<td>Robinson River Basin</td>
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<td>Calvert River Basin</td>
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<td>Pt Settlement Creek Basin</td>
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<th>Tennant Creek Region</th>
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<tbody>
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<td>Barkly District</td>
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<td>Pt Wiso Basin</td>
<td></td>
</tr>
<tr>
<td>Barkly Basin</td>
<td></td>
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<td>Alice Springs Region</td>
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<td>Pt Wiso Basin</td>
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<tr>
<td>Todd River Basin</td>
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</tr>
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<td>Finke River Basin</td>
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<td>Mackay Basin</td>
<td></td>
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<tr>
<td>Hay River Basin</td>
<td></td>
</tr>
<tr>
<td>Pt Georgina River Basin</td>
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</table>

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Towards a vegetation management strategy

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Fox RE, 1974. Checklist of tree species of known susceptibility to termite attack in the Darwin region of the Northern Territory, Technical Note 9, Forestry & Timber Bureau, Canberra.

Friedel MH, 1985. The population structure and density of central Australian trees and shrubs, and relationships to range condition, rabbit abundance and soil, Australian Rangeland Journal 7(2), 130–9.


CHAPTER 18

MANAGING RANGELANDS FOR PRODUCTION WITHOUT DEGRADATION

AJ Ash, JG McIvor and WH Winter

Introduction

The savannas of northern Australia cover an area of approximately 1,500,000 km² stretching from Central Queensland to the north-west of Western Australia, excluding the wet tropical zone adjacent to the east coast. Average annual rainfall ranges from 500 to 1500 mm and is characterised by a marked summer dominance. Rainfall variability between years is high, particularly in the southern and inland regions where the monsoonal influence is less reliable. Evaporation rates are high and generally exceed mean rainfall for all months. These patterns of rainfall and evaporation produce growing seasons of 14 to 30 weeks (McCown 1982).

The predominant soils are lithosols, red, grey and yellow earths, neutral red duplexes and solodics (Isbell 1983; Hubble & Isbell 1983). Most of these soils are infertile being commonly deficient in nitrogen and phosphorus. The vegetation is dominated by open eucalypt woodlands with an understorey of perennial tussock grasses. The most important of these grasses are Themeda triandra, Heteropogon contortus, Chrysopogon fallax, Bothriochloa spp, Dichanthium spp, Sorghum plumosum, Sehima nervosum and Aristida spp.

During the early part of the wet season these grasses provide a diet high in protein and low in fibre resulting in rapid weight gains, whereas other nutrients are not limiting. However, the grasses quickly mature and become senescent, and the resultant decline in quality can lead to considerable weight loss by cattle during the dry season. This pattern of weight gain and loss is associated with calving percentages as low as 45–50% and steers taking at least five years to reach a marketable weight (Mott et al 1981).

This chapter describes the land use history of the northern grazing lands and the consequences of their overutilisation in recent decades. We also examine the effects of various forage management options on pasture and animal production together with a description of a study aiming to determine the effects of land condition on productivity. For the purposes of this discussion the north-east (NE) refers largely to the Burdekin Basin and Gulf country while the north-west (NW) takes in the Katherine, Victoria River District (VRD) and Kimberley regions.

Land use history

Beef cattle and sheep were introduced into the northern Australian rangelands upon settlement about 150 years ago but extensive beef cattle production has been the major form of land use in the last 100 years. Management in the early days consisted of little more than provision of some watering points and a small amount of fencing. British breeds of cattle were grazed at low stocking rates to allow maximum selection of the better parts of the available forage and to minimise losses during drought years. Pastures remained in good condition although there were changes in botanical composition. Most notably, Themeda triandra was replaced by Heteropogon contortus in north-eastern Australia as a consequence of regular burning and grazing (Tothill 1969).

Since the 1960s there has been widespread adoption of the tropically adapted Bos indicus cattle and increased use of supplements which has led to reduced mortality, increased calving percentages and more rapid growth rates. This improved productivity of cattle combined with a slump in beef prices in the 1970s resulted in a large increase in cattle numbers in northern Australia in the mid-1970s (Fig 1). Increased cattle numbers in the Northern Territory during this time can also be partly attributed to improved infrastructure, eg new roads, abattoirs.

At the time, the consequences of the greatly increased cattle numbers on the condition of the
land were only visible in the NW where earlier damage along the frontage country of the major river systems (Fitzroy, Ord, Victoria) was accentuated with further losses of valuable native grasses and soil. In the NE better than average seasons through the 1970s (Table 1) enabled the country to support the higher numbers of cattle without any noticeable deleterious effects on land condition. However the 1980s saw a run of years with below average rainfall and bare ground became a dominant feature of the landscape on many properties.

Other than the frontage country, widespread overgrazing was not as apparent in the NW in the 1980s as the seasons were more reliable and above average. However, the introduction of the brucellosis and tuberculosis eradication campaign (BTEC) in 1982 resulted in significant changes in cattle management with some deleterious effects on the land. The campaign has forced landholders to improve fencing for testing of cattle and declaration of disease free status. While the industry will benefit in the longer term, the short-term effect has been to concentrate cattle on easily accessible paddocks with resultant degradation in many areas. The live shipping of cattle to south-east Asia may also be a contributing factor in the concentrating of cattle into the more accessible areas, to supply the trade during the wet season.

### Table 1 Pasture growth days per year

<table>
<thead>
<tr>
<th>Period</th>
<th>Charters Towers</th>
<th>Katherine</th>
<th>Kimberley</th>
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<tr>
<td>1971–75</td>
<td>145</td>
<td>133</td>
<td>125</td>
</tr>
<tr>
<td>1976–80</td>
<td>126</td>
<td>144</td>
<td>111</td>
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<tr>
<td>1981–85</td>
<td>92</td>
<td>153</td>
<td>104</td>
</tr>
<tr>
<td>1986–89</td>
<td>85</td>
<td>137</td>
<td>104</td>
</tr>
<tr>
<td>Long term average</td>
<td>103</td>
<td>132</td>
<td>103</td>
</tr>
</tbody>
</table>

Calculated by the methods of McCown (1973), for five year periods between 1970 and 1990 for Charters Towers, Katherine and Kimberley Research Station.

Source: McCaskill, pers. comm.
Consequences of overgrazing

Overgrazing of the northern rangelands has produced marked changes in the landscape. The perennial tussock grasses are sensitive to overgrazing (Mott et al 1985) and are lost first from the pasture. In the absence of invasive perennial species such as the stoloniferous grass Bothriochloa pertusa, annual grasses and dicots replace the perennial grasses. These species are generally less palatable and provide soil cover for only part of the year. As a consequence of reduced foliar cover soil loss is increased (Fig 2). A cover of approximately 40% is necessary to minimise soil loss as bed load and suspended materials (Gardener et al 1990). Annual rates of soil loss from the Burdekin (Fleming et al 1981) and Ord (Ord Irrigation Project 1976) River catchments have been estimated at 20 and 24 million tonnes, respectively. In the Ord River catchment erosion has not been halted despite some successful revegetation work (Winter 1987a).

The invasion of shrubs and woody weeds into degraded pasture land has become of increasing concern in recent times. In the NE, Cryptostegia grandiflora (rubber vine), Ziziphus mauritiana (Chinese apple), Acacia nilotica (prickly acacia), Prosopis spp (mesquite), Parkinsonia aculeata (Parkinsonia) and Carissa ovata (currant bush) have become serious pests while in the NW, Calotropis procera (rubber tree), Terminalia vultuicis (rosewood) and Lysiphyllum cunninghamii (bauhinia) have increased rapidly over the last decade. The increase in these weeds can be attributed to both an absence of regular burning due to a lack of fuel and reduced competition from perennial grasses.

In the past, property management has been governed by the economics of the cattle herd with little emphasis having been placed on the health of pastures or the consequences of their degradation. Indeed overgrazing has to some extent been encouraged through the provision of drought subsidies. Recent increased concern at the state of our natural resources is placing pressure on graziers to become more environmentally aware and to implement sustainable land management practices. However, it is likely such practices will only be adopted by land managers where a positive benefit/cost ratio can be demonstrated (MacLeod & Johnston, pers. comm.). It has been and remains the aim of CSIRO pasture research in northern Australia to develop management strategies for improved beef production without degrading the resource.

**FIGURE 2** Relationship between relative soil loss and percentage cover at Cardigan (a)

(a) Soil loss was measured in run-off troughs following a 62 mm rainfall event in March 1987. Soil was collected in 10 m troughs placed on a surveyed slope across the landscape.

Source: Williams, Gardener & McIvor, pers. comm.
Forage resource options to sustain and improve beef production

Extensive beef cattle production in northern Australia is constrained by lack of facilities, remoteness from markets, size of operation and often unfavourable terrain. Even with these constraints, the greatest limitation to production is still the quantity and quality of the herbage produced. Forage management options to improve cattle production in northern Australia therefore revolve around improving the quantity and quality of the forage resource as well as increasing the efficiency with which the forage resource is utilised.

Fire

Fire is used widely as a management tool in the savannas of northern Australia (Anderson et al 1988). (See also chapters 13, 14 & 15 in this volume — eds.) Burning removes rank, mature pasture with the resultant regrowth being of high quality and providing easily accessible green leaf to the grazing animal (Ash et al 1982; Winter 1987b).

As well as improving animal performance, the strategic use of fire can play an important role in maintaining pasture stability. Andrew (1986) found that by burning half of a paddock in the dry season, cattle were attracted to the burnt area in the following wet season thus removing the grazing pressure from previously utilised areas. Patches that had been formed and which might have otherwise become bare and scalded (Mott 1987) with time were allowed to recover during the growing season. The unburnt portion of the paddock was burnt in the following dry season thus setting up a sequence of rotational burning which appeared to stabilise the pastures.

Fire can also play an important role in the control of shrubs and woody weeds. Most shrub seedlings are susceptible to fire when young and it is known they can be controlled in the semi-arid woodlands with prescribed burning (Hodgkinson & Harrington 1985). A similar approach should apply to the control of shrubs and woody weeds in northern Australia.

Sowing improved species and removal of trees

An increased forage supply, and hence increased carrying capacity, can be achieved by sowing improved pasture species and by killing trees to remove competition for water and nutrients. Sowing legumes has the added benefit of providing higher quality herbage and increasing the nitrogen supply to the companion grasses. Figure 3 shows an example of the positive effects of tree killing and oversowing native pasture with improved grasses and Stylosanthes legumes on pasture yield on a red duplex soil at Cardigan, 40 km south-east of Charters Towers. At a second site, Hillgrove, 80 km north of Charters Towers on a more fertile eucalypt soil, the response in pasture yield to tree killing has been greater while the impact of sown species has been less, presumably due to the greater fertility of the soil. At both sites the response to tree killing has been greatest in dry years when competition for moisture is increased. The increased herbage cover that results from sowing improved species and/or killing trees significantly reduces soil loss (Fig 4), particularly in dry years.

Under trees, the stylos are able to outcompete the grasses for soil moisture and nutrients and form a greater proportion of the sward compared with stylo pastures where trees have been killed (Fig 3). Indeed where soil fertility is low, stylo pastures under trees can become legume dominant at the expense of native grasses (Winter 1988). This legume dominance is potentially unstable, because if the legumes were to disappear, their most likely replacement would be weeds and annual grasses rather than perennial grasses. Research is currently under way to investigate the effects of introducing improved grasses into stylo dominant pastures.

Herbage quality is enhanced with the sowing of improved grasses and legumes (Table 2). Legumes are of particular benefit as the season progresses and the grasses mature. Results from both Hillgrove and Cardigan show that the quality of the herbage growing in paddocks where trees have been killed is lower for much of the year. This trend is not apparent at Katherine where there was no effect of killing trees on herbage quality (Winter et al 1989). It is not clear as to why there is a beneficial effect of trees on pasture quality in the Charters Towers studies. The tree densities would appear to be too low to suggest a direct effect of shading.

Animal production studies in the NE and the NW have shown large responses to the sowing of legumes (Stylosanthes spp) and a smaller but still significant effect of tree killing (Table 3). As with pasture yields the response to tree killing is greatest in dry years. The size of the response to oversown pastures appears to be related to soil fertility with much greater increases in animal production with sown pastures in the Katherine study. While there are benefits in tree killing, economic analyses show that net returns are greater for sowing pastures and leaving the native woodland intact (McIvor & Gardener 1992). Tree killing can also have an adverse environmental impact through increased risk of salinisation of the landscape. In addition, the
FIGURE 3 Yield of herbage produced at Cardigan in response to killing trees and oversowing with improved grasses and legumes (a)
(a) Mean of paddocks stocked at 5, 3 and 2 ha/beast and two levels of superphosphate (0 and 100 kg/ha/year).
Source: McIvor & Gardener, pers. comm.

FIGURE 4 Effect of killing trees and oversowing with improved grasses and legumes on the bed load soil loss at Cardigan (a)
(a) Soil loss was measured in run-off troughs after a 62 mm rainfall event in March 1987.
Source: adapted from Gardener et al 1990.
TABLE 2 Effect of oversowing native pasture and tree killing on the in vitro digestibility of plucked herbage harvested at Hillgrove(a,b)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sample</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>July</th>
<th>Sept.</th>
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</thead>
<tbody>
<tr>
<td>+ trees</td>
<td>Grass</td>
<td>44.1</td>
<td>63.9</td>
<td>56.1</td>
<td>52.5</td>
<td>44.2</td>
</tr>
<tr>
<td>- trees</td>
<td>Grass</td>
<td>42.8</td>
<td>62.8</td>
<td>53.7</td>
<td>50.5</td>
<td>44.5</td>
</tr>
<tr>
<td>Native</td>
<td>Grass</td>
<td>42.3</td>
<td>61.5</td>
<td>54.3</td>
<td>49.8</td>
<td>42.6</td>
</tr>
<tr>
<td>Sown</td>
<td>Grass</td>
<td>44.5</td>
<td>65.2</td>
<td>55.6</td>
<td>53.3</td>
<td>46.2</td>
</tr>
<tr>
<td>Sown</td>
<td>Legume</td>
<td>41.8</td>
<td>68.5</td>
<td>59.7</td>
<td>59.8</td>
<td>59.0</td>
</tr>
</tbody>
</table>

(a) Mean of paddocks stocked at 5 and 3 ha/haest and two levels of superphosphate (0 and 100 kg/ha/year).  
(b) Wet season did not commence until the end of March.  
Source: Ash & McIvor, unpublished data.

TABLE 3 Response in annual liveweight gain (LWG) of steers to oversowing native pasture with *Stylosanthes* spp and tree killing

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Site</th>
<th>Pasture</th>
<th>SR (ha/b)</th>
<th>LWG (kg/ha)</th>
<th>Response (%)</th>
<th>Reference</th>
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<td>Legume</td>
<td>Lansdown (NQ)</td>
<td>Native</td>
<td>1.7</td>
<td>76</td>
<td>113</td>
<td>Gardiner &amp; McCaskill (in prep).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sown</td>
<td>0.8</td>
<td>162</td>
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<tr>
<td></td>
<td></td>
<td>Sown</td>
<td>1.4</td>
<td>62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree</td>
<td>Kangaroo Hills (NQ)</td>
<td>+ trees</td>
<td>3.3</td>
<td>29</td>
<td>41</td>
<td>Gillard 1979.</td>
</tr>
<tr>
<td>killing</td>
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<td>- trees</td>
<td>3.3</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Katherine (NT)</td>
<td>+ trees</td>
<td>1.4</td>
<td>35</td>
<td>40</td>
<td>Winter, Mott &amp; McLean 1989.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- trees</td>
<td>1.4</td>
<td>49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

benefit received from tree killing may disappear with time as regrowth from trees is likely to compete with pasture growth. At Hillgrove, the leaf area index of nine year old regrowth is approximately 2/3 that of native woodland (McIvor, pers comm).

*Overcoming nutrient deficiencies*

The use of supplements to overcome nutrient deficiencies has become increasingly important across northern Australia over the last 20 years. Whilst animal production can be increased in response to supplementation with nitrogen (Lindsay *et al* 1982), sodium (Winter 1987b) and sulphur (Hunter *et al* 1979), phosphorus deficiency has received most attention in recent years. It is deficient across much of northern Australia and negatively impacts on both pasture and animal production. Phosphorus can be supplied either as fertilizer or as a direct supplement to the animal. Application of phosphorus fertilizer to native pasture is unlikely to be economic, especially where nitrogen is also a major limiting nutrient (Jones 1990). However, phosphorus fertilizer is important in the establishment and maintenance of stylo based native pastures (Gillard 1979; Winter 1988).

Beef production is greatly increased in response to superphosphate application of stylo pastures (Winks...
et al 1977; Winter et al 1990) through increased phosphorus levels in the diet (McLean et al 1990) and improved pasture yield and composition (Coates et al 1990). In some instances relatively small applications of superphosphate can improve pasture yield and composition but have little benefit on animal production as phosphorus concentrations in the pasture are not greatly increased (Winter 1988).

Supplying phosphorus directly to the animal, either as medicated water or as a dry mix or block, has been shown to dramatically increase animal production right across northern Australia (Table 4). The response to supplementation occurs in the wet season and its magnitude appears to be related to the phosphorus status of the soil (Kerridge et al 1990). Also, liveweight gain responses to phosphorus supplementation are greater with cattle grazing stylo pastures compared with native pastures as more efficient use can be made of the high protein diet provided by the stylo in the absence of a phosphorus limitation.

Phosphorus improves animal production through stimulating intake (Little 1968; O'zanne et al 1976; Rees & Minson 1977). The result of an increased intake is a reduced pasture availability (Fig 5). If stocking rates are not adjusted to accommodate an increased intake then the grazing system may not be sustainable.

Stocking rate

Stocking rate is probably the most important management variable with the potential to influence animal production, profitability and land condition more than most other variables. On an annual basis, as stocking rate increases gain per head decreases while production per hectare increases to an optimum level and then declines (Jones & Sandland 1974). This model, however, does not take account of seasonal effects or the interaction between stocking rate and botanical composition. Hart (1978) has suggested that in the early growing season animal production is independent of stocking

<table>
<thead>
<tr>
<th>Site</th>
<th>Pasture</th>
<th>Treatment</th>
<th>SR (ha/b)</th>
<th>LWG (kg/ha)</th>
<th>Response (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swan's Lagoon (NQ)</td>
<td>Native</td>
<td>-P</td>
<td>2</td>
<td>42</td>
<td>10</td>
<td>Winks, Lamberth &amp; O'Rourke 1977</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>2</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stylo</td>
<td>-P</td>
<td>2</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>2</td>
<td>67</td>
<td>37</td>
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</tr>
<tr>
<td>Spring-mountain (NQ)</td>
<td>Native</td>
<td>-P</td>
<td>4.1</td>
<td>12</td>
<td></td>
<td>Miller pers comm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>4.1</td>
<td>20</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Lansdown (NQ)</td>
<td>Stylo</td>
<td>-P</td>
<td>1.3</td>
<td>63</td>
<td></td>
<td>Coates 1990</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>1.3</td>
<td>114</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Katherine (NT)</td>
<td>Native</td>
<td>-P</td>
<td>16</td>
<td>4</td>
<td></td>
<td>Winter 1987b, 1988</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>16</td>
<td>8</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stylo</td>
<td>-P</td>
<td>1.4</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>1.4</td>
<td>62</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>VRD (NT)</td>
<td>Native</td>
<td>-P</td>
<td>10</td>
<td>7</td>
<td></td>
<td>Sullivan 1990</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+P</td>
<td>10</td>
<td>10</td>
<td>43</td>
<td></td>
</tr>
</tbody>
</table>

(a) P deficiency was moderate at Swan's Lagoon and severe at all other sites.
FIGURE 5 Pasture availability in response to phosphorus supplementation of steers grazing stylo pastures in north-east Queensland (a) and the Northern Territory (b) at stocking rates of 1.3 and 1.4 ha/beast, respectively

Sources: (a) Coates, pers. comm., (b) Winter 1988.

rate so long as feed is not limiting. However, this is also the time when the native, tussock perennial grasses are most susceptible to heavy grazing (Norman & Begg 1966; Tootill & Mott 1985) thus bringing into conflict pasture stability and animal production.

The long term effect of a high stocking rate is to decrease basal area of perennial grasses, herbage cover and to alter botanical composition. The palatable, perennial tussock grasses decline while prostrate perennial grasses, annual grasses and weeds increase as stocking rate increases (Table 5).

In the NW, Themeda is replaced largely by Chrysopogon and Brachycaena in response to heavy grazing while in the NE, spear grass (H. contortus) is rapidly being replaced by Indian couch grass (B. pertusa) and annual grasses.

In range or land monitoring terms such botanical changes indicate a shift from good to poor condition. However the consequences of these botanical changes for animal production are not known. As mentioned earlier, liveweight gain per head declines as stocking rate increases but are the rates of decline different for land in different conditions? In terms of diet selection, studies with improved pastures in temperate (Hamilton et al. 1973) and sub-tropical (Chacon & Stobbs 1976) regions have shown a decline in quality with increasing utilisation, which can be attributed to a decrease in the amount of leaf available to the animal. No such data are available for the more complex native pastures of northern Australia. However, overseas studies on native rangelands suggest quality of the herbage may not decline with increasing utilisation or change in land condition.
TABLE 5 Pasture species which 'increase' or 'decrease' in response to prolonged heavy utilisation

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Decreaser species</th>
<th>Increaser species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monsoon tallgrass</td>
<td><em>Themeda triandra</em></td>
<td><em>Chrysocephalus fallax</em></td>
</tr>
<tr>
<td>eg Katherine</td>
<td><em>Sorghum plumosum</em></td>
<td><em>Brachyacne convergens</em></td>
</tr>
<tr>
<td></td>
<td><em>Sesbania nervosum</em></td>
<td><em>Aristida spp</em></td>
</tr>
<tr>
<td>Tropical tallgrass</td>
<td><em>Themeda triandra</em></td>
<td><em>Bothriochloa pertusa</em></td>
</tr>
<tr>
<td>eg Charters Towners</td>
<td><em>Heteropogon contortus</em></td>
<td><em>Eragrostis spp</em></td>
</tr>
<tr>
<td></td>
<td><em>Bothriochloa ewartiana</em></td>
<td><em>Sporobolus australasicus</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Tragus australiana</em></td>
</tr>
</tbody>
</table>

Source: adapted from McIvor & Orr 1991, 93.

(Danckwerts 1989; Heitschmidt et al 1989). This would suggest the only effect of a change in land condition would be on the amount of herbage produced which would in turn influence animal production through a change in carrying capacity (Fig 6).

To answer some of the above questions, a new project, as part of the CSIRO Land and Water Care Program, has been established. Animal production is being measured at a range of herbage utilisation levels on areas of land in good and poor condition to determine the effects of both stocking rate and land condition. Sites have been established at Katherine and Charters Towers. Preliminary results show that liveweight performance at any utilisation level is similar on the areas in the two condition classes but that herbage production decreases as condition declines.

FIGURE 6 Hypothetical response of animal production to increasing utilisation and stocking rate on land in poor and good condition.
Conclusions

The pasture lands of northern Australia are a valuable and fragile resource which need better understanding to maximise their use without degradation. Large improvements in animal production from these pastures can be achieved through augmentation of native pastures with legumes and strategic use of supplementation. However, careful consideration needs to be given to the adoption of these and other new technologies and their interaction with the environment, eg increased consumption of pasture by cattle with phosphorus supplementation. Even with increased use of new pasture technology over the next decade, native pastures will still occupy a large majority of the pasture resource of northern Australia. The condition of these native pastures is generally declining and will continue to do so until we can demonstrate to land managers the environmental and economic benefits of maintaining pastures in good condition.

References


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CHAPTER 19

THE PASTORAL INDUSTRY IN THE ARID ZONE OF CENTRAL AUSTRALIA

Robert Millington

As part of the general topic 'Conservation and Development in North Australia' this chapter looks at pastoral land use in the Northern Territory Arid Zone.

Speaking generally, primary industry is export oriented, earning some 30% of Australia's export income. In the current competitive market place efficiency of operation is essential. Productivity measured by unit cost is improving at almost twice the rate of non-rural enterprises. New markets are being sought and it is estimated that by the year 2050 Asia will offer a market twice the size of the European Community and America combined. Biotechnology is developing rapidly. Retrograde practices of the past, aggravated by misconceived Government incentives and inappropriate expert opinion, are being remedied. In the NT Arid Zone properties generally are family owned and operated. This gives the motivation for both efficiency and a respect for the future. Operations are becoming more and more capital intensive. Pastoralism like all primary industries is a business and, as such, the economic success of the enterprise is important.

The history and development of the Centrallan Land Management Association

The Federal Government has declared the 1990s to be the 'Decade of Landcare'. Government realising the difficulties of the past, aspirations of the present and needs of the future has supported the formation of Landcare Groups, some 700 around Australia. Simply put, the aim is firstly to develop interaction between land users so that a district approach to problem solving can evolve and secondly, by a public awareness campaign, alert the community to the need for protection of the landscape, and the environment generally, so that provision is made for the needs of future generations.

The realisation of the need for the inclusion of the study of Landcare Principles in the education curriculum is growing. There is also a growing awareness amongst the general public that there is such a thing as a world community, that everyone has a responsibility within and to that community and that every member of this world community has the right to an acceptable standard of living. This can only be achieved through viable production enterprises, tolerance and good management of resources.

The Central Australian district of some 600 000 km² is roughly half under pastoral lease. Other major non-urban land uses are for tourism, Aboriginal lands, mining and conservation. These users together provide the backbone of the district's economy and its contribution to the wider community. Each has an impact on the other. Mutual respect and understanding of each other's needs and aspirations is essential to achieve the goals set.

Historically the pastoral industry opened up Central Australia. Following the building of the Overland Telegraph, large company pastoral leases were set up. These mostly collapsed because of climatic conditions and company structure and operational difficulties. In their place smaller family enterprises were established and this type of management has continued to the present day. Its success has been based on the character of the operators, their ability to persist through periods of extreme pressure, both financial and climatic, and their deep perception, gained through experience and 'hands-on' contact with local conditions.

Urban development, transport and communication infrastructure followed and opened the way for other industries to develop. These have not subrogated pastoralism but complemented the industry by creating the atmosphere for change from isolation, both in a social and technological sense, to the developing sophistication of today's industry.

In 1989 a group of Centrallan pastoralists met together to discuss trends in the industry and the
recently announced Government Landcare initiatives. The outcome of this meeting was the formation of the Central land Management Association. Its primary objective was defined as the promotion of management practices that would assure sustainable and productive use of our pastoral lands. To achieve this, four main aims were identified:

1. To encourage landholders to develop management strategies for sustainable use of the resource.

2. To promote integration of the knowledge and experience of managers and scientists.

3. To promote public awareness of the objectives and activities of the association.

4. To advise Government of regional management issues requiring research or extension attention as appropriate.

From the outset, the association has had difficulty in fitting into the Landcare 'catchment' philosophy of more climatically favoured parts of the continent. This is one of the most difficult hurdles the Association has to cross when dealing with legislative and financial administrators — pastoralism in the Arid Zone is not wheat farming in the wheat belt. Properties are large, averaging 3 500 km² in area, distances long, the district area extending up to 500 km from its centre, Alice Springs. Numbers are few, there being only 68 pastoral leases in the district.

The climate is harsh with temperatures marked by strong seasonal and annual fluctuations. Peak summer temperatures for extended periods are in excess of 40 °C. Mean minimum temperatures in winter are between 3 °C and 10 °C. Annual rainfall averages range from 300 mm in the north to 200 mm in the south but is erratic in distribution and frequency. For example during the last significant rainfall event, the south west of the district received only some 35 mm whereas the north east got in excess of 350 mm. There is no predictable rainfall pattern.

Salinity is not a significant soil problem and pollution from use of agrochemicals non-existent. This latter makes a chemical free end-product available to the market — a rare situation today. All these factors make it difficult for program developers to understand that our concerns are different.

Industry development based on sustainable productivity conjures up jargon for which different groups have their own interpretation. Perhaps some definition as we see it will make our approach clearer. Sustainable productivity is the long-term maintenance of livestock production and its production resource. Degradation is a negative level of sustainability. Due to the inherent instability of the Arid Zone System, resulting from seasonal and unpredictable annual fluctuations of climate, there will be periods of degradation of the production resource. Land managers understand how to reverse these short-term negative trends back to positive long-term sustainability.

Sustainability and degradation must be considered over a long-term framework. Basic criteria to assess the resource are pasture composition, ground cover and soil physical condition. For assessments to be useful, there must be a known base line from which to work and a proven methodology of assessment. In the Arid Zone, with its great temporal and spatial variability and unpredictable rainfall, much remains to be done to set up effective systems. The first step in this, a resource inventory, is underway to assist in providing primary data for land capability assessments.

Some of the major management issues industry faces as it strives for sustainable productivity

Drought

Drought is probably the most significant factor in decision making. In the Arid Zone rainfall sufficient to promote pasture growth may fail to occur one out of every four years. However this is only an average and a series of years with effective rains and a group of years without is common. This creates short term vegetation decline during bad times with positive responses when good years occur.

Management therefore during periods of low rainfall needs to de-stock, be it either by sale or agistment. Computer programs are being developed based on the probability of a certain event and, coupled with management experience, assist with the decision as to when this step needs be taken. In periods of positive response, spelling of areas, rotationally, to allow for improved seed set is the practice. There are three major constraints: markets and fiscal policies, adequate fencing and appropriate distribution of watering points.
**Better knowledge of the resource**

The second significant management factor is knowledge of the resource. In spite of some very good work done to date, there are massive gaps in our information and a shortage of professional input. Land unit mapping is the start and use of air mosaics to define these at a management usable level is increasing. With back up support from Government agencies, this is an on-station do-it-yourself activity. Monitoring of the resource is the next step with measurement, photographs and record keeping providing the station-based data for guiding management. Ideally this should be done on all areas, but on a practical level selected sensitive areas and experience will give the information. Better knowledge of the resource means better decisions on infrastructure locations and it assists to define areas that are naturally poor and those where due to past activities rehabilitation is required. In the Arid Zone pitting and ponding techniques, in conjunction with rotational spelling of areas, are used to rehabilitate degraded areas. The process is expensive and to be economic areas that are naturally poor due to any factor, such as soil type, do not warrant treatment by these methods. One need here, for environmental stability, is developing the technology to harvest seed of native species for rehabilitation works, a process which is currently being investigated.

**Feral animals**

Feral animals have an effect of the landscape that not only results in negative productivity but also creates environmental damage both by denuding vegetation and competing with native fauna. During the BTEC program most of the larger feral species were destroyed. Wild horses are still a problem in isolated areas. Control of these is simple but overpopulation creates unnecessary difficulties. Although apparently of no impact on productivity, feral cats are an environmental curse but again emotionalism prevents effective control.

The most significant feral pest is the rabbit. Thousands of square kilometres of the Arid Zone are infested. Pastoral land is reduced to nil productivity because of the rabbit and vast areas are completely denuded of vegetation. Native fauna have been supplanted. CLMA has sponsored a 250 km² rabbit control demonstration on three adjoining stations to show control techniques. With Agency support the program will assess vegetation response and determine the cost of control. Early figures put control at about $475/km². The demonstration area has had no rain since the work began but responses at two other locations to similar work are impressive.

Because of their source and distribution, rabbits are a national problem no matter from whose angle you look at the situation. For sustainable productivity in affected areas, control on a national level must be initiated.

**Fire**

Fire as a management tool in the Arid Zone is often supported by certain groups. However there are others who feel that by removing vegetation cover subsequent wind erosion is a major problem. Response of individual species is unclear. Wildfires are a natural phenomenon and containment of these is part of management practice. To assist with management decision it is imperative that some guidelines be developed on the use of fire. CLMA has sponsored an honours student from the University of Adelaide to do a literature search on Arid Zone fire. This should be completed by the end of 1991. It should then be possible to decide what research may be necessary to achieve the desired results from this management tool.

**Native woody species**

Weed infestation is generally not a problem in our part of the Arid Zone but following a series of good years there has been a general increase in native woody species, Acacias, Eremophilas, Cassias, in places almost of weed intensity. Decision as to control is hampered by lack of knowledge as to whether or not this is part of a natural cycle. As discussed there is little information on the response of individual species to the most economic control technique, fire. Treatment of high value areas, for example around bores and yards, is an essential part of management. In these situations the cost of chaining or blade ploughing is justified. Investigations currently in progress and continuing research will be needed to guide future decisions.

**Bureaucratic procedures and enterprise efficiency**

This is not the forum to elaborate on general national issues affecting the industry but some comment is appropriate as these affect the cost structure and therefore efficiency of any enterprise.

Over-regulation, resulting from minority group pressures and bureaucracy self-interest, needs curbing. A complete reassessment of taxation and associated policies is long overdue. The
ever-increasing demands of ineffectual, time-wasting paperwork forced on business needs stopping. It is suggested that to gain the maximum benefit for the tax-payer dollar, the costs and inefficiencies created by duplication or confusion of function in or between agency groups needs assessing from outside the bureaucracy.

Summary

In summary, sustainable productivity or development is synonymous with good management. As a result of the BTEC program a new awareness of resource management has emerged.

Many problems of our resource relate to an historic period of lack of understanding of, or information on, resource maintenance but these are not beyond reversibility within property management.

Control of livestock numbers and movement, the removal of feral animals, improved watering point distribution and land type oriented fence location are improving resource management. Management principles encompassing the climatic diversity of the district is the key to resource maintenance.

Considering all the factors affecting management, the bottom line in achieving sustainable productivity is stocking rate. The optimum level for each property and within it each land type can be achieved through management experience, technical input, adequate fencing, well distributed watering points, rotational spelling and effective marketing.
CHAPTER 20

LAND MANAGEMENT MODEL FOR THE SEMI-ARID TROPICS

Peter Hairsine, Mark Silburn and Mohammed Dilshad

Introduction

Future land management in the semi-arid tropics of Australia necessitates a balance between improving the efficiency of production and sustaining the resource. In the semi-arid tropics, land degradation is a common feature of the landscape. It is recognised that the historical approach of land development with a single overall objective of maximising short-term productivity is not sustainable (Winter 1990). For this region to have a sustainable productive future, land managers require predictive tools for assessment of the land degradation resulting from land management strategies.

The semi-arid tropics of Australia are characterised by strong seasonality and variability of rainfall and ground cover levels. Although some small-scale cropping occurs in the region, current commercial land use is predominantly beef cattle grazing with a wide range of viabilities (Young et al 1986). Historically the semi-arid region has had a relatively low stocking rate. More recently, adoption of feed supplements and better-adapted zebu cattle has resulted in major increases in grazing pressure. Rates of land degradation have accelerated due this increase in grazing pressure (Gardner et al 1990).

While land managers face a range of constraints to the short-term viability of the their land (Young et al 1986), land degradation poses a major threat to the sustainability of land uses in the semi-arid tropics. Soil erosion is largely an irreversible process in which soil is removed from a landscape element. Rates of soil formation are generally two orders of magnitude smaller than the rates of erosion in a degrading land system. Soil structural decline is largely a reversible process though intensive ameliorative practices are often not viable on extensive grazing lands.

Land managers are faced with complex choices of management strategies, ranging from prescribed burning to stocking rates. This decision making must also consider climatic variability. For a land use system to be sustainable the objectives of minimising the risk of land degradation while enhancing the efficiency of production must be met. Balancing these two objectives requires an understanding of the soil, water, plant and animal interactions as well as a recognition of the variable nature of the inputs. The proposed LAMSAT model will provide a framework which permits these processes to be modelled while recognising climate variability. The model will predict runoff and erosion rates over several cycles of climate and environmental response. With this information the land manager will be better able to assess the sustainability of a proposed land management strategy.

This is a collaborative project between CSIRO Division of Soils, Queensland Department of Primary Industries, the Conservation Commission of the Northern Territory and the Northern Territory Department of Primary Industries and Fisheries. Figure 1 shows the relationship of the LAMSAT model with other projects.

Key Issues

For a model to respond appropriately to differences in land management, it must recognise key relationships and processes. Some of these key issues for the semi-arid tropics are listed below:

1. The temporal variability and interaction of climate and ground cover must be combined. In the semi-arid tropics, runoff and associated erosion are episodic. The model must realistically model cover and soil moisture dynamics in intervening periods.

2. The influence of cover on water infiltration and thus on the runoff must be recognised. Pressland et al (1992) found a non-linear relationship between total ground cover and percentage surface runoff. This relationship is expected to vary for different plants/soils combinations.
 FIGURE 1 The integration of the LAMSAT model with other projects

3. Bridge et al (1983) found overgrazing in a dry savanna woodland resulted in large changes in the soil hydraulic properties. Formation of surface seals resulted in a greater proportion of rainfall running off. Thus the model must recognise that the soil properties themselves change with degradation.

4. Ground cover takes several forms: vegetative, litter and stone cover. Each of these types of cover have different effects on the erosion processes. As most erosion models have been developed for cropping land, the description of the erosion processes and the influence of cover must be re-examined in this new environment.

5. The influence of strategic burns on soil erodibility, soil hydraulic properties and cover levels. The model must simulate ground cover recovery.

6. The competition between trees and grass in terms of soil water and the associated pasture growth must be described.

7. The rate of establishment of crops or pastures, and associated changes in soil erodibility due to soil disturbance with this establishment is a key issue (for improved pastures and crops). The risk of erosion is large in this establishment phase due to the combination of high erodibilities and low cover.

Model description

Figure 2 sets out the general components to be represented in the LAMSAT model structure. The majority of the algorithms describing the links between components exist in the literature. New relationships require development in the key areas listed above. All existing algorithms will require some parameterisation for the semi-arid tropics environment.

Much of the description of the soil/water/plant/animal system in the LAMSAT model will be drawn from existing models. These models include: GRASP (McKeon et al 1982) — a pasture growth model; PERFECT (Littleboy et al 1989) — a soil water/plant growth/runoff/erosion model; GUEST (Hairsine & Rose 1991; Misra & Rose 1989) — an erosion mechanics model and WEPP model (Laflen et al 1991) — an erosion simulation model. An overview of each of these models and their relevance to the LAMSAT model is given below.
PERFECT (Productivity, Erosion, Runoff Functions to Evaluate Conservation Techniques) (Littleboy et al. 1989) simulates plant-soil-water management dynamics of agricultural systems through time. It was developed to simulate the major effects of management and the environment on runoff, soil loss, soil drainage, crop growth and yield. It can be used for a wide range of investigations into the effects of inputs (e.g., climate and management) and state of the system (e.g., soil water holding capacity) on outcomes (e.g., soil erosion and crop yield). PERFECT will provide the systems basis for the LAMSAT model.

The GRASP (Grass Production) model (McKeon et al. 1982) predicts biomass yield of native pastures through time, accounting for variation in seasonal conditions and effects of management options such as burning and grazing pressure. An experimental methodology has been developed and applied to provide parameter for this model for a range of species/environment combinations in Queensland (McKeon et al. 1988).

The Griffith University Erosion and Sedimentation Template (GUEST) model uses the algorithms of Hairsine and Rose (1991, 1992) to calculate the sediment concentration for a user specified combination of land slope, slope length, soil erodibility, runoff rate, soil settling velocity distribution (a measure of aggregate/particle deposition rates) and flow geometry. It is sensitive to soil roughness, aggregate stability and cover which provides either flow resistance or raindrop interception (Hairsine et al. 1992). As surface roughness and cover are expected to be key manageable properties of grazing lands, this model will form part of the LAMSAT erosion sub-model.

The Water Erosion Prediction Project (WEPP) model is a simulation model being developed by the United States Department of Agriculture as a replacement for the Universal Soil Loss Equation (USLE). The model has sub-components describing climate, plant growth, residue decomposition, soil water balance, runoff and erosion mechanics (Lane & Nearing 1989). The model requires extensive parameterisation for Australian soils and climates.
and has had no validation in Australia at this stage. The approach to modelling overland flow and surface roughness in rangeland are of immediate application to the LAMSAT model.

Data Inputs

Table 1 sets out sources of data to be used in the parameter evaluation and validation phases of model development. All of these field sites are no longer fully operational with the exception of the Douglas Daly site in the Northern Territory and Springvale in Central Queensland.

As part of the current project, runoff and erosion are being monitored at the Douglas Daly site. Treatments are improved pastures, under a range of stocking rates, native pastures and maize. Each of the treatments is confined in a contour bay with runoff and net erosion rates being measured at the bay exit. This site provides a data set with a strong monsoon influence. The primary data that will be collected from the contour bays at Douglas Daly are:

- rainfall totals and intensity
- runoff hydrographs at bay scale (approx 4 to 8 hectares)
- soil loss (at bay scale)
- soil moisture to 150 cm
- ground cover (total and contact)
- meteorology (evaporation, humidity, temperature, wind) — agronomy (yield, phenology)
- animal production
- pasture yield and phenology (six monthly)

Erosion and runoff at the overland flow scale will also be monitored using Geriach trough plots within each pasture bay, near the soil water/pasture monitoring sites. A permanent bare plot (simulating extreme pasture condition) and an enclosure (no grazing) plot will also be installed. As runoff and soil loss for a wide range of cover levels is recorded for each event, a robust model of the effects of cover can be developed. Measurement of erosion at both the plot and bay scales enables examination of the soil erosion and re-distribution of sediment within bays in addition to the loss of sediment to the natural drainage system.

<table>
<thead>
<tr>
<th>TABLE 1 Details of existing and future data to be included in modelling</th>
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<tbody>
<tr>
<td><strong>Site</strong></td>
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<tr>
<td>----------</td>
</tr>
<tr>
<td>Douglas Daly</td>
</tr>
<tr>
<td>Douglas Daly (current)</td>
</tr>
<tr>
<td>Pinarindi</td>
</tr>
<tr>
<td>Cardigan</td>
</tr>
<tr>
<td>Springvale</td>
</tr>
<tr>
<td>Burdekin</td>
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<tr>
<td>Charleville</td>
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<td>Torrens Creek</td>
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</tbody>
</table>
Validation and parameter evaluation

All models require extensive validation and evaluation of parameters during their development. These two processes must be separated by using independent data sets for these two phases.

Validation of the model will be approached at two levels. Firstly, new or modified model components can be tested with measured inputs. For instance, using measured hydrology and cover, the predictions of the erosion components can be tested against a measured soil loss data set. The second level is the overall validation where only end-user inputs (eg climate and management) are used in the model and model outputs (soil loss and runoff amounts) are compared with measured values.

Projected outcomes

LAMSAT aims to introduce quantitative assessment of land degradation into the land management debate for the semi-arid tropics. As a simulation model, LAMSAT may be used to examine the cumulative soil erosion for periods of over one hundred years. This permits realistic predictions of the erosion risk for a land management option given the highly variable climatic sequences. Only via such a modelling process can the results of costly field experiments be extended beyond the experiment's 'climate window' and to other locations.

End users of the model will include state and territory agencies with responsibility for managing lands in the semi-arid tropics. The 'product' will be a parameterised computer model with a plain English manual. The model will also provide a framework which identifies the strengths and weaknesses of our knowledge of land degradation in this environment. Models have an important role in communication. Knowledge accumulated at the field sites can be transferred through use of the model.

Acknowledgments

The project is supported by the Land and Water Resources Research and Development Corporation, CSIRO Division of Soils, Queensland Department of Primary Industries, the Conservation Commission of the Northern Territory and the Northern Territory Department of Primary Industries and Fisheries. The authors gratefully acknowledge the assistance of the researchers in the latter four organisations for permitting access to the data set out in Table 1.

References


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CHAPTER 21

SPECTRAL ASSESSMENT OF RESIDUAL RANGE CONDITION IN CENTRAL NORTHERN TERRITORY

Susan Ringrose and Wilma Matheson

Introduction

Little analytical work to date has been published from Thematic Mapper (TM) imagery in Northern Australia although examples from similar environments can be found from other parts of the world. Information and experience exists in various government departments, particularly in the Northern Territory. Work on rangeland applications in the arid zone have been undertaken by a number of authors using Landsat Multispectral Scanner (MSS) data, eg Pickup & Puran (1987); Onetz et al (1988). Because of the pixel (resolution) size, (30 x 30 m) considerably more data are obtained per unit area on Landsat TM (relative to Landsat MSS). The factors of cost (and earlier, data unavailability) have been major impediments to the use of TM imagery in the past. Future operational work on rangeland condition may concentrate on the use of TM data for problem areas, while undertaking a broader sweep using, for instance, NOAA AVHRR data (1.1 km x 1.1 km pixels). This work is particularly timely as it should add to the data base for rangeland monitoring required to implement the Pastoral Land Act 1992 in the Northern Territory.

Whereas indicators for range condition can best be assessed by comparing wet season and dry season imagery, the most critical time in terms of pasture management and carrying capacity occurs towards the end of the dry season (Tothill & Mott 1985). Dry season indicators of range condition (using Landsat MSS) have been broadly defined in terms of live (green) tree, shrub and herbaceous cover (as surrogates for edible browse and grass species). Difficulties arise in separating out herbaceous species from woody plant cover types on 80 x 80 m resolution data.

To determine the value of Thematic Mapper imagery in an assessment of dry-season range condition, the present preliminary analyses entailed work on a 30 x 30 km area in central Northern Territory referred to as the Barkly area. This included a combination of fieldwork, aerial photograph interpretation, Landsat derived (6 channel) TM data and 4 channel radiometer data specifically to consider:

1. the spectral characteristics of the first four TM channels in the Barkly area in four biophysical areas;
2. the spectral separability of vegetation and soil using radiometer data and site specific vegetation-cover trends;
3. image analysis techniques necessary to separate out residual vegetation from the dominantly soil reflectance background.

Background literature

A number of authors analysed data content on seven channel TM imagery to produce combinations specifically for vegetation detection. Despite published data on identifiable features on specific channels (Table 1), actual feature discrimination differs in different environments. Stenback and Congalton (1990) produced six preferred combinations each of which included TM5 to help detect the presence of vegetation understoreys, with a mapping accuracy of 55-69 percent.

Peterson et al (1987), using airborne TM data in Oregon, observed a strong relationship between the Leaf Area Index (LAI) of closed coniferous forest stands and a ratio of the near infrared band (TM4) and the chlorophyll absorption band (TM3). This relationship can be useful in areas where near infrared (NIR) reflectance greatly exceeds chlorophyll absorption, otherwise the use of vegetation index ratios is often negated by the darkening effect (eg Ringrose et al 1989).

A number of authors have either used colour composite or classified TM data for vegetation mapping in different parts of Australia including the Northern Territory, (eg Corner 1990; Orr & Morgan 1990). Mostly TM imagery has been found useful for detailed (1:100 000) vegetation mapping compared with 1:250 000 using MSS data.
TABLE 1 Characteristics of the TM spectral bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (μm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45–0.52 μm (blue)</td>
<td>Provides increased penetration of water bodies as well as supporting analyses of land use, soil, and vegetation characteristics. The shorter-wavelength cutoff is just below the peak transmittance of clear water, while the upper-wavelength cutoff is the limit of blue chlorophyll absorption for healthy green vegetation. Wavelengths below 0.45 μm are substantially influenced by atmospheric scattering and absorption.</td>
</tr>
<tr>
<td>2</td>
<td>0.52–0.60 μm (green)</td>
<td>This band spans the region between the blue and red chlorophyll absorption bands and therefore corresponds to the green reflectance of healthy vegetation.</td>
</tr>
<tr>
<td>3</td>
<td>0.63–0.69 μm (red)</td>
<td>The red chlorophyll absorption band of healthy green vegetation which represents one of the most important bands for vegetation discrimination. It is also useful for soil-boundary and geological boundary delineations. This band may exhibit more contrast than bands 1 and 2 because of the reduced effect of atmospheric attenuation. The 0.69 μm cutoff is significant because it represents the beginning of a spectral region from 0.69 to 0.75 μm, where vegetation reflectance crossovers take place that can reduce the accuracy of vegetation investigations.</td>
</tr>
<tr>
<td>4</td>
<td>0.76–0.90 μm (reflective-infrared)</td>
<td>For reasons discussed above, the lower cutoff for this band was placed above 0.75 μm. This band is especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil-crop and land-water contrast.</td>
</tr>
<tr>
<td>5</td>
<td>1.55–1.75 μm (mid-infrared)</td>
<td>This band is sensitive to the turidity or amount of water in plants. Such information is useful in crop drought studies and in plant vigor investigation. In addition, this is one of the few bands that can be used to discriminate between clouds, snow and ice, so important in hydrological research.</td>
</tr>
<tr>
<td>6</td>
<td>2.08–2.35 μm (mid-infrared)</td>
<td>This is an important band for the discrimination of geological rock formations. It has been shown to be particularly effective in identifying zones of hydrothermal alteration in rocks.</td>
</tr>
</tbody>
</table>

Source: after Maier 1987.

Study area

Whereas ultimately more of the Northern Territory will be analysed, an initial study area in the centre was chosen for preliminary analysis. At about 19°30' south, rainfall, hence vegetation cover, was intermediate in terms of the range of available conditions in the Territory. Rainfall in the Barkly area ranges from 400–600 mm/yr. The area although actively ranged throughout is characterised by a diversity of topography, soils and stocking conditions.

The area comprised part of the semi-arid transition zone between the Barkly tablelands to the north and the eastern part of the Tanami Desert. The area comprised 900 km² centered on 19°20'S and 135°50'E (Fig 1). Thematic Mapper data was obtained on high density diskettes from the Australian Centre for Remote Sensing as part of the northwest quadrant of Path 101 Row 74 dated 29/12/90. The image was preprocessed by ACRES to the 04 level which entailed full radiometric corrections for sensor calibration and across-track geometric corrections (ACRES 1991, 12–13).

On the 1:250 000 map published by Perry (1960) the Barkly area was contained within an extensive map unit. Vegetation towards the north of the unit consisted of low Eucalypt woodland with spinifex (Plectachne pungens) understorey, whereas towards the south grass with scattered shrubs prevailed. The study area was subdivided into four broad biophysical areas using 1:250 000 colour composite satellite imagery, Perry's (1960) map and Christian et al (1952) land systems mapping, geological data (Randall 1966) and field work results (Matheson 1991). These areas included:
1. The north–northwest section comprised undulating terrain of mixed silty-clay, low calcrete ridges with sandy intervening areas. The silty-clay lower panlike areas tended to support mainly grass cover (approx 10%) whereas the higher peripheral areas supported mixed grass and woodland with a total alive vegetation cover averaging between 15–20% with localised stands of much higher densities. Typical species included *Acacia georginae* and *Cassia helmsii*.

2. The north–central section comprised undulating terrain of semicircular and ovoid, partially laterised, calcrete ridges with minor evidence of solution hollows with intervening sandy areas. Traces of a paleodrainage network cross the area which supported moderately dense grass and woodland with a total alive vegetation cover of between 25–35%. Typical species included *Acacia* spp and *Atalaya hemiglauc*.  

3. The southwest section comprised a series of low-lying sand dunes with variable vegetation cover. The low amplitude longitudinal dunes were oriented northwest to southeast. They ranged in height from 1.0–1.5 m. Although covered with grass and woodland, densities varied mostly due to past burning patterns. Total alive cover however ranged between 35–45%, making this the densest part of the entire area. Typical vegetation included a range of *Acacia* spp and *Eucalyptus* spp.

4. The southeast area consisted of non-linear hummocky dunelike features and laterised calcrete ridges crossed by low longitudinal dunes. Most of the area was covered by moderately dense grass and woodland which ranged in density from between 25–35% total alive cover. Typically *Acacia* species were most prevalent.

---

**FIGURE 1 Location of the Barkly area**
Methodology

Four main approaches were taken to accomplish the objectives: fieldwork, aerial photograph interpretation, ground radiometry and digital analysis of spectral data. Fieldwork took place during December 1990 to coincide with the satellite overpass. Data collection from field sites entailed six transects through a 160 x 160 m area. Along each transect records were taken of vegetation species, canopy cover, herbaceous cover, soil and topography. Details of methods used can be found in Ringrose and Matheson (1987).

Ground radiometry was accomplished using a handheld Exotech 100BX-MTS radiometer. Readings were taken at 1.0 m above soil and vegetation targets on still, cloud free days within two hours of local solar noon. Digital analysis was undertaken using two PC based software packages, namely MicroBRIAN (Harrison & Jupp 1990), and ESIPP (Bahlia & Taylor 1990).

Data analysis

Data content was determined using MicroBRIAN software specifically aimed at evaluating the first four TM bands to determine how these differed in the four biophysical areas. A summary of the results is shown in Table 2. TM1 and TM2 provided relatively low contrast imagery partly because of the haze while feature differentiation was consistently better in TM3 and TM4.

A series of cross plots were generated to show the relative data content in two-dimensional space where the data size (n) equalled 249,001 pixels. The results of cross plot analysis are shown as Figure 2. Consistently throughout all four areas maximum variability was found between TM1 and TM4. Least correlation was found within the sand dune area probably resulting from the higher vegetation cover. The overall spectral similarity of the four sub-areas was evident and probably due to consistent and dominant sand reflectance as sand colour and type varied little throughout the study area.

| TABLE 2 Visual evaluation of data content and histograms for four biophysical areas: Barkly |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Channel        | Overall Clarity | Overall Feature | Feature Type    | Histogram       |
|                | Clarity         | Recognition     |                 |                 |
| NW-1           | hazy            | low             | good soil (pan) definition | unimodal skewed |
| NW-2           | hazy            | low             | soil & vegetation differentiation | unimodal skewed |
| NW-3           | clear           | high            | soil & vegetation differentiation | unimodal normal |
| NW-3           | clear           | intermediate    | soil & vegetation differentiation | unimodal normal |
| NE-1           | minor haze      | intermediate    | dark ridges     | unimodal skewed |
| NE-2           | minor haze      | low             | dark ridges     | unimodal skewed |
| NE-3           | clear           | high            | dark ridges & calcrite | unimodal normal |
| NE-4           | clear           | intermediate    | dark ridges & calcrite | unimodal normal |
| SW-1           | minor haze      | low             | dark ridges     | unimodal normal |
| SW-2           | minor haze      | low             | dark ridges     | unimodal normal |
| SW-3           | clear           | high            | dark ridges     | unimodal normal |
| SW-4           | clear           | intermediate    | dark ridges     | unimodal normal |
| SE-1           | minor haze      | intermediate    | hummocky terrain, minor dunes | unimodal skewed |
| SE-2           | minor haze      | intermediate    | hummocky terrain, minor dunes | unimodal normal |
| SE-3           | clear           | low             | some hummocks   | unimodal normal |
| SE-4           | clear           | low             | no clear features | unimodal normal |
FIGURE 2 Crossplots showing the distribution of data on the least correlated channels for four biophysical areas.

(a) A = Pans and peripheral woodland, B = Laterised calcrite ridges, C = Sand dunes, D = Non-linear and linear dunes and laterised calcrite ridges.

This overall merging of spectral response and lack of clear differentiation of vegetation and soil in terms of separate spectral bands has been noted elsewhere using Landsat MSS in dry semi-arid environments (Ringrose et al. 1989). Part of the problem is the low proportion of effective photosynthetic active radiation which was not overcome at the higher resolution of TM imagery. Total green vegetation at the end of the dry season was masked by either soil or dry grass reflectance even though individual plants may be spectrally separable.

Radiometer results

An attempt was made to determine the relative usefulness of the first four TM channels in terms of separating out vegetation from soil using radiometer data obtained from the field. The range of soil reflectance values for the area are depicted on Figure 3a. These show a gradual reflectance increase from the visible wavebands (TM1, 2, 3) to the near infrared (TM4). Results of the vegetation survey indicated that the most prevalent green canopy species included Acacia spp, Plectachne
pungens and dead wood (Matheson 1991). The reflectance characteristics of these were measured over typical soils resulting in the comparative data shown in Figures 3b, 4a and 4b. Results indicated that species such as *Acacia lysiphloia* (a woody weed) was separable from soil in TM3 as it darkens the soil reflectance. At TM4 where the plant cover is greater than 20%, reflectance is increased. Hence *Acacia lysiphloia* appeared to be separable.

**Image processing**

Initial results indicated that whereas some vegetation content was available on the first four TM bands, expanded possibilities could be explored by adding TM5 and TM7. Evidence from the literature indicated that additional information, particularly on stressed plants, could be found on TM7 (Elvidge & Portugal 1990).

**Figure 3a** Range of spectral reflectance characteristics of soils in the Barkly area using hand-held radiometer data

**Figure 3b** Spectral reflectance characteristics of increments of *Acacia lysiphloia* against 5 yr 5/6 sand using radiometer data
FIGURE 4a Spectral reflectance characteristics of increments of *Plectrachne pungens* against 2.5 yr 5/6 sand using radiometer data

FIGURE 4b Spectral reflectance characteristics of increments of dead wood against 2.5 yr 5/6 sand using radiometer data

An ESIPP software package was used to analyse six channel TM data which consisted of 1000 x 1000 pixels. Initially dark pixel (atmospheric) correction was undertaken on each band using the minimum value in each case because of the absence of dark features in the scene. This had the effect of standardising all the bands and removing visible haze. Each of the six channels were viewed individually as 800 x 600 pixel images and visually assessed in terms of their residual vegetation content relative to features identified in the field. Some residual vegetation was evident on all bands as darkened areas relative to the soil background. In terms of relative data content, TM2, TM4 and TM7 contained a higher proportion of vegetation data than TM1, TM3 and TM5. Principal Component Analysis (PCA) on TM2, TM4 and TM7 resulted in a relatively high proportion of residual vegetation data occurring on the image of the first principal component, (PC1). Channel subtraction was also
undertaken as this technique has proved useful in the analysis of MSS data (Matheson 1991). The three subtractive images which revealed good vegetation cover data on the image display were TM4–TM3, TM5–TM3 and TM7–TM3.

Finally, all of the potentially useful images were merged into a data file which contained the six original TM channels, the two best PCA images and the three subtractive channels. A series of ten locations were developed from field observations which comprised units of known green vegetation cover. Data files for the relevant areas were generated by interactively describing the relevant locations on the screen. Digital values for output pixels were printed out and regressed against known vegetation cover (Table 3). Interestingly the image data which registered the highest correlation with the ground truth data were derived from original channels TM2, TM4, and TM7, which showed significant negative correlations.

### TABLE 3 Correlation between selected channels and ground truth sites: Barkly

<table>
<thead>
<tr>
<th>Channel</th>
<th>( r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM1</td>
<td>(-.771)</td>
</tr>
<tr>
<td>TM2</td>
<td>(-.861)</td>
</tr>
<tr>
<td>TM3</td>
<td>(-.653)</td>
</tr>
<tr>
<td>TM4</td>
<td>(-.887)</td>
</tr>
<tr>
<td>TM5</td>
<td>(-.739)</td>
</tr>
<tr>
<td>TM7</td>
<td>(-.818)</td>
</tr>
<tr>
<td>COV–PC1</td>
<td>(-.775)</td>
</tr>
<tr>
<td>COV–PC2</td>
<td>(-.615)</td>
</tr>
<tr>
<td>TM4–TM3</td>
<td>(.487)</td>
</tr>
<tr>
<td>TM5–TM3</td>
<td>(.302)</td>
</tr>
<tr>
<td>TM7–TM3</td>
<td>(.466)</td>
</tr>
</tbody>
</table>

\((1)\ \text{TM2} = -304VC + 22.606\)
\[ p = .0014 \]

\((2)\ \text{TM4} = -221VC + 40.976\)
\[ p = .0006 \]

\((3)\ \text{TM7} = -594VC + 75.865\)
\[ p = .0038 \]

Image classification was then undertaken using the three negatively correlated channels. Signature files were generated from training areas located in areas of homogeneous reflectance over sites of known vegetation cover density. Class files were developed from the signature files for both the Minimum Distance (MD) and Maximum Likelihood (ML) classification transformations. Background information on the classification algorithms can be found in Mather (1987). The results of the two classification analyses are given in Table 4.

The classification results were smoothed using a 7 x 7 filter. Whereas the results appeared reasonable in terms of the distribution of vegetation cover on the ground, a comparison of the two data sets showed that the areas varied by as much as 11% (or 90 km²) in the worst case, (unit 3). Accuracy assessments over the entire area were undertaken using mapped data derived from aerial photograph interpretation. The classified images were gridded and 462 points were selected in a random stratified pattern from both data sources. Contingency tables showed an overall classification accuracy of 65% for the MD classifier and 54% for the ML classifier. The low accuracy percentages were mainly attributed to errors of omission, as the mapped detail on the TM images was far greater than the detail obtained from aerial photograph interpretation at the 1:83 400 scale. Hence classification accuracies may have been larger than those quoted. Future steps include the re-mapping of aerial photographs including the addition of more ancillary data and the integration of these with classified maps into a GIS to provide a more rigorous assessment of both classification and mapping accuracy.

### Conclusions

The Barkly area consisted of four biophysical zones described here as pans and peripheral lowlands, hummocky laterised calcrete, low elevation sand dunes and a mixed area of laterised calcrete and sand dunes. Despite morphological diversity, most of the area was overlain by red or yellowish red sand which dominated the overall reflectance thereby enabling the area to be treated as a homogeneous unit.

Hand held radiometer results indicated that soil reflectance occupied a wide but contiguous range. Specific plant species showed little separation from soil background in TM1 and TM2. Increments of plant material indicated that maximum separation (from soil) could be achieved on TM3 and TM4. Vegetative darkening was apparent on all wavebands when whole scene data were displayed. Attempts to enhance the residual (darkened) vegetation led the development of a series of transforms: a) running PCA, b) subtracting channels. Eleven channels were finally regarded as containing the greatest amount of residual vegetation cover data. Pixel values from the eleven channels and total green vegetation cover from known field sites were compared using linear
TABLE 4 Class Interpretation Including approximate vegetation densities and areas using minimum distance and calculated maximum likelihood classifiers: Barkly

<table>
<thead>
<tr>
<th>CLASS</th>
<th>COLOUR</th>
<th>INTERPRETATION</th>
<th>MINIMUM DISTANCE</th>
<th>MAXIMUM LIKELIHOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dark</td>
<td>Mostly peripheral to pan complexes comprising relatively dense vegetation cover (50% total cover) and areas of exposed laterite</td>
<td>10.71</td>
<td>47.34</td>
</tr>
<tr>
<td>2</td>
<td>Dark</td>
<td>Areas of open pans, mostly covered with grasses and shrubs</td>
<td>31.86</td>
<td>9.36</td>
</tr>
<tr>
<td>3</td>
<td>Bluey Green</td>
<td>Areas mainly peripheral to pan complexes and in hummocky zone, comprising sparse grass and woodland vegetation cover (15-25% total cover)</td>
<td>182.52</td>
<td>95.58</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>Areas mainly on sandy calcrites rich in diamicrite soils with moderate grass and woodland vegetation cover (30-35% total cover)</td>
<td>213.30</td>
<td>164.52</td>
</tr>
<tr>
<td>5</td>
<td>Purple</td>
<td>Areas mainly on sandy soils and in dune complexes with moderate-sparse grass and woodland vegetation cover (25-30% total cover)</td>
<td>16.38</td>
<td>25.38</td>
</tr>
<tr>
<td>6</td>
<td>Light Brown</td>
<td>Areas mainly in sand dunes and in hummocky zone with moderately dense grass and woodland vegetation cover (35-40% total cover)</td>
<td>59.49</td>
<td>107.73</td>
</tr>
<tr>
<td>7</td>
<td>Light Grey</td>
<td>Areas mainly in sand dunes and in hummocky zone with dense grass and woodland vegetation cover (40-45% total cover)</td>
<td>113.85</td>
<td>152.10</td>
</tr>
<tr>
<td>8</td>
<td>Dark Grey</td>
<td>Areas mainly in the pans and the sandy calcrites zones (further south), with little or no vegetation cover, also may be indicative of localised overgrazing (15-20% total cover)</td>
<td>27.72</td>
<td>30.24</td>
</tr>
<tr>
<td>9</td>
<td>Light Blue</td>
<td>Areas mainly grassland and shrubs mainly on sandy calcrites zones with moderate-sparse vegetation cover which also form part of the hummocky terrain</td>
<td>84.24</td>
<td>49.14</td>
</tr>
<tr>
<td>10</td>
<td>Light Green</td>
<td>Areas in transition zone comprising grassland and shrubs between pans and moderately dense woodland on sandy calcrite soils (25-30% total cover)</td>
<td>159.48</td>
<td>170.82</td>
</tr>
<tr>
<td></td>
<td>Unclassified</td>
<td></td>
<td>0.45</td>
<td>47.88</td>
</tr>
</tbody>
</table>

Percentages calculated based on the total area covered by each class.
regression analysis. The most highly correlated channels were the original bands TM2, TM4 and TM7 at the greater than 90% significance level. (F-test). These three channels were then used as input data for both minimum distance and maximum likelihood classification routines. Accuracy assessment of the resulting mapped data was low being 65% in the case of the minimum distance classifier and 54% in the case of maximum likelihood. The errors were mainly those of omission due to extensive detail on the TM derived map compared with aerial photograph data.

Problems arising from such procedures as the classification of TM data and the fact that most residual is contained in TM2, TM4 and TM7 indicates that colour composite images involving these three bands are most appropriate for late dry season vegetation cover monitoring. These can be compared visually or digitally with early dry season imagery to determine the extent of residual cover consumption and/or the extent of green cover regeneration. Further work needs to be undertaken in the area to determine the feasibility of this approach for detailed vegetation monitoring under the Pastoral Land Act 1992.

Acknowledgments

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CHAPTER 22

PLANNING FOR RURAL DEVELOPMENT IN ABORIGINAL COMMUNITIES: A COMMUNITY-BASED PLANNING APPROACH

Allan Dale

AEDP: the champion of Aboriginal self-determination?

The principal Federal government policy encouraging the implementation of rural development projects on Aboriginal communities is the Aboriginal Employment Development Policy (AEDP), launched by the Prime Minister in October 1987 (AEDP 1987a). AEDP forms part of the broader Federal policy of self-determination and self-management. Originally, the Department of Aboriginal Affairs (DAA), the Aboriginal Development Commission (ADC) and the Department of Employment, Education and Training (DEET) were responsible for the coordinated implementation of the policy, though the AEDP functions of the ADC and DAA have now been amalgamated into the Aboriginal and Torres Strait Islander Commission (ATSIC).

AEDP's primary aim is to achieve Aboriginal employment and income equity and reduce welfare dependency to a level commensurate to that of other Australians (AEDP 1987a, 3). Five broad implementation strategies are centred on public and private sector employment, community-based employment and enterprise, education and formal training, and inter-agency coordination and consultation (AEDP b, c, d & e). These major strategy areas were developed in accordance with Aboriginal concerns raised in the mid-1980s by the Committee of Review of Aboriginal Employment and Training Programs (Miller et al 1985). In a radical departure from previous employment programs, the Miller Report stressed that the Aboriginal community must be allowed to 'drive' policy implementation. Hence, when AEDP was finally formalised, the government declared that the pace and direction of economic change should be entirely consistent with Aboriginal aspirations:

The AEDP can only succeed if Aboriginal people themselves make the decisions about the direction and pace of change and the ways in which they will earn their livelihood.

The Government will encourage Aboriginal people and communities to formulate their own strategies and objectives, and will assist and support them to achieve the objectives and directions that they have set for themselves (AEDP 1987a, 16).

Thus, the original policy intentions of AEDP clearly championed the most basic principles of Federal self-determination and self-management policies (see HRSCAA 1990, 3).

The policy intention also directly accommodated recent theoretical developments in the planning literature that suggest that effective social planning must be bottom-up rather than top-down. Numerous workers in the field of rural economic development have now found that the common failure of third world and indigenous development projects largely arises from conflicts between the land use 'perspectives/objectives' of project donors and project recipients (eg see Bauer 1976; Turner-Ruffing 1976; Colson 1983; Rondinelli 1983; Gondolf 1986; Wolfe & Strachan 1987; Swartz 1988; Wolfe 1988b; Crittenden & Lea 1989; Söderbaum 1990). These conflicting views of land use/project goals are often cross-cultural. Thus, academics have increasingly called upon governments to help indigenous communities control their own development planning through the conduct of community-based planning processes (see Wolfe 1984; Boothroyd 1984; Wolfe & Strachan 1987; Wolfe 1988a & b).

The poor performance of AEDP-funded rural enterprises suggests that planning for AEDP implementation largely remains top-down and program-based. To explore this possibility, the planning involved in a failed AEDP-funded cattle project in north-eastern Australia was examined. Departures from three essential community-based planning principles were determined, and it was found that deficiencies in participatory and technical planning had resulted in project failure.
Community-based planning and development: some general concepts

Consideration of community development has increased in the indigenous and third world economic development literature in recent years (eg Korten 1987). However, the term is often misused to refer to any form of 'development' within a community (eg capital and infrastructural developments in Aboriginal communities are often referred to as community developments, even if they are not in line with local perceptions of community needs). Turner's (1979, 42) definition correctly stresses that community development must evolve from within the community, and facilitate the community's capacity to determine the values that orientate people's actions, and their ability to accumulate and expand these values through productive activity under their own control.

Hence, community-based planning is the term used in this paper to refer to the planning process that facilitates real community development, and consequently, long-term project success. As with all planning, the process is flexible and variable to accommodate differing planning contexts, and consequently, the many community development approaches expounded by the international development literature vary considerably. Unfortunately, there are few practical examples of community-based planning within the Australian literature. Nonetheless, Howitt et al (1990) outline an excellent approach to community-based development planning in Aboriginal communities in central Australia, while Dale (1992) discusses the community-based planning approach to resource management at Kowanyama in north Queensland. Walker (1985) makes a case for a holistic integrated development planning approach as a pre-requisite to the application of sectoral projects.

The common characteristic of all community-based approaches should be that they belong to the community and are conducted under community control. However, an examination of changes in planning theory since the 1940s suggests that community-based planning agencies, ie community councils and representative organisations, must apply three essential planning principles (see Simon 1947; Davidoff 1965; Friedman 1973, 1981; Bryson & Delbecq 1979; Masser 1983; Dorsey 1986; Faludi 1987; Susskind 1987; McDonald 1989). These principles include (i) optimised community participation; (ii) competency in technical planning; and (iii) a commitment to effective bargaining and negotiation both within the community and with external actors.

Community-based planning agencies can readily incorporate these three principles into planning for project developments in Aboriginal communities. The principles can be used to encourage the development of a sound planning environment as follows:

(i) Optimised community participation
Community participation in project planning should be holistic, integrated, and promote human capacity building and leadership. Project planning should reflect community values/priorities and effectively link decisions and actions (see Wolfe 1988, 225; Boothroyd 1984);

(ii) Competent technical planning
There is little benefit in embarking upon projects that are unable to overcome predictable technical constraints and take advantage of the available development opportunities;

(iii) Effective bargaining and negotiation
Effective bargaining and negotiation procedures must be adopted by community-based planning agencies to assist the implementation of community plans, resolve internal community conflicts, and promote greater involvement in the Aboriginal and mainstream regional, program and policy planning processes that affect communities.

Community acceptance of the community-based planning concept must remain optional. However, many communities understand that they need to be able to articulate their needs in both Aboriginal and European terms if they are to control the implementation of government policy upon them. A growing number of communities in the United States and Canada, have now been able to establish solid internal planning processes and bargaining platforms that have reinforced traditional notions of independence and self-management (eg see Pinkerton 1985; Williams & Graves 1988; LIBC 1989; TFW 1990; Ryser 1988; WPP 1988).

AEDP and the failure of rural enterprise projects

As the vast majority of Aboriginal land resources are situated in rural Australia, commercially and employment oriented rural development projects are commonly implemented in Aboriginal communities in an attempt to achieve AEDP's community-based employment and enterprise strategies. Within the AEDP bureaucracy though, there has been limited
comprehensive assessment and monitoring of the performance of such projects.

Nonetheless, there is growing cumulative evidence that the commercial and long-term employment outcomes of rural development projects under self-determination policies have been far from impressive. Indeed, the success of such development to date has been extremely limited. As Young (1988, 82) concedes:

During the past two decades a variety of economic enterprises have been established in Aboriginal communities, among them crocodile and emu farms, mining companies, cattle stations, craft ventures, clothing workshops and retail stores. Within a few years of their establishment, many such enterprises cease to exist, and people formerly involved have been thrown back into the vast pool of the unemployed, often well aware that, in the eyes of the non-Aboriginal outsiders, they alone are responsible for their failures.

There are countless other examples of failed rural development projects within the Australian literature (eg see Ellanna et al 1989, 253; Bryan & Reid 1982; Thiele 1982; Ledger 1985; Willis 1988). Tesfaghiorgis and Altman (1991, 25) reveal that between 1971 and 1986, Aboriginal employment (a key program performance indicator), declined relative to the total population. Tesfaghiorgis and Altman (1991, 27) also found that, while the economic situation of Aborigines improved between 1971 and 1986, this required the rapid escalation of Aboriginal program expenditure in real terms.

While many of these findings relate to pre-AEDP projects, there is growing evidence from recent government-based inquiries and reviews to suggest there have been few improvements in project performance under AEDP (see HRSUAA 1988, 1989 & 1990; AAO 1989a & b). Also AEDP program guidelines have not changed significantly from pre-AEDP times, and some inherent contradictions in AEDP strategies may have already limited program effectiveness. These include the growing number of young Aborigines, the great economic disparities between urban and remote Aborigines and the low chance of achieving employment equity in remote areas given Aboriginal resistance against migration to labour markets (Tesfaghiorgis & Altman 1991, 27).

If commercial demise is the general result of implementing AEDP-funded rural development projects, then the impact of project failure upon the recipient client or community must be an important consideration. It is difficult for any Aboriginal individual or community to bear the blame for the failure of government funded projects for which they are responsible. Project failure can damage community and personal pride and result in great financial loss for project recipients, personal hardship, and further degradation of already scarce land resources (Dale 1989, 9). It perpetuates economic dependency upon government welfare, and this may result in declining health, increasing substance abuse and reduced self-esteem.

We have already seen that AEDP originally intended to encourage Aborigines to set 'their own pace' for development. However, not only have AEDP-funded rural development projects generally failed (and resulted in the afore-mentioned negative impacts), but AEDP also envisages Aboriginal socio-economic equality with mainstream Australians by the year 2000 (AEDP 1987a, 3). This imposition of a government target on the rate of economic change that was to be decided by Aborigines, casts some doubt on the integrity of the policy's concern for self-determination. Both these factors suggest that instead of supporting community-based development, planning for AEDP implementation is top-down and program-based. If this is the case, then AEDP implementation is largely contrary to the original Miller intentions and recent developments in planning theory.

To explore the possibility that AEDP implementation for rural development projects is top-down and program-based, this paper examines the planning conducted for a failed pastoral project in the Aurukun Aboriginal community in north Queensland. The examination determines where planning for the project has departed from the three primary community-based planning principles, and illustrates how these departures have led to project failure. Where project planning has adhered to these principles, the positive effects on project outcomes are also illustrated.

While only the Aurukun Cattle Project is detailed in this paper, the results represent just one of nine AEDP-funded rural developments examined by the author in northern Queensland. In each project, the departure and adherence of project planning from community-based planning principles was examined, and the influence that this has had on project outcomes determined. To date, few workers have accounted for the almost universal failure of Australian Aboriginal enterprises under self-determination policies (Ellanna et al 1989, 253). Thus, this research aims to impress the importance of community-based planning upon those
government agencies responsible for AEDP implementation.

Methods

To examine the Aurukun Cattle Project's departure and adherence to the three essential community-based elements and the influence of this on project outcomes, two primary research methods were used (given community consent). However, these methods first depended on the establishment of a comprehensive data base for the Aurukun community. This comprised detailed descriptions of those factors considered relevant to the operation of the cattle project. Data collection depended upon spending considerable time in the Aurukun Community, and during the course of the research, three main phases of field work were conducted between 1987 and 1990: pre-planning, data collection and analytical revision.

To determine the nature and influence of community participation and bargaining on project outcomes, it was necessary to develop a method termed Strategic Perspective Analysis (SPA) to qualitatively establish the nature of these two planning principles within the rural development planning process. SPA is based on modified components of strategic planning, (see Ascher & Overholt 1982) and position analysis (see Soderbaum 1976, 1990a & b). It first establishes whether effective and appropriate participatory planning techniques and bargaining procedures have been applied to project planning. The influence of these procedures on project outcomes can then be determined. Lane et al (1990) briefly outline the rationale and conduct of the SPA method.

To determine the influence of the third planning principle (technical planning procedure) on project planning, no new methods were required for analysis. Those analyses used were firmly grounded in the technical project assessment disciplines of agricultural science and land resources management. Technical assessments of project performance were first related to the project targets established by government policy (ie commercial viability, employment and training etc). Deficiencies or strengths in the technical planning procedures undertaken in project planning (identified within SPA) were then related to these project outcomes. These technical analyses utilised information from the community data base.

In brief, a number of specific areas of technical analysis were considered. A financial analysis was conducted on the project from a purely commercial viewpoint. The efficacy of resource usage and project management was also determined. General technical constraints and opportunities facing commercial viability and other AEDP objectives were outlined. From this information, the ability of technical planning to overcome constraints and take advantage of opportunities was identified, and its influence on project outcomes determined.

The Aurukun Community Incorporated and the Aurukun cattle project

Aurukun Shire, (in Cape York Peninsula), covers a large land area (750 000 ha) and offers a plethora of renewable land resources. It is remote, and consequently, residents of the Aurukun township (members of the 'Wik' nation) still hold strong traditional affiliations to land in the Shire. The Wik experienced a mission-based history and suffered repeated attempts at assimilation through church-funded rural development projects till the early 1970s. Until 1989, the Federal government funded the Aurukun Community Incorporated (ACI) to run a major pastoral project in the southern part of the Shire. ACI is an incorporated Aboriginal Company (established in 1974) and its board of 20 directors are said to represent all the clan groupings within the Aurukun community.

The Aurukun cattle enterprise

The Federal government's AEDP involvement in the Aurukun cattle industry sought to increase Aboriginal employment, establish a long-term, viable economic base, develop economic independence and improve self-determination and self-management for the Wik. In the late 1970s, all cattle existed in a feral state as management had been neglected since the collapse of the mission-industry in 1974. As a high proportion of stock was TB infected, in 1980, the Queensland Department of Primary Industries (DPI) forced ACI to commence a cattle eradication program under the Brucellosis and Tuberculosis Eradication Campaign (BTEC).

Under a DPI-approved cattle destock program, it was originally intended to retain 2 000 to 3 000 head of tested, TB-free breeding stock behind secure management paddocks. The remaining feral herd was to be eradicated using DPI BTEC compensation provisions for non-marketable stock and the sale of suitable destock animals direct to the meatworks. The destock/restock operations were to be completed by the end of 1988, after which, the DPI was to conduct a controlled shootout of remaining feral cattle in unfenced areas. Throughout the destock/restock period (1979–1989), the cattle
operation consisted of ACI coordination of contract mustering teams and DPI shooting crews. ACI's own Cattle Team (consisting of a European Cattle Manager and some 10 Wik stockmen) was charged with management of the retained TB-free domestic breeding herd.

The actual performance of the project fluctuated over this period. At the start of the BTEC program (1979/80), cattle revenue was received for the first time in ACI's history, but operations were sporadic and disorganised. In these early years, there was poor control over ACI ground operations and external contract crews. Contract teams are believed to have profited enormously before tighter controls were enforced in the mid-1980s.

ADC grants and profits from ACI's general store propped the industry up prior to the receipt of full BTEC compensation in 1984/85, but after this, most profits were derived from compensation receipts. Massive ADC enterprise loans were also given on the assurance of BTEC compensation. DEET grants for stock wages were important, though the project could have traded profitably without them.

After full DPI compensation commenced, compensation payments averaged $380 000 over the ensuing four years, resulting in the first profits being made from the project. The importance of compensation relative to the value of cattle trading fluctuated though, compensation income being less then the trading figures in two of these four years. Trading figures remained consistently high for the remainder of the destock operation because of the operational controls they both imposed. This resulted in the strong physical performance of the approved BTEC program, with some 22 000 feral cattle being removed between 1983 and 1988.

At the end of the 1988 season (and with the BTEC compensation profits) the ACI cattle industry was in a position to make the last of its loan repayments to the ADC, well before the end of the original terms. However, a total destock order was enforced by the DPI in December 1988 after several TB reactors were found in the TB-free domestic restock herd. This order crushed any prospect for the long-term survival of the Aurukun Cattle Project. However, in the short term, ACI had managed to marginally improve the economic independence of the Aurukun community, both through massive capital investments in the community between 1984 and 1988, and through reserving $500 000 in cash upon its completion. This will give ACI some flexibility in deciding future economic options. However, it should be remembered that these profits have simply arisen from the conversion of existing ACI cattle assets into liquid and capital assets.

The destock order also crushed the long-term employment and training objectives espoused by vocational agencies like DEET. Before this though, ACI's cattle industry employment and training schemes suffered very high turnover rates and did not provide an effective training opportunities for young Aborigines. Overall training and employment outcomes from the project were poor. The project also provided no significant advances towards the achievement of the broader policy of long-term Aboriginal self-determination. Apart from full Aboriginal representation on the ACI Board, few local people were directly involved in the operational management of the cattle industry. However, through their involvement in ACI, Aboriginal directors were able to experience the management difficulties facing enterprise operations in northern Australia.

Hence, there were some positive short-term and disappointing long-term outcomes to the ACI cattle project from the viewpoint of government policy. It is suffice to say that many of the government's original AEDP intentions were not achieved by the time the project collapsed in 1989, (particularly long term viability and employment and effective enterprise training). Given these project outcomes, the nature of the three critical planning principles are outlined below. Their appropriateness and efficacy in relation to project planning is outlined, and their influence on project outcomes determined.

Community participation and its influence on project outcomes

There have been both effective and ineffective aspects to community participation in planning for the design and implementation of the Aurukun cattle project. While ACI is directed by a board of 20 Aboriginal directors that represent all clan groupings with traditional affiliations to land in the Shire, it is not an effective corporate structure for encouraging community participation in land use decision making. Indeed, in the early 1980s, the ACI Board was clearly not a united body of clan representatives seeking a common corporate vision of commercial development within the Aurukun Shire. In 1983, a consultant to ACI suggested:

ACI appears to be an artificial European structure superimposed on a community which enjoys little or no identification or loyalty from either the directors or the broader community (Edgerton 1983, 10).
To support this, he stated that the directors regarded their role primarily as an opportunity to extract from the system the maximum amount of benefits and government money for their immediate family and clan. The consultant felt this behaviour was rational given the rubber stamp role they had become accustomed to playing under ACI's European administration. A pattern had developed where directors were consulted on trivial matters and excluded from major policy considerations. Confusion was rife as to the representativeness of the board and the directors seemed unaware that ADC loans were not grants-in-aid. They were also not properly informed of the overall monetary performance of the Company (Edgerton 1983, 10).

With a nominal Aboriginal company established as a target for the receipt of Federal commercial development funding (see Dale 1990, 2), it is easy to understand how the cattle project was initially established on a very poor participatory basis. As ACI was effectively a vehicle for the implementation of European administrative policy ideals upon the Wik, under BTEC rules in the early 1980s, the DPI was forced to impose particular conditions upon the Aurukun Community and ACI. Reform within the Aurukun cattle operation had become a State government priority because of the high incidence of TB on the property. If Aurukun failed to embark upon a government approved TB eradication program, it faced a complete de-stock without compensatory benefits.

Faced with this daunting option, ACI could either conduct its own complete de-stock with compensation, or attempt to establish an ACI controlled, commercially viable cattle enterprise in the southern part of the Shire. However, most of the Wik retained strong traditional ties with clan estates in this area, and these lands formed the resource base of the Aurukun outstation or homeland movement. Before BTEC, feral cattle were a central protein source and acted as important social capital for these outstation groups (even though all stock belonged to ACI in legal terms). Many outstation groups had participated in the pre-BTEC, decentralised, non-commercial cattle enterprise as their involvement legitimised traditional claims to land/cattle and encouraged the expenditure of government resources on outstation development (see Martin 1984).

Thus, the ACI directors were forced to select the second option as the Wik already had a long association with the mission cattle enterprise and were reluctant to see all the cattle in the Shire eradicated. Many directors felt that outstations would be able to re-establish their own decentralised cattle herds once the BTEC program was completed in 1988, and in later years, ACI management promised that it would help outstations achieve this. In the meantime though, the decision to establish a centrally controlled, corporate and commercially viable cattle industry superimposed an European notion of resource development upon traditional owners. This conflicted with the basically traditional land management principles held by most ACI directors and outstation groups. Hence, there was effectively no community participation in the decision as the BTEC imperative simply provided no acceptable alternative.

Being the provider of funds (and until the ACI became self-funding in the late 1980s) the ADC was able to demand that the Company operate within guidelines that ensured the economic viability of the project, (whether it suited the non-commercial objectives of the Wik or not). Hence, the Commission exerted significant control over ACI action. Given its poor economic performance up till 1983/84, if further funding was to be forthcoming, ACI was required to employ a competent European General Manager, the destock program was to be taken over by a competent Cattle Manager, and later, an agricultural consultant was to be used to develop a technical management plan for the project. Given that there was often no alternative funding source for Aboriginal organisations like ACI, these were common control mechanisms used by the ADC to ensure the economic imperatives of rural development projects were met.

Under terms of reference established by the ADC, the consultant conducted technical planning in close consultation with both the ACI's new Cattle and General Managers. Although the consultant occasionally addressed board meetings, the main input from the directors only came in deciding upon the final development options that he proposed. Under the terms of BTEC though, the selection of options that favoured strict economic control were always a foregone conclusion. Economic viability for the operation was paramount for the ADC, and technical decision making was conducted on a consultative rather than participatory basis (consider the findings of the HRS/CA 1990, 47–57). Similarly, DPI representatives frequently consulted directors at board meetings, fully informing them of BTEC requirements.

Given ADC and ultimately DPI control over the enterprise in the mid-1980s, it is not surprising that the ongoing operation of ACI was not based on Aboriginal community control. Owing to government concern about the 'accountability' of the Board, the 1983/84 appointment of the current
General and Cattle Managers sought to impose commercially rational planning procedures upon ACI. Both managers had a clear mandate to ensure the viability of the cattle operation, a situation the ACI directors were forced to accept if they were to retain their company, cattle, BTEC compensation and government funding.

To break down the system of manipulation and dealing that existed in ACI prior to 1984, the new General Manager placed strict monetary controls on directors and ACI’s European staff. However, while he maintained fiscal control over all ACI operations, the directors continued to bargain with him for the resources required by their respective clan groups (particularly for outstations). Hence, the General Manager acted as a broker between the community and bureaucratic arena, though his role as commercial controller of ACI enterprise favoured patronage to external funding agencies. His position was dependant on ACI’s commercial accountability, and indeed, this was easier to achieve than being accountable to the conflicting demands of a number of competing clan groups.

Despite attempts by the General Manager to inform directors to enable them to make effective corporate decisions about the cattle project, there were a number of limitations constraining them from fully controlling ACI decision making: (i) directors had trouble coming to terms with complex technical and financial issues (though this improved after the conduct of a number of courses aimed at helping them understand their roles and responsibilities); (ii) the profile of directors on the board changed continually, and there was not always an even distribution of power among the clans represented; (iii) bulky and trivial information about project development was not always presented to directors; and (iv) meetings were run by the General Manager in English, at best, the second language of most directors. Consequently, when the board made decisions as a corporate entity, the directors tended to follow the economic rationale of the General Manager, rather than broader Wik philosophies.

The ACI General Manager controlled most enterprise specific decisions, and the DPI appointed Cattle Manager operated under his direction. However, the Cattle Manager had extensive experience in BTEC destocking and had close associations with the DPI, neighbouring property owners, transport companies and cattle contractors. Many of his decisions were based on direct negotiations with these non-community actors. Because of this and the physical isolation of the cattle enterprise from the Aurukun township, the Cattle Manager significantly influenced cattle operations on the ground. His actions were not always in accordance with ACI management and the board, and they reflected the predominant economic rationality of cattle production and disease control.

The Cattle Manager exerted operational control over contract teams and was ‘boss’ for the Wik stockmen on the ACI Cattle Team. Older stockmen from the mission era were the only permanent stock hands, and they generally appreciated working for the Cattle Manager as he was strict, consistent, reliable and able to organise their living requirements. Younger stockmen often resisted European stock camp authority. However, as Aboriginal stockmen only played a minor role in the project’s implementation, subtle sabotage through poor work efficiency and absenteeism had little effect on the overall economic efficiency of the destock/restock program. Although there was an average of ten workers at cattle camp prior to 1989, labour turnover was extremely high and hence training continuity was poor.

Some of the reasons for the high labour turnover rate are worthy of mention. Many young workers frequently sought to return to the canteen and their spouses in Aurukun. The need to attend ceremonies, avoid poison relatives and fulfil responsibilities to country also made working under a European work schedule difficult. Many found it difficult to cope with the European management factor and there was some dissatisfaction with cattle wages compared with the work conditions available under Aurukun’s Community Development Employment Program (CDEP). Under the stress of getting BTEC completed, ACI management was unable to make the workplace more acceptable to Wik perspectives.

It is interesting to note that the ground-based DPI cattle shooting team independently developed close relationships with relevant clan leaders before working on particular clan estates. Apart from informing and allowing clan leaders to have an input in work programs, they often ensured that someone with knowledge for particular tracts of country worked with them in the field. This concern for Aboriginal sites and land management values earned them strong respect within the community, despite their role being potentially offensive to Aboriginal people. While non-DPI contract mustering teams had little to do with outstation groups, they were required to respect sites under the terms of their contracts with ACI, and they often provided emergency assistance to outstation groups.
ACI's Use of Participatory Procedures to Avoid Land Use Conflict

The Aurukun cattle project was given precedence over other land uses in the southern part of the Shire because of DPTI's disease control priorities and the economic imperatives of ACI. However, the overall conflict with the traditional land use perspectives of clan groups remained. The basis of conflict revolved around ACI utilisation of clan estates with the consent, (but not necessarily the approval), of traditional owners. Indeed, the BTEC destock/restock program imposed many limitations on the preferred lifestyles of those outstation groups whose clan estates fell within the boundaries of the cattle project.

From the disease control viewpoint, without the full support of outstation groups, a threat to the disease-free security of the paddock-bound re-stock domestic herd existed. Indeed, paddock security was breached by outstation users on a number of occasions, and paddock management was occasionally affected by traditional burning without ACI approval. The 1988 failure of the BTEC program may have resulted from such breaks in paddock security, which in turn reflect this inherent conflict. ACI was never able to fully resolve the overall conflict, though in the shorter term, it was able to lessen its impact on project outcomes through the application of a number key participatory planning mechanisms.

To at least partially appease the conflict, ACI negotiated grazing agreements with individual clans with assistance from a resident anthropologist in 1986. The Company was not required to make this arrangement under European law, and the agreements were not legally binding. Indeed, when legal proceedings were lodged against the Company in 1987, it exerted its legal right to over-ride excessive compensation claims for the use of Wathanin as the centre of previous musters. These proceedings were lodged by the Wathanin Clan Leader (Statement by Acting General Manager, ACI, to Aboriginal Development Commission, 19 October 1983).

This particular conflict originated from the Wathanin Clan Leader's dissatisfaction over the replacement of outstation-based mustering crews with European contract mustering teams after the appointment of the current Cattle Manager. On the 14 June 1983, the ACI Board resolved to pay the Clan Leader $10 000 compensation and agistment fees on a once only basis, but the decision lapsed after the appointment of the current General Manager. In 1987, the matter was resolved on the steps of the Cairns District Court as the solicitors of both parties agreed that ACI was fully within its right to proceed with its operations without having to pay any form of compensation to traditional land owners (Bill Whiteman, pers comm, 1992).

To ward off future claims, ACI also agreed to pay $1000 annual agistment/compensation to each outstation group that signed the 1986 grazing agreements. Payment was made to the ACI-based Outstation Support Group (the service arm of the outstation movement) rather than individual outstations, and its expenditure was decided by ACI directors. Although Wathanin did not sign an agreement, it still received compensation. The Company also stressed that it provided other benefits to outstations, including improved road access, water supply and airstrips and increased on-site employment opportunities.

The payment of this type of compensation was an unprecedented overhead for a cattle operation in Queensland. Considered against the poor longer term income potential of a re-stocked cattle operation at Aurukun, it posed a major constraint on commercial viability. However, the negotiated compromise between ACI and the Wik outstation groups created a political basis upon which the industry could operate on a commercial basis.

Conflict also began to arise between the burning practices of traditional owners and the operation of the cattle project after 1986. The Wik often used fire to socialise the landscape and as a key component of subsistence resource management. (When the clan land has been burnt for a considerable time, the Wik often say that it has 'gone wild'. Burning represents a human responsibility to 'look after' country and reinforces traditional claims to land.) Once TB-free cattle were used to re-stock well defined operational paddocks, 'uncontrolled' burning began to pose a severe threat to paddock management. In 1988, a traditional burn in the Kencherang paddock destroyed all available pasture. Such events seriously disrupted paddock management plans, though ACI was never able to negotiate a compromise solution with traditional owners.

When localised conflict occurred over damage to Aboriginal sites and the actions of the ACI Cattle Manager, the General Manager would effectively negotiate compromise solutions. For example, in one instance, ACI paid $1000 compensation to traditional owners for damage to a 'story place' during road construction in 1983 (Aurukun Shire Council Minutes, 14 June 1983).
The influence of participatory deficiencies: a summary

The Aurukun cattle project essentially sought to fulfil the BTEC destock imperatives of the DPI, and the commercial and training perspectives of ACI management and associated AEDP funding bodies. While this occurred with the corporate consent of ACI directors, the project was not completely compatible with the perspectives of traditional land owners. Despite the conflict, the project was able achieve its destock and short-term commercial objectives for two, somewhat contradictory, reasons.

Firstly, direct operational control over the project was maintained by ACI's European management and external funding agencies. While this allowed the project to achieve its objectives in the shorter term, with no firm Aboriginal community commitment to the project concept, it would be likely that the operation of ACI would have again collapsed with the departure of the current General and Cattle Managers. While the retention of this form of project control may suit economic rationalists, it falls short of self-determination's claim that Aboriginals should decide 'their own way' of living.

Alternatively, ACI's European management effectively used a number of participatory planning mechanisms to resolve land use conflicts while seeking to achieve its commercial mandate. Directors were consulted and well informed of the technical facts, and traditional land ownership was formally recognised via ACI grazing agreements. This facilitated the ability of clan groups to bargain and negotiate with ACI over specific land use issues.

While ACI's European management maintained control over the project, in the shorter term, these participatory planning mechanisms smoothed over potentially destructive conflicts between the cattle operation and clan groups. The participatory mechanisms used, however, did not go far enough to create a lasting resolution. While the project finally collapsed as a result of a technical factor (TB infection of the restock cattle), the possibility exists that breaches in paddock security resulted from this integral conflict.

Bargaining among actors within and external to the community

While ACI's economic imperatives conflicted with the traditional land use values of outstation groups in the south of the Aurukun Shire, the Company's European management team ran an effective commercial operation that was based on effective bargaining with actors both within and external to the community. Indeed, the General Manager was largely able to minimise the basic cattle enterprise/outstation conflict because of his interpersonal bargaining skills within the Aurukun community.

When individual or coalitions of directors considered that cattle industry activities would directly impinge upon their clan concerns, then they would bargain directly with the General Manager in ACI Board meetings. The need to bargain primarily arose over issues affecting outstation groups. Extensive interpersonal bargaining also occurred in the lead-up to and following these meetings.

The bargaining skills of ACI management also extended beyond the community. Despite DPI's ultimate control, the General Manager's bargaining skills successfully secured extensive Departmental support for ACI's attempts to establish a viable, TB-free enterprise within the guidelines of an approved destock program. DPI staff worked closely with ACI management throughout the project, and they were heavily involved in technical project planning and implementation. All contracts with external mustering teams were also well negotiated and monitored.

The political need to establish a TB-free industry also put ACI in an unusual position of bargaining strength, allowing the General Manager to seek greater command over the ADC's expenditure priorities. As the Commission already had a long history of involvement in the project by the mid-1980s, it would have been politically embarrassing for it to be seen to be responsible for the collapse of an Aboriginal cattle operation that posed a TB infection threat to adjacent stations. If the destock program failed, the resultant 'white backlash' also would have affected ADC attempts to purchase cattle leases in the district. At the time, the failure to purchase Archer Bend for the Winchanam group had made property acquisition in Queensland a political priority within the Commission. Hence, in the late 1980s, the ADC became heavily committed to supporting ACI as the Company demonstrated a high commercial potential. This was illustrated at an ACI board meeting in 1988, when an ADC Project Officer stated:

The Company had made remarkable progress over the past five years and was an example of success to other Aboriginal organisations. ACI was one of the most successful organisations in Australia and the

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To enhance the ACI's bargaining position as a cattle producer in Cape York Peninsula, the General Manager also ran for, and was elected as President of the Peninsula Branch of the Cattleman's Union in the late 1980s. In this role, he was able to negotiate speedy resolutions to several issues of threat to the ACI cattle enterprise (eg constantly changing BTBC compensation rates and delays in the receipt of compensation payments). This bargaining position was boosted by the Queensland cattle industry's high regard for the destock abilities of the ACI Cattle Manager.

These bargaining strengths were central to ACI averted the collapse of the project on a number of occasions, and ensured the enterprise was able to operate within a political environment that suited commercial viability. Had the Company not operated as effectively on this basis, the short-term gains achieved would not have been possible, and it is likely that the DPI would have enforced a complete destock order without compensation sometime in the mid-1980s.

Technical planning and its influence on project outcomes

Failure to get the cattle project operational before 1983 primarily resulted from ACI's ad hoc and ineffective technical planning abilities, and the poor technical advice offered to it by government departments. A number of feasibility studies were conducted by short-term agricultural consultancies, but these were unable to adequately address the political and technical constraints facing cattle production at Aurukun. These technical assessments were commonly only concerned with project design, rather that making appropriate implementation recommendations and providing adequate monitoring to ensure effective implementation. Like many consultancies in Aboriginal communities, they discussed the type of development that was desirable from the viewpoint of the government, but ignored what was possible in the socio-physical environment within Aurukun Shire. At that stage, ACI did not have the managerial capacity to conduct competent technical planning, yet DAA and, later, ADC assessments of funding submissions never identified these deficiencies.

After 1983/84, ACI operated as an effective commercial operation, as its activities were finally based on sound technical planning. This was made possible through the combined technical planning skills of the ACI Cattle and General Managers, and the competent technical consultancies conducted by the ADC appointed Agricultural Consultant. Sound technical planning enabled ACI to conduct an effective destock operation and eventually stockpile $500,000 by 1989.

However, a number of insurmountable technical constraints on the operation of the destock program meant this final stockpile figure was lower than it could have been. While the project planning conducted by ACI after 1983/84 was highly competent technically, it was still unable to predict bureaucratic changes in BTBC compensation rules. Also, if the ACI board had had access to better technical advice before 1983, it may have decided to commence a complete destock instead of attempting to establish a TB-free commercial operation with a high probability of disease re-infection and subsequent quarantine.

Conclusions: some implications for AEDP planning

The positive and negative outcomes of the AEDP-funded Aurukun Cattle Project depended on the nature of project planning conducted by the responsible community-based planning agency (ACI). The lucrative short-term commercial success of the project resulted from certain positive aspects in ACI's approach to community participation, and the application of effective bargaining and technical planning procedures after 1983. However, the cattle industry collapsed in 1989 because of ongoing deficiencies in participatory planning, early deficiencies in technical planning and inadequate ACI bargaining abilities before 1983. Training and employment outcomes for the Wik were always limited, and the Aboriginal community neither initiated the project or controlled project planning.

Eight other AEDP-funded rural development projects have been examined by the author at Woorabinda and Aurukun. All but one have failed to adequately meet basic AEDP objectives, and these failures were also found to have resulted from deficiencies in the three central community-based planning elements (Dale Unpub.). This clearly suggests that planning for AEDP project implementation commonly is top-down and program-based. AEDP-funded development projects are often being implemented before clients have the appropriate community-based participatory, bargaining and technical planning systems in place. This is contrary to the basic
principles behind self-determination and those recent developments in planning theory that recommend that project planning should be bottom-up or community-based if rural developments are to achieve their long-term objectives.

Whilst recent moves towards the adoption of community-based planning within DEET and ATSIC are to be commended (see Elderton 1991), potential pitfalls must be avoided and some baseline principles adopted. Clearly, these principles need to include: (i) effective community-based systems of community participation in development planning; (ii) competent community-based systems of technical planning; and (iii) a client commitment to adopting effective bargaining and negotiation procedures. If these guidelines are not carefully followed, then the ATSIC/DEET community-based planning initiative may itself become a government program that is implemented upon Aboriginal communities in a vain attempt to achieve policy objectives established in Canberra.

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Glossary

Aboriginal rural development
The development of any form of Aboriginal activity that is based on the in situ utilisation and management of available rural land resources.

Planning
Planning is a somewhat nebulous term that broadly refers to the linkage between knowledge and organised action (see Friedmann & Hudson 1974). As planning occurs at almost every level of human activity, one must ask 'who is planning for what?' to identify its role and context.

Technical planning
Technical (Procedural or Rational) planning is an idealistic model of decision making which is based on the premise that there should be an explicit technical relationship between means and ends, and a logical presentation of argument supported by the systematic use of evidence (Healy 1983, 20). It aims to overcome technical constraints on the achievement of planning objectives, and has philosophical roots in scientific method, especially logical positivism. The approach has four classical elements: goal setting; identification of policy alternatives; evaluation of means against ends; implementation of decisions. The process is not always undertaken in this sequence, and each stage permits multiple iterations, feedback loops and elaborate subprocesses (Hudson 1979, 388).

Participatory planning
Refers to the use of a range of interactive planning mechanisms that constructively attempt to overcome political constraints on the achievement of an actor's planning objectives. These mechanisms include consultation, public involvement in objective setting, and conflict resolution (including dispute prevention, mediation, conciliation, arbitration, bargaining and negotiation). (Commission of Inquiry into the Conservation, Management and Use of Fraser Island and the Great Sandy Region 1990, 8).

Community planning
For the purposes of this paper, community planning is considered as the essentially technical planning process that has often been used by government departments to set program driven 'development' priorities for Aboriginal communities. Community Plans are the resultant product of this process, and they are often represented by infrastructural plans or standard European town planning ordinances etc. While they may be technically competent, they are often lacking from the viewpoint of the Aboriginal community.

Community-based planning
Community-based planning establishes activity within an Aboriginal community as a social, political, economic and spiritual entity. It requires that the community participates fully in the process of planning for and carrying out its own development, and that it exerts control over priority setting and decision making (Wolfe 1988b, 214).

Integrated holistic community-based planning
Integrated planning is considered in this paper as an approach which considers all (holistic) aspects of community life and livelihood and their inter-relationships in a formal and systematic way. It utilises rational steps, is understood by all parties, and involves documentation (Boothroyd 1984, cited Wolfe 1988b, 214). (The author utilises the term 'holistic' in place of the Canadian term 'comprehensive'.)

Bargaining
The framework for planning processes in which two or more parties attain a mutually agreeable contract about limited resources (Frazier & Hippell 1984, 176). In the context of this paper, the author refers to bargaining as a process mechanism in land use planning.

Negotiation
Negotiation involves the human interactions that form the environment of the bargaining process (Frazier & Hippell 1984, 176).
Planning for rural development in Aboriginal communities

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CHAPTER 23

CONSERVATION PERSPECTIVES ON THE SUSTAINABLE MANAGEMENT OF NORTHERN TERRITORY RANGELANDS

Richard Ledgar

Introduction

There are a number of schools of thought on what is the best approach to achieving sustainability on NT rangelands. One could develop a list of objectives and then set about to achieve them. One such list which I have presented (Ledgar 1987) in the past is:

1. Maintain the land’s productivity for future generations,
2. Use the land within its natural capabilities,
3. Conserve all elements of natural ecosystems,
4. Regeneration and rehabilitation of degraded areas,
5. Meet the aspirations of the indigenous people,
6. Protect areas of national heritage,
7. Deal in an equitable manner with current users.

The problem with this approach is that it ignores what is actually happening in the real world. In a perfect situation it may be possible to work through a set of objectives such as these and achieve the desired goal at the end. However, we do not live in a perfect world, therefore in order to achieve sustainable management through the implementation of environmental change, it is necessary to examine the reality of the political and social components of Australian society, so that the administrative arrangements through which change will be implemented, counterbalances the strengths and weaknesses of the various competing elements which may seek to thwart or misinterpret the overall goal of sustainable use.

This chapter examines how current administrative, social, environmental and political dimensions will impact on the process of achieving environmental change within the context of the NT pastoral activities.

Environmental constraints

The Bureau of Rural Resources recently published a document entitled *Sustainability: Physical and Biological Considerations for the Australian Environment* (Hamblin 1991). In this document they set out a number of basic parameters which exist with respect to the use of the natural environment for primary production. They are as follows:

1. **Primary industries are dependent on biological systems**

   The upper limits to production are set by inputs of light, water, gases and nutrients.

   All production technologies are dependent on the life-cycles and reproduction requirements of a range of life-forms, including micro-organisms, plants, invertebrates and vertebrates.

2. **Time-scales relevant to biological, hydrological and soil processes are long — from one to many decades**

   They do not fit well with the short (annual) timeframes of political, monetary and production or harvesting systems. Perception and knowledge of changes in the natural systems are often limited by our short-term viewpoint.

3. **Australia’s geographic position and geological evolution make this continent one of the least productive regions of the world**

   The climates are too arid and variable, the soils too old and infertile, and the adjacent seas too low in nutrients, for high production per unit of land or sea.

4. **Historically European attitudes to Australian natural resources have been chronically over-optimistic**

   They have concentrated on the small population and apparently unlimited, cheap space, without assessing its real potential.
5. Major shifts of ecosystems have taken place since European settlement. It would not be possible to return all environments to a pristine pre-European condition, even if this were considered desirable.

Invasions by successful alien species, together with great changes to vegetational composition have altered many Australian environments permanently. Modified ecosystems have developed and it is from these that we must assess future trends in sustainability.

6. Most renewable resources on which primary industries depend are currently over-exploited

Australian soils, waters, native vegetation, fisheries and coastal zones all show widespread evidence of depletion and degradation resulting from our past and current methods of harvesting and production. In comparison with other technologically advanced economies, most of Australia's agricultural production is characterized by low input systems.

7. Many current practices in farming, forestry and fishing are not sustainable

Current practices are either causing irreparable deterioration of natural resources (such as secondary salinisation, extinction of species or nutrient run-down) or are intrinsically unstable and very vulnerable to stress.

8. Adoption of successful sustainable practices will depend on adequate information bases, monitoring the performance of changed practices and improved management levels

Appropriate sustainable management practices will need to use a range of biological, economic and social indicators which are cast in relevant time-frames and value-sets. Examples of well managed sustainable practices include groups of farms collectively using whole catchment planning and forests managed for multiple and different needs.

In many instances an appropriate sustainable management practice may be technically or theoretically available, but is not able to be implemented on a broad scale because of lack of appropriate socio-political, economic or educational structures.

At a Territory scale, large areas currently under pastoral use are unsuitable for pastoral production. Many soil types are inherently unstable. The vegetation communities, when grazed by cattle, have a high degree of vulnerability to loss of perennial species which leaves the soil bare at a time when erosive rainfall events are most likely. Like the majority of this continent, the carrying capacity of most land systems in the NT is low.

Pastoral use of the Territory is characterised by low levels of inputs of both capital and labour with the majority of stock are sold to the lower end of the market. Control of grazing patterns is difficult due to a lack of fences and the intermingling of potentially suitable grazing areas with unsuitable ones.

All of these constraints are beyond the control of the 'industry' and consequently represent a severe limitation to the options for sustainable management available to producers. Government on the other hand, while it cannot alter the physical constraints, does have the ability institute a range of administrative procedures and programs to address and prevent degrading practices.

Commonwealth Initiatives

The Federal government has in recent years made a number of important policy decisions concerning management of the natural environment. Since the Prime Minister's statement on the environment in July 1989 (Hawke 1989) there has been increased recognition that development must be done within ecological parameters.

Due to a recognition of the extent of land degradation caused by pastoral and agricultural activities, a major priority of the Federal government has been to substantially increase funding to the National Soil Conservation Program (NSCP). The main theme and focus of this funding is a concept called 'landcare'. Landcare originated in Victoria as a community based program to raise awareness and focus community action on land degradation. As a result of a joint submission put to the Federal government by the National Farmers Federation and the Australian Conservation Foundation, the Victorian idea was coupled by Canberra based bureaucrats with the concept of whole farm planning and delivered to the Australian public, with bipartisan support, as the solution to our land degradation problems.

While there is some evidence that 'landcare the program' may provide some solutions in the more populated and productive regions of Australia it has a number of fundamental flaws which make its application in the arid and semi-arid regions highly questionable.
The philosophy of landcare is fine where the system on which the program is being applied is sustainable in the long term. But where the system is unsustainable or requires a radical change in management perspective away from primary production, the underlying assumption of sustainability within the landcare program, places an unrealistic expectation on rural communities and the people who seek to make a living from primary production.

These flaws within the application of landcare programs are examined later in this paper in the context of the interplay between competing interests and the implementation of new initiatives for the management of marginal lands.

Another Federal government initiative is the Ecologically Sustainable Development (ESD) working groups, which are an attempt to reconcile some of the thorny issues which arise when environmental imperatives are given equal footing with economic growth parameters.

Currently the draft reports from these working groups are being circulated for public comment. The working groups generally have a heavy membership bias in favour of the industry they are examining, but it is interesting to note that despite this bias the draft Agriculture Report makes strong recommendations concerning the clearing of native vegetation and the impact previously unsustainable use has had on the natural environment. For example the draft report recognises that despite available knowledge and an understanding of environmental processes we are still continuing to have problems such as land degradation (ESD Working Groups 1991, 86). The draft report goes on to state:

*The Working Group believes that management of vegetation removal in the future should be against clearly defined criteria which take into account environmental and economic aspects, including the potential for land degradation, the need to maintain the integrity of ecosystems and biodiversity, and long-term land capability:*

- it also recommends that these measures be underpinned by appropriate sanctions and that these sanctions should be applied rigorously (ESD Working Groups 1991, 126).

Statements such as these are a general indication of the attitude being taken nationally towards the prevention of land degradation and the further loss of biodiversity.

The development of a National Strategy for the protection of Biodiversity is also a major move towards reversing the trends of the last 200 years which have led to the loss of numerous endemic species and a massive invasion by feral plants and animals. It is expected that the Strategy will recommend a range of programs, administrative arrangements and implementation procedures, necessary for a change in the use and management of the natural environment.

**Northern Territory Government attitudes**

The Northern Territory Government has a firmly held belief that continued development of the Territory's environment can be done in a sustainable manner. Unfortunately this attitude translates into actions which allow development regardless of the social or environmental costs. This attitude is manifested in proposals such as the Litchfield Park development. The Northern Territory government also considers exploitation of the natural environment is of greater social importance than protection of natural ecosystems. Its continued calls for mining at Coronation Hill despite the area's cultural and natural significance is testimony to this attitude.

Of particular relevance to this paper is the NTG's attitude towards leasehold land. It has been stated to me on a number of occasions by NT ministers that the government considers that pastoral land belongs to the lessees, and it is only organisations such as the Environment Centre which keep insisting leases are public land.

Amendments to the Crown Lands Act in 1982 allowed the conversion of pastoral leases from 50 year term leases to a lease in perpetuity. There has been some effort to ensure that lessees could not convert unless the property was being properly managed but in practice increased security of tenure has not been in a direct relationship with better environmental management.
The government is currently in the process of drafting new legislation to cover the administration of NT pastoral land. In this legislation it is proposed that further conversion to perpetual title occur prior to adequate assessment of land capability, thus entrenching pastoral use over some 52% of the NT at a time when the whole basis of exploitation of the natural environment is being examined.

This stance within the new legislation is not unexpected given the Country Liberal Party's close alignment with the pastoral industry and the inordinate influence the small industry lobby has on government policies regarding use and control of NT land.

Currently we are also going through the development of the draft Decade of Landcare Plan for the NT. To date this so called community document strongly reflects the prevailing attitudes of the Northern Territory Government rather than the community in general.

The principle of the Decade Plan is to develop a process of reform which has a longer time frame than the life of a particular government in office.

The second draft of the NT Decade of Landcare plan instead of presenting new ideas to combat land degradation and to deal with our rangelands in a sensitive and ecologically sensible manner, assumes the status quo will remain. The draft also suggests that extension, which to date has proven to be ineffective in preventing overuse will suddenly become effective. This optimism is not supported by any hard data or realistic implementation programs which indicate how extension activities will bring about sustainability.

The draft fails to critically address the extent of land degradation in the NT and the failure by both government and industry to manage land in a sustainable manner. It is highly selective in the way information is used and presented and attempts to perpetuate the myth that NT rangelands are capable of sustaining existing cattle populations.

It does not commit the pastoral industry to any major reforms other than the formation of landcare groups (for example the Central Land Management Association in the Alice Springs region, see Millington, Chapter 19 in this volume — eds) and the draft suggests that these landcare groups will take over responsibility for determining government spending and administrative actions with respect to pastoral activities.

The failure to recognise and discuss the role of regulation in achieving sustainable land use leads the draft to present 'landcare the program' as the 'miracle' solution to land degradation which will be performed without any major changes to land management policies.

The draft fails to recognise that a large proportion of NT rangelands have already been identified as unsuitable for pastoral use and that 'landcare the program', if it is to protect the natural environment of NT rangelands, will have to address the removal of cattle from these areas, the rehabilitation of the land and the re-training of the people who currently manage them.

In its current form the draft fails to reflect community attitudes towards sustainable management of NT rangelands. While it is legitimate that the government should assist the interests of people wishing to run cattle in the NT, there must also be mechanisms whereby other management regimes can be allowed to examine options for future use of land which has to date not been managed in an environmentally sustainable manner.

Pastoral industry attitudes

A third major player is 'the pastoral industry' represented by the Northern Territory Cattlemen's Association (NTCA), a lobby group, which is affiliated with other state and national farming organisations. In reality the industry consists of less than 290 leases of which some 120 are owned by interstate or foreign companies, in total there are less than 300 businesses (Campbell 1991; Ledgar 1987). The rate of turnover of managers is high with the average stay being about 3 years, except in the Alice Springs district where the number of owner managers is higher.

The NTCA claims to represent 75% of leaseholders, the remainder either leave the establishment of policy regarding pastoral activities to others or make personal efforts to reform or change government policies. Individual leaseholders are also represented at a government and administrative level through their local landcare groups which are currently demonstrating a strong alliance with conventional attitudes to the management of pastoral land. Mike Back in the NTCA Year Book 1990/91 states: I'm unimpressed by the fact that 25% of NT pastoralists are not members of the NTCA ... You members are carrying them. They benefit from our wins too (NTCA 1991, 29).
These representatives of the pastoral industry argue that much of the existing land degradation was done by previous owners and managers and that today the 'majority' of lessees are responsible managers. There is some truth to this statement however it does not absolve current managers from ensuring that management regimes which caused the earlier degradation are not still being perpetuated in some other form. There is considerable evidence that soil erosion and shifts in vegetation composition from perennial to annuals are still occurring.

The NTCA has released an 'environmental code of ethics for rangeland managers in the Northern Territory'. It sets out philosophical, educational and operational principles. In its preamble it states:

*Before embarking on a quest to address land degradation in the Territory it is imperative that beef cattle producers, in particular, put for public scrutiny their fundamental position on environmental management of our rangelands (NTCA 1990, 1).*

The document does not acknowledge any of the environmental limitations which apply to the NT nor does it acknowledge that the continued ecological health of NT rangelands will depend on significant areas being destocked.

The NTCA document has been used in a number of contexts to convince others that the NT pastoral industry is now an ecologically literate and operating industry. This may be true at the philosophical level but how does it translate into action on the ground?

Individual leases may have changed hands since the 'bad old days' but we have not had a transformation in managers and owners into trained ecologists. The people who work the land, or control the ones who do, are still first and foremost attempting to make a living. Therefore when it comes to a decision which calls for a choice to be made between the health of the natural environment and the health of their overdraft, lessees will inevitably lean towards protection of monetary assets.

There is still limited availability of information suitable for use in the development of meaningful whole farm plans. For many areas of the NT there are only 1,250,000 base maps, limited fine detail land capability data and no specific commitment by either government or individual lessees to cease immediately management practices which are known to degrade. Industry representatives on the other hand are attempting to persuade the wider community that pastoral management is now sustainable.

The 'industry' as represented by NTCA and several landcare groups is espousing 'landcare the activity' as the vehicle whereby pastoral activities can be made ecologically sustainable.

Mike Back also states in the NTCA Year Book that the NTCA is seeking greater security of tenure for NT pastoralists, increased government funding for landcare groups and a system of rangeland monitoring which will maintain and enhance NT rangelands so that productivity 'can be not only maintained but improved' (1991, 30).

The NT pastoral industry representatives therefore are strongly promoting a continuation of the status quo without any real attempt to address the environmental limitations which exist in the NT.

**Interplay of government, industry and administrative programs**

What then is the consequence of the interaction between the various interests for achieving environmental change in the NT?

The first thing which must be recognised from this interaction is that regardless of political attitudes, the environmental constraints discussed earlier continue to apply. If the Northern Territory Government is serious about addressing the sustainable use of NT rangelands and the NTCA has a true commitment to preventing further degradation, it should be in everyone's best interests to ensure that the administrative arrangements and on the ground programs developed through the new legislation and the Decade of Landcare do not continue to promote degradation. It we continue on our current course, given the political attitudes of the Northern Territory Government and the NTCA, we are in danger of doing just that, because there has been no formal recognition of the unsustainable nature of much of the NT pastoral operations.

With the passing of the proposed Pastoral Lands Administration Legislation, *(Pastoral Land Act 1992)* land which has already been identified as unsuitable for pastoral operations (NT Department of Lands & Housing 1991), will become further entrenched in a pastoral management regime.

It is also proposed that this entrenched will be compounded by the programs developed under the NSCP and the Decade of Landcare plan philosophy. As stated earlier, I believe that 'landcare the program' has a number of inherent and imposed flaws which will work against the development of long-term sustainable management.
Firstly 'landcare the program' fails to acknowledge that in the arid and semi arid grazing areas there are considerable tracts of land where pastoralism is unsustainable. This land will have to be destocked of cattle and managed in a manner totally unrelated to pastoral activity. This flaw already results in landcare activities being directed towards continuing pastoral activities in some areas regardless of the inherent capability of the land to sustain pastoralism. By not insisting that landcare funded activities can only be carried out in accordance with information based on the ecological attributes of a lease, 'landcare the program', like the proposed Pastoral Lands Administration legislation, is further entrenching pastoral management.

In the south and the higher rainfall areas where primary production is based on completely modified environments, there is little point in assessing the land's original capability; what is required for the future is that this now highly modified system be stabilised. This will involve the restoration of natural communities over parts of the landscape but much will remain as agricultural land. In the extensive grazing areas, however, future ecological stability depends on an assessment of the land's capability and a willingness to remove land from pastoral use where necessary. Currently within 'landcare the program' there is no obvious mechanism to deal with the removal of land from primary production.

An imposed flaw within 'landcare the program' is that it has a strong production orientation. This flaw occurs because the application of 'landcare' concepts on land other than agricultural has not been considered for extensive rangeland areas. The current draft NT Decade of Landcare plan, as already discussed, reflects a strong productivity ideology. This bias towards increased production rather than ecological stability will force pastoralists into what I have phrased as the 'pressure to improve' syndrome.

Because landcare programs do not question the basic validity of the current use, pastoralists who accept that management must change in order to prevent further degradation have no choice but to intensify management. They are not being given the option of reducing cattle numbers. NT government programs are designed to encourage pastoral use, the NTCA's stated aim is to 'promote the development of the cattle and land resources of the Northern Territory' (NTCA 1991, 9), and the current orientation of the NT Decade of Landcare plan towards production, all work together to push leaseholders into an intensification of use.

Given the environmental limitations and inherent low productivity of NT rangelands, an intensification of management means more fencing, more control at watering points and closer herd management. Not unsound advise in certain circumstances but all will require an increase in investment which will in turn need to be paid for through more cattle being turned off or receiving a higher sale price.

There are serious doubts as to whether NT leases can carry more cattle which leaves the option of increasing sale price. Under native vegetation grazing regimes, at a minimum this option requires a substantial reduction in the number of cattle carried. The clearing of savanna woodland has major environmental problems given NT soil types and the establishment of non-native grasses has not proven to be viable even if it was environmentally acceptable.

By allowing landcare activities to dominate the issue of environmental management of marginal lands, we are yet again placing a huge expectation on remote rural communities to be able to make major changes to management procedures within an agro-economic framework.

If it is not the government's intention to allow pastoralists to repeat the mistakes others in the past have made, then it should from the outset allow a range of environmental change programs to come into play. Landcare as discussed already, has now assumed a very specific operational culture. It is the program whereby rural communities will address the sustainable management of land which is to remain under agricultural use.

There is only a limited area of land in the NT which has the environmental potential to be able to sustain pastoral activities — parts of the Barkley and Alice Springs pastoral districts for example.

The remaining leases, due to environmental, topographical and physical limitations, can all be classified as marginal and therefore need to be considered in a context other than through an administrative program which is designed to promote the activity which is a prime cause of land degradation and the loss of biodiversity in the NT.

An examination of alternative management regimes will be made much more difficult if perpetual title is granted on enactment of the new legislation and if the Decade of Landcare plan does not contain programs to creatively manage land which has to be withdrawn from conventional primary production.
So what can we do about it?

How can we therefore ensure that future management of NT rangelands is sustainable? Firstly it is suggested that the new legislation should not convert term leases to leases in perpetuity without proper environmental assessment. It could also be argued that currently existing perpetual leases should also be subject to a review of sustainability and a revision of land management obligations prior to granting rights under this new legislation.

An initial 'desktop survey' of existing leases could be done to categorise all existing leases into a number of viability classes. Those which are considered to be viable under pastoral based management regimes could be offered a pastoral lease, the remainder will probably fall into two other broad categories, non viable and possibly viable.

The new legislation would need to address the issue of compensation so that lessees who fall into the latter two categories will have psychological security to enable them to work with government in order to bring about a change of management. There appears to be a fear within the rural community that a change in management away from the running of cattle, means that people will be forced off the land. I do not believe that this will be so in the majority of cases. The Australian landscape has evolved with human intervention and it will continue to require organised management input.

The Commonwealth rural reconstruction program is the obvious administrative vehicle through which management of the non viable leases can be addressed. The possibly viable will require more detailed land capability analysis so that future management options can be examined from a variety of view points to ensure wider community goals — ecological sustainability and the protection of biodiversity — are properly considered.

Lessees must be provided with alternative programs which will allow the land to continue to be managed but not necessarily for the purpose of running cattle. It is expected that as a result of the ESD process and the development of a strategy for the protection of biodiversity, a whole new range of initiative will be forthcoming. It does not make good sense to lock large areas of the NT out of such programs.

It is vital that the new legislation does not preclude the development of lease specific covenants based on the results of land capability analysis and that these covenants are able to contain a range of general land management provision which include the complete removal of all non-native feral and domesticated animals. There are substantial proportions of existing leases which are not capable of supporting grazing therefore the legislation must present administrative structures which do not lock management into production orientated attitudes.

Proposals to develop covenants under the guise of a whole farm plan are too open, undue emphasis being placed on farming solutions. Covenants must be developed on the basis of ecological sustainability and a recognition that continued economic viability of pastoral operation depends on maintenance of the natural vegetation and ecological processes.

The new legislation also must place specific obligations on the government to act to protect ecological sustainability and biodiversity. It is no longer acceptable for any government to blatantly ignore these fundamental principles when developing legislation. These obligations must include the ability to act swiftly, and with no delays, to halt activities which are seen to be degrading. The option to restore the activity always remains.

Those obligations also extend to ensuring there is adequate resourcing of government agencies responsible for assessment and monitoring and that policy decisions are formulated with the proper representation of community interests.

Just as there are obligations on government to protect the wider community interest, so too are there obligations on landusers to acknowledge the concept of sustainability. The law is a major tool of policy. It can promote and strengthen sound environmental management. Laws exist to define antisocial behaviour, protect and encourage the law-abiding, and guide and influence citizens' activities. The application of sanctions to those who break the law is an important deterrent to antisocial behaviour. The proposed new NT pastoral legislation must enshrine the ethic of sustainability into the general duty of pastoral lessees.

If we are serious about bringing about environmental change, then the process of change must be made as clear as possible to the people who will be most affected. The legislation sets the ground rules and the Decade of Landcare plan is an opportunity to spell out, in detail, the transition process which will move NT rangelands onto a sustainable and stable basis.
The decade plan therefore, must reflect growing community awareness of the need to protect the natural environment. It must recognise that primary production is but one option in a range of management options available for these areas.

The Decade plan is also a prime opportunity to educate the community and specifically current landusers about the need to change management regimes. The plan needs to promote other uses as equally legitimate as the running of cattle.

If the government and the industry is serious about getting land degradation under control then the proposals I have made here are the minimum that is required. None of these proposals threaten the operation of leases which are viable. They do not impose restrictions on managers and owners who seek to manage land in a environmentally sustainable manner.

Notes

1. At the time of finalising this paper the draft decade plan was undergoing a major re-write. It is hoped that the new version will correct many of the faults contained in the draft version which is the subject of discussion in this paper.

References


CHAPTER 24

REHABILITATION AT RANGER URANIUM MINES

CJ Unger and AR Milnes

Introduction

The Ranger uranium deposits are located within a 79 km² project area in the lowlands of the Alligator Rivers Region, about 230 kilometres east of Darwin, surrounded by Kakadu National Park. Mining of Orebody No. 1 commenced in 1980, with reserves expected to last until 1994, and 3000 tonnes of yellowcake (U₃O₈) are produced annually. Mining of Orebody No. 3 will extend the life of the mine until approximately the year 2012.

The mining operation incorporates an open cut pit, tailings dam, stockpiles of ore and construction materials, dumps of waste rock, sediment and water retention ponds, and processing plant. About 3 km² of land is disturbed. When mining is completed and the processing plant and other infrastructure has been removed, it is anticipated that the operational areas and structures including the tailings dam and tailings-filled Pit No. 1 (from the processing of ore from Orebody No. 3) will be covered by a landform constructed of waste rock and below ore grade material. A water-filled Pit No. 3 and other sediment control ponds are also part of the rehabilitation plan. The objective is to produce a rehabilitated landform that will evolve in equilibrium with the climatic and geomorphic environment, releasing contained elements at a rate and loading that is not significantly different from the natural landforms. Final land use of the project area will be determined in liaison with the Aboriginal land owners.

In this paper we present an overview of rehabilitation planning and a general description of some of the research projects which have dealt with rehabilitation of a waste rock landform, tailings management and rehabilitation, and contaminant movement in wetlands.

Rehabilitation planning

From 1987, rehabilitation of the project area has been planned at three levels, including:

- the long-term conceptual plan for the minesite at completion of the mining operation,
- the five year plan which is updated regularly as new developments take place and results from investigations are made available, and
- an annual plan which specifies rehabilitation investigations to be carried out, and identifies disused infrastructure to be removed during the dry season and areas to be revegetated in the coming wet season.

The results of research projects provide input to the continued development and fine tuning of the rehabilitation plan and progressive annual rehabilitation enables new knowledge to be applied.

Long term plan for rehabilitation

Mine plans for both Orebodies 1 and 3 provide approximate total quantities of waste products which permit the shape and size of the landform to be defined (Fig 1). Conceptually, the final landform will be kept as low and flat as possible to minimise the likelihood of serious erosion, while considering also the practical aspects of dump development and haul distance from the mine. The southern part of the proposed landform will be completed during mining of Pit No. 1, while the northern part will be constructed of waste materials from Orebody No. 3. Construction of the landform is planned so that progressive shaping and vegetation can be undertaken. The highest part of the landform will be over the present tailings dam, and surface drainage will be directed to catchments to the northeast and northwest. Surface preparation will be designed to minimise infiltration into the tailings, but the remainder of the landform will require no special surface treatment.

Research directed towards developing design characteristics for the proposed final landform includes investigations of weathering processes and products in waste rock, slope stability, mine...
FIGURE 1  Surface contour plan for final landform constructed of waste rock to cover operational areas of the Ranger Project Area
development, revegetation and construction of sustainable ecosystems, hydrology of constructed landforms and solute transport, and contaminant mobility in wetlands.

**Five year rehabilitation plan**

Ranger has for some years adopted five year plans for achieving established company goals. The five year rehabilitation plan is updated regularly to enable changes in the mining operation to be incorporated into the final landform plan. Major operational changes can have a large impact on rehabilitation planning. In some instances progress is dependent upon approval by Supervising Authorities.

Some key areas of mine development have important impacts on rehabilitation planning. For example, the size and development of ore stockpiles, below ore-grade material stockpiles, stockpiles of rock suitable as construction material, alternative neutralisers such as magnesite, and dumps of waste rock impact significantly on water management in the project area. Tailings deposition strategies influence requirements for the size of the containment dam and the height of the walls. The progress of the mining operation itself, in terms of completing ore extraction from No. 1 Pit and commencing development of No. 3 Pit, affects progressive rehabilitation because of operational requirements for haulage distances of waste rock and other materials and the placement of access roads.

**Annual rehabilitation plan**

In March of each year, following a review of the past year’s work, an annual plan is devised for the following year describing dry season erosion control works, seed collecting and revegetation requirements.

**Rehabilitation research**

Since mining commenced in the Ranger project area, several specific areas of research have been addressed in the context of the proposed rehabilitation strategy. These include characterisation of waste rock and comparison of minesoils with natural soils, investigations of slope stability in waste rock dumps, aspects of native vegetation establishment utilising cultured symbiotic micro-organisms collected from the local woodlands, characterisation of tailings, and the behaviour of the tailings repository with respect to seepage and contaminant transport. The results of these research investigations have been incorporated into rehabilitation plans and have provided directions for subsequent research.

**Characterisation of waste rock**

Initial studies of the older waste rock dumps and very low grade ore stockpiles focussed on the petrology, mineralogy and chemistry of representative rock types, geotechnical investigations of mass stability of slopes, the development of rudimentary soils (minesoils), and infiltration characteristics (Milnes et al 1988).

Investigations of weathering processes were undertaken in order to define the nature of products that might affect the strength and erodibility of waste rock, and identify contaminants that might impact on the environment. Milnes (1988) presented a simplified overview of the weathering reactions and products (Fig 2). The major weatherable minerals chloride and muscovite were discovered to be progressively altered through various regularly and randomly interstratified clay minerals to smectite and kaolinite. The older dumps contain waste rock from the upper mine benches, and so some of this alteration may be due to weathering under geological conditions in or below the pallid zone. However, rapid physical degradation following exposure of many of the rock types in the dumps is clearly evident. In addition, chemical weathering is indicated by efflorescent salts covering rock surfaces and iron oxyhydroxide precipitates in retention pond waters immediately adjacent to waste rock batters. Degradation of sulphide minerals in the waste rock dumps, although they are not as abundant in this ore deposit as in base metal and gold ores throughout the Pine Creek Geosyncline, leads to some sulfuric acid generation and the limited development of seeps rich in Fe, U and base metals (Milnes et al 1992).

The upper surfaces and batter slopes of the waste rock dumps rapidly develop a surface gravel lag free of fines as a result of raindrop impact and the loss of fine material through infiltration or lateral flow. As a consequence, the surfaces tend to be protected from erosion unless the gravel lag is breached. The surface materials are highly saline, and vesicular crusts formed of fine sediment between the rock classes are effective in substantially reducing infiltration. On batter slopes, fines are initially rapidly dispersed and washed into cavities by rainwater, or carried downslope, leaving a rock-mulched slope. With time and weathering (physical degradation) of the rock, new fines are produced and the slope becomes mantled by soil-like material with comparatively good infiltration characteristics.
Simplified schematics of rock weathering and weathering products

FIGURE 2 Simplified schematic diagram showing mineralogical and chemical pathways for rock weathering at Ranger

Geotechnical measurements of the strength of materials near the surface of the dumps, together with theoretical analyses (Richards et al 1986), indicate that the waste rock dumps are inherently stable at angle-of-repose slopes (around 36°). However, a reduction in shear strength due to creep and continued weathering in the long term are likely to produce mass instability and favour lower slopes between about 10–20°, assuming that the dumps remain uniform throughout. Further research is required on materials at depth in the dumps to investigate this assumption, and to determine the water content and internal hydrology of the structures.

Erosion of waste rock

Experimental slopes constructed on the batters of existing waste rock dumps have been used to determine erosion losses and the effects of slope shape on erosion. Based on research in landscapes elsewhere in the region (Cull & East 1987), concave slopes of a similar shape to natural footslopes were constructed with gradients ranging from 1:3 near the top to 1:5 midslope and 1:8 at the base. Straight slopes with a gradient of 1:3 were also constructed as controls. Duplicate slopes, making a total of four plots, were produced. One pair (concave and straight) was mulched with schist (considered to be comparatively resistant to weathering and commonly used for on-site construction), and the other pair with run-of-mine waste rock consisting of a mixture of resistant chert to weatherable massive chlorite rock.

Wet season water flows were recorded using depth probes in flumes built at the base of each slope plot. Water samples were collected using automatic water samplers and analysed for suspended solids and solute concentrations, together with selected chemical properties. Rainfall was also recorded. Erosion pins inserted in rows across the plots were measured before and after each wet season to assess rates of surface lowering and deposition. Bedload troughs were installed to trap coarse material.

Some results have been published by East et al (1989) and Curley (1990), and indicate that the concave slopes may have superior erosional stability. This provides an important criterion for design of the final landform, although the effect of vegetation cover on erosion has yet to be investigated. All experimental slopes registered storm runoff of both sediment and dissolved salts by the same processes, although concave slopes had lower peak discharges than straight slopes, and produced lower concentrations of suspended sediment and yield. Differences were also recorded between the different rock mulches. The supply of fines available for transport in suspended load did not appear to change over two monitored wet seasons, although the solutes were depleted.
markedly by the end of each wet season and appear
to have been replenished by weathering processes
through the following dry season.

Formation of soils from waste rock

The character and properties of a range of
rudimentary soils ('minesoils') formed from waste
rock were noted during the early research
investigations on waste rock dumps (Fitzpatrick
1986; Fitzpatrick & Milnes 1988; Milnes et al
1988). Later detailed studies (Fitzpatrick et al
1989) compared these minesoils with natural soils
from the native woodlands and soil materials from
the established stockpiles, particularly in terms of
their capacity to support plant growth. Profiles were
described, and representative samples were
collected for physical, chemical and mineralogical
analyses. In addition, samples of vegetation were
collected and analysed for selected nutrient and
trace elements, including uranium.

Fitzpatrick & Milnes (1988) summarised the
characteristics of minesoils and proposed a
generalised scheme for their development (Fig 3).
The more detailed investigations (Fitzpatrick et al
1989) found that natural soils from the woodlands
could be subdivided into upland and floodplain
soils. The upland soils are loamy coarse sands.
They tend to be highly leached and have pH values
between 4.5-5.6 (1:5 soil:water extract), a low base
status (12-29 mmol(+)]kg(-1)), a low clay content
(6-15%) dominated by kaolinite, high
concentrations of ironstone gravel, and an organic C
content between 0.65-2.0%. In terms of fertility
they are low in available N and P, low in Zn, and
exhibit a small excess of exchangeable Mg relative
to Ca. Chemical analyses of selected tissues of
native plants growing in these soils reflects the data
for the soil analyses.

Natural floodplain soils are fine sandy loams. They
are weakly leached and have pH values around

Generalised scheme of minesoil development

- LITHOSOLS
  Bouldery and stony.
  Weathering of chlorite and other minerals from mine rocks. Fe, Mg, and other
  elements released in solution.
  Rainsplash detachment of fines and sheetwash

- SOILS WITH GRAVEL LAGS AND VESICULAR CRUSTS
  Stony, gravelly, sand to silt
  High concentrations of exchangeable Mg, dispersible fines, vesicular crust.
  Sealing of soil surface and low infiltration enhances runoff

- POLYSEQUUM SOILS
  Gravel to silt
  Sediment accumulated in topographic lows from sheetwash events
  Ephemeral water ponding

- PSEUDO-ACID SULFATE SOILS
  Gravel to clay
  Characteristic mottling, high concentrations of exchangeable K and soluble S

FIGURE 3 Characteristics of minesoils formed in waste rock in the Ranger Project Area, and a
generalised scheme for their development
4.9–5.1, a base status double that of the upland soils, a moderate clay content (24–35%) dominated by kaolinite, and relatively high concentrations of organic C (3.4–4.9%). In terms of fertility, these soils are deficient in N and Zn. There is much more exchangeable Mg relative to Ca than in the upland soils. In addition, Al accounts for up to 50% of the exchangeable cations. Analyses of tissue samples from plants growing on these soils indicate adequate P.

The various stockpiles of natural soils in the project area contain a mixture of original soil horizons and saprolitic material. Samples have a range of pH values between 4.4–4.7, and base status values between those for natural upland and floodplain soils. Clay content and mineralogical composition of the clay fractions are typical of upland natural soils, as might be expected. Total organic C contents are between 0.36–2.03%. Samples are deficient in P and Zn, but N levels are unexpectedly high compared with natural soils.

As a consequence of the mining operation, the most recently dumped waste rock materials are essentially angular gravels consisting of a mixture of coarse and fine materials. These starting materials for the formation of minesoil have pH values around 7.3, which is considerably higher than in natural woodland soils. In addition, they have a base status similar to that of natural floodplain soils, a low clay content (7–8%) dominated by chlorite and muscovite, and negligible organic C. The imbalance between exchangeable Ca and Mg is much greater than in natural soils, but exchangeable Al levels are considerably lower. Compared with most natural soils, concentrations of extractable and total metals (Cu, Pb, U) and soluble S are high. In terms of nutritional status for plant growth, these starting materials for minesoils are deficient in N, P and Zn.

In areas of the waste rock dumps where vegetation trials have been established, older examples of minesoils are silty to coarse sandy loams which range in pH from 5.6–6.5. They have a high base status dominated by Mg, a moderate clay content (12–25%) which consists mainly of smectite-vermiculite-chlorite and muscovite, and a variable organic C content up to 0.7%. In terms of fertility, these soils have some P available for plant growth, but there is an extreme imbalance in the ratio of exchangeable Mg to Ca and K. In some places, periodic waterlogging in furrows of rip lines has facilitated redox reactions to produce iron mottling.

Glasshouse bioassays using ‘bait’ plants identified VA mycorrhizas in all samples except the starting materials for minesoils. Ectomycorrhizas were identified in all natural soils, in one sample of stockpiled soil, and in one sample of minesoil. Other bioassay results indicate that VAM propagule numbers were very low in stockpiled soils and in minesoils without vegetation cover, but intermediate to high numbers of propagules were present in vegetated minesoils and natural soils.

Plant nutrition studies using *Acacia holoserica* and *Chloris gayana* demonstrated that both plant species grew best in minesoils; seedlings on average produced 500% more biomass than did seedlings grown in either the natural or stockpiled soils, where growth of both species was comparatively poor. Nutrient application to the natural and stockpiled soils resulted in substantial increases in plant growth, and largely eliminated the differences in plant growth between all soils. P deficiency is one major limitation on plant growth in the natural and stockpiled soils.

Under the 1979 *Uranium Mining (Environmental Control)* Act, Ranger is required to stockpile topsoil from disturbed areas for use in rehabilitation, and this has been carried out since commencement of mining. However, a clear alternative is to utilise the capacity of waste rock to weather and form minesoils that will form a suitable substrate for vegetation establishment and growth. New research investigations are presently in progress to establish self-sustaining woodland ecosystems in minesoils.

**Revegetation science**

To date, experimental revegetation has been undertaken in three trials on the waste rock dumps. These experiments determined, in a practical sense, that native plants could establish and grow in waste rock. However, the trials were not planned in a rigorous scientific manner to re-establish ecosystems of viable and self-sustaining floral and faunal communities. Research investigations of this type are currently in progress.

The preliminary components of these studies have involved some assessments of the existing vegetation trials, including determination of nutrient levels in samples of various plant tissues (Fitzpatrick *et al* 1989), recognition of possible Cu deficiency as a cause of stem deformation in *Acacia concinocarpa* (Reddel & Playfair 1990), and measurement of excessive accumulation of litter beneath stands of *Acacia* in the oldest two vegetation trials (Reddel 1989). In general, differences in the concentrations of nutrient and contaminant elements in plant tissues at different
sites reflect the differences detected in mine soil samples. However, there were exceptions, for example the concentration of Al in plant tissue compared with exchangeable Al in mine soils. It was also observed that P concentrations decrease with leaf (phyllode) age, and are lowest in woody stems, branches and bark (Fitzpatrick et al. 1989). These sorts of investigations will be undertaken more systematically in future re-vegetation trials. The reasons for the slow rates of litter decomposition in the existing vegetation trials are not clear at this stage. Several possibilities exist, including the absence of appropriate decomposer organisms or the particular properties of the litter itself. There are important consequences of this observation for the development of self-sustaining ecosystems on the final landform.

Studies by Fitzpatrick et al. (1989) had suggested that symbiotic micro-organisms such as rhizobia and mycorrhizal fungi are common in the soils of the natural woodlands around the Ranger project area, but were absent or poorly represented in the stockpiles of natural soils and in mine soils without vegetation cover. In addition, there was a lack of information on the specific symbiotic requirements of most northern Australian plants. Consequently, surveys and collections of mycorrhizal and rhizobial associations were undertaken in the woodlands in a variety of ecological niches to provide material for laboratory culture (Reddell & Joyce 1989; Reddell et al. 1992). The investigations suggest that the majority of plants occurring in the woodland and rainforest communities in the region are dependent to varying degrees on associations between their roots and soil micro-organisms for efficient nutrient acquisition. This has important consequences for attempts to reconstruct viable and self-sustaining ecosystems on waste rock dumps, as is well known in the mine rehabilitation literature.

Some investigations have focussed on other aspects of the microbiological populations of mine soils, particularly in relation to bacterial weathering of waste rock and the role of bacteria in mine soil formation. Moen & Kimber (1989) have undertaken preliminary studies of the patterns of bacterial occurrence and characteristics in the project area. They investigated three genera (Pseudomonas, Thiobacillus and Bacillus) and discovered that there are marked differences in abundance of the genera between sites. In particular, Thiobacilli predominate in mine soils but are lowest in abundance in native soils. The results are yet a further example of the need to consider the role of functional groups of organisms in ecosystem reconstruction.

**Assessment of burning regime**

As fire is an integral component of the management strategy for the region surrounding the Ranger lease, the concept of total exclusion of fire from the rehabilitated landform is therefore unsound. In the long term, vegetated areas will be connected to the surrounding woodland and will probably be burnt at the same frequency. Burning of part (approximately 1200 m²) of a vegetation trial established in 1984 on the waste rock dumps was undertaken during August 1986. The vegetation consisted mainly of two year old Acacia and Eucalyptus species averaging 2–3 m in height. The flammable material, consisting of 60% grasses and 40% leaf litter, was collected from 1 m² plots prior to burning, and was calculated to have an abundance of 0.5–1.5 t/ha with a moisture content of 7.4%. The moisture content of the mine soil was 2.6%.

Observations four months after the burn revealed regenerating Eucalyptus and Acacia species averaging 200–300 mm in height. The majority of Eucalyptus re-growth came from lignotubers, but the Acacia species did not seem to have coped so well. At present, the burnt and unburnt areas are well contrasted. The burnt section displays a greater diversity of species including Melaleuca, Acacia, Grevillea and Eucalyptus. The unburnt area continues to be dominated by Acacia species (Acacia maugeordiae and Acacia holococercia) which appear to be nearing the end of their life, and has an excess of leaf litter over the mine soil surface. Secondly, with the more open canopy associated with the burnt area, a dense ground cover has developed.

These trials have highlighted some important effects of fire, and further rigorous experiments will need to be carried out as investigations of ecosystem reconstruction continue.

**Tailings management**

Tailings comprise a potential source of radioactivity and water borne contaminants. The current environmental requirements specify that the tailings be removed and placed in No. 1 Pit after mining is completed. However, an alternative possibility is to rehabilitate the tailings dam in situ, if it can be shown that this strategy will not have any greater impact on the environment in the long term.

Several research investigations have been undertaken on the physical, chemical, hydraulic and geotechnical properties of tailings. One of the aims of this research has been to provide predictions about consolidation rates in the short and long term,
and the stability of the tailings under capping materials. In the first of these investigations (Richards et al 1989), field data was collected from several sites in the tailings dam using a specially designed penetrometer to determine the strength of materials in vertical profiles through the tailings deposits. Various surface samples were also collected for measurements of particle size, permeability, consolidation, shear strength, and mineralogical and chemical composition. On the basis of these data, several dewatering strategies, including combinations of drainage wicks, pumped drains and surcharge loading were evaluated. The results of field investigations indicated that there was no increase in penetrometer resistance with depth, and so little self-weight consolidation has occurred in the time since deposition. Subsequent laboratory data demonstrated that the permeability of the tailings is low ($3.5 \times 10^{-7}$ m/s at zero effective stress, reducing to about $10^{-10}$ m/s at higher effective stresses). However, a significant increase in permeability was observed as the solute content of the water was reduced to that of distilled water. These data indicate that dewatering utilising wicks or pumping on vertical drains will have only a small effect on the rate of settlement and will not contribute significantly to the ultimate settlement.

Subsequent research investigations have sought to explain the physical behaviour of tailings from a detailed understanding of their chemical properties (Fordham & Beech 1989). At the same time, specially designed piezometers (Richards & Peter 1989) were installed in the tailings dam to measure permeability in situ, and to obtain water samples for chemical analysis of solute concentrations (Richards et al 1990; Fordham 1992). In addition, a coring device (Peter & Wright 1992) was devised and constructed in order to take undisturbed samples of tailings from selected depths for detailed characterisation. These studies have provided the basis for rejecting the notion of using wicks or pumping vertical drains as practical methods for dewatering the tailings. In addition, there is comprehensive data on solute species and concentrations for investigations of seepage from the tailings dam and its impact on the groundwater and surface water environment.

Current research studies are aimed at an understanding of groundwater flow and solute transport, and address matters such as water quality in retention pond 1 (RP1) if water from the seepage collector system around the tailings dam were to enter it under gravity flow, the sources of water that enter the seepage collector system, and the impact of seepage from the dam on groundwater sampled in observation bores.

**Wetland filtration**

The behaviour and mobility of contaminant elements released from waste rock into wetlands, and the uptake of these elements by wetland and dryland plants in the Ranger project area, are currently being studied to improve our understanding of natural filtration processes in the short and long term. The capacity of wetlands to immobilise water borne pollutants is well documented, and has been adapted to treat industrial, municipal and urban run-off waters. The concept of wetland filtration is based upon the absorption or adsorption of various environmentally harmful pollutants by plants and substrate sediments.

Early investigations concentrated on analysis of sediment substrates, plants and waters in channels which drain the waste rock dumps, construction material stockpiles, and the very low grade ore stockpile, as well as in retention pond 4 (RP4) which has been a long-term repository for sediments and waters draining the waste rock dumps (Milnes et al 1990). These studies aimed to discover whether natural or artificial wetlands in the Ranger project area could significantly modify the mobility of water-borne contaminant elements (such as Ca, Mg, S, U, Ra and base metals) through the complex interaction of biological, hydrochemical and sedimentological processes.

In terms of total plant data, assessments of nutrient element levels in leaf and vegetative tissue samples collected in both wet and dry seasons throughout the drainage systems indicate that the primary deficiency is P, and that Ca and Zn are marginally deficient. This has implications for establishment and maintenance of wetland plants. In terms of contaminant elements, Mg (0.54%) and S (0.50%) concentrations border on an arbitrary toxicity threshold in the dry season, but decrease in the wet season. Mean concentrations of Na (0.22-0.26%) are below the arbitrary toxicity threshold, but are surprisingly high for this environment. Analyses of plant tissues from different drainage channels provide a general indicator of the different sources (waste rock, construction material or low grade ore stockpiles) of contaminant elements, as well as information on the differential uptake of elements by different plant species and by different individuals of the same species. For example, the average concentration of Mg in plants from all sites in the channel draining the waste rock dumps was above that at which Mg would interfere with uptake of K and Ca. A positive correlation of S with Mg suggests that these elements may be taken up as charge-balancing counter ions.
High Cu concentrations (averages ranging from 12–50 μg g⁻¹) were registered in plants growing in the very low grade ore drainage channel. Copper (Cu) concentrations between 150–220 μg g⁻¹ in samples of Cynodon sp are considerably in excess of levels regarded as toxic to most plant species. Average Mn concentrations in plants in RP4 in the dry season were significantly above levels (600 μg g⁻¹) considered to be toxic to many agricultural plants, but were below these levels in the wet season. In a further breakdown of the data, it has been possible to identify certain ‘accumulator’ plant species. For example, Echinrichia colona, Philydrum lanuginosum, Eleocharis sp and Typha orientalis accumulate both Mg and S at concentrations greater than 0.5%. Nympheoides megasperma accumulated high levels of NaCl (>0.7%). In addition, individuals of Cynodon sp growing in contaminated areas have accumulated very high concentrations of both U and Cu.

Chemical data for sediment samples collected from the same sites as plant tissue generally reflect the pattern registered by the plant analyses. Analyses included total concentrations of major and trace elements, the concentrations of selected elements in water-saturated extracts to simulate their mobility and dispersion capacity, and exchangeable cations. Field measurements of pH, Eh (Redox potential) and temperature of waters were undertaken at the time of sampling, and laboratory analyses of water samples were carried out subsequently. The data indicate that the major ions are Mg and S, with other important ions being Ca, Na and K. Water samples from some sites adjacent to seepage zones along the batters of the very low grade ore stockpile contained U values up to 18 ppm, which correlate directly with high total and extractable U concentrations in the sediment and in plant material.

Analysis of the dataset for these early investigations is continuing, and the interpretations will be extended to research studies on the constructed wetland in the catchment of RP1.

A field trial involving the release of RP4 water through a wetland environment downstream from the bund wall, towards Djalkmara Billabong, was designed to evaluate the degree of attenuation of various elements in waste rock runoff, characterise the processes of immobilisation, and evaluate the feasibility of using wetland filtration for operational releases from the project area (Ranger Uranium Mines Pty Ltd 1990). The experiment involved the controlled release of water over the retention pond spillway and through a constructed waterway to pond in a vegetated swamp. The trial was conducted in two parts: one being retention of water for three days in the swamp, and the second a flow-through system for three days. Water quality and hydrological data collected during the experiment were used to estimate solute attenuation.

The results indicated that Mg, S and U were attenuated in significant quantities. The degree of attenuation was dependent upon flow rate through the wetland and consequently chemical interactions with sediments and biomass. Mn concentrations were variable and at times higher than in RP4 waters, suggesting that the wetland added Mn to the system. In addition, the mass of Ca measured in the wetland was approximately 30% higher than was initially released from RP4. This observation suggested that Ca-containing minerals exist in the wetland, but further investigations are required to check this interpretation. Other studies carried out as part of this trial demonstrated that the toxicity of RP4 water to adult mortality and reproduction of the cladoceran Moinodaphnia macleayi was reduced by wetland filtration.

There is clearly a considerable scope for research in this field to ensure that wetlands that will eventually occur in the immediate vicinity of the rehabilitated project area have a natural capacity for sustained exposure to water-borne contaminants, or can be manipulated to immobilise or reduce the rate of transmission of such contaminants.

Summary

A variety of research investigations undertaken on specific aspects of rehabilitation of the Ranger project area have focussed on the strategic plan to construct a large landform of waste rock over the operational areas of the mine and tailings dam. Many of the research projects have involved multidisciplinary teams of scientists and practitioners. They have dealt in a reconnaissance sense with such problems as characteristics and behaviour of waste rock in a constructed landform, tailings characterisation and the behaviour of tailings in the long term, contaminant mobility from constructed landforms and the effects of wetland environments on contaminant filtration, and revegetation science, particularly from the viewpoint of accelerated establishment of whole ecosystems on waste rock substrates without utilising natural soil covers. The results of these projects are now being integrated into second stage research investigations which will concentrate on rigorously controlled field trials in order to provide data to establish and calibrate predictive models for medium- and long-term behaviour. Observations of these field trials in the context of progressive rehabilitation of the project
area during the remainder of the mining operation will be a gauge of success of the various strategies, and can be utilised in the context of short and long term rehabilitation plans by Ranger.

Acknowledgments

Much of the information summarised in this paper has come from unpublished reports by colleagues working on several aspects of rehabilitation of the Ranger Project Area, and we are grateful for access to these documents.

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CHAPTER 25

THE USE OF ANTS TO ASSESS RESTORATION SUCCESS FOLLOWING MINING: A CASE STUDY AT RANGER URANIUM MINE

Alan N Andersen

Introduction

The goal of land rehabilitation following large-scale disturbance varies widely according to perceptions of the value of the original land, and to the future use of that land. In environmentally sensitive areas such as National Parks, a common objective of rehabilitation following mining is to restore the original ecosystem. This means re-establishing the composition, structure and functioning of the biota, often on an altered substrate or landform.

Ecosystem restoration faces two important challenges. The first is to manage the land so as to accelerate succession processes (Bradshaw 1987). The second is to assess the success of the restoration program. Such an assessment must consider the proper functioning of an ecosystem, rather than just be a superficial appraisal of its general appearance (Salwasser & Tappeiner 1981; van Horne 1983; Ewel 1987). It must also be able to gauge how well restoration is proceeding, rather than be restricted to an evaluation of the end result; this is so management procedures can be appropriately modified, or land managers released from further obligation.

In northern Australia, ants have frequently been used as indicators of restoration success following mining (Majer 1984, 1985; Majer et al 1984). This is because ants are so diverse and abundant, are functionally important, interact with many other components of ecosystems, and are sensitive to environmental change (Majer 1983; Greenslade & Greenslade 1984; Andersen 1990) — in short, they have the ability to integrate a wide range of ecological variables.

The traditional approach to using ants in this context is to track species succession and the build-up of species richness over time, and to relate these to other environmental variables (Majer 1984, 1985; Majer et al 1984). A complementary approach is to investigate changes in the functional group composition of ant communities, as this provides information on the ecological types, rather than just numbers, of species present (Andersen 1990).

Greenslade (1978, 1979) has identified seven functional groups of Australian ants based on their habitat requirements and competitive interactions, which are the major factors influencing ant distribution. The most important group comprises dominant species of Iridomyrmex, which exert a strong competitive influence on other ants because of their great abundance, high rates of activity, and aggressive behaviour (Greenslade 1976). Species of Iridomyrmex occur primarily in open habitats, where the soil surface is highly insulated, and their activity is not impeded by heavy litter. The remaining functional groups comprise species which either occur in habitats not favoured by Iridomyrmex, or which possess specialisations reducing their interaction with Iridomyrmex (see Andersen 1990 for details). One of these other groups comprises 'opportunists', which have many parallels with 'weeds' in plant communities (Andersen 1991): they are unspecialised, poorly competitive ants characteristic of disturbed sites (eg Andersen & McKaige 1987; Andersen & Burbidge 1991) or other habitats where the abundance of Iridomyrmex is low (eg Andersen & Majer 1991). Their abundance relative to that in undisturbed habitats therefore provides a useful indication of the extent of recovery from disturbance.

This chapter summarises the results of a survey of ants at a range of sites undergoing restoration at Ranger uranium mine, operated by Energy Resources Australia (ERA). A full account of the study will be published elsewhere. Ranger is located within, although is not formally part of, Kakadu National Park in the Northern Territory. The restoration program at Ranger has been proceeding for eight years, and is still at a preliminary stage due to ongoing mining operations (see Unger & Milnes, Chapter 24 in this volume). Because the mine is surrounded by Australia's most
The use of ants to assess restoration success

prestigious National Park, there is considerable public interest in ERA's environmental performance at Ranger. Its ability to restore the minesite may well determine whether or not mining is permitted elsewhere in the Kakadu region, and possibly in environmentally sensitive areas elsewhere in Australia.

This paper has two major objectives. First, it aims to illustrate a functional group approach to the use of ants as indicators of restoration success following disturbance. Second, by evaluating Ranger's preliminary restoration program, it aims to provide useful information for future restoration management practices at the mine.

Methods

Ants were sampled during July (mid dry season) 1990 at eight sites within the Ranger lease, six of which had been disturbed by mining operations, with the other two (sites C1 and C2) representing undisturbed controls. The vegetation at the control sites were savanna woodlands dominated by species of Eucalyptus (particularly E. teredonia), with Sorghum intrans being the predominant grass. The management histories of the six disturbed sites are summarised in Table 1. Four of these were located on top of the mine's main waste rock dump. Revegetation had commenced two (site 2A), four (sites 4A, 4B) and eight (site 8A) years previously. Unlike these four sites, the remaining two were located relatively close (within 50 m) to intact vegetation and therefore to potential sources of recolonisation. They had respectively been revegetated four (site 4C) and eight (site 8C) years previously.

The preliminary revegetation program at Ranger is heavily dominated by fast-growing species of Acacia (especially A. holosericea), even when the seeds of a variety of plant taxa were sown. The young acacias at site 2A were still low and sparse, but at the other revegetated sites they had formed a dense scrub 4–6 m in height, with a thick litter layer and patchy grasses. The one exception was site 4B, which had been seeded with a wide variety of plant taxa, including eucalypts, and had undergone a management burn after 3 years. This burn appears to have prevented dominance by Acacia, and the site supported a mixture of shrubs and small trees up to 6 m, mostly species of Acacia, Eucalyptus and Grevillea. It tended to have lower canopy cover, higher grass cover, and lower litter cover than the other revegetated sites.

Ants were sampled using pitfall traps, consisting of 4.5 cm diameter plastic vials partly filled with 70% ethanol as a preservative. Fifteen traps were located at each site, arranged in three lines of five traps, with traps and lines separated by 10 m. Sites 4A and 4B were not wide enough to accommodate three lines of traps without possible edge effects, so at these sites the 15 traps were arranged in two lines. Traps were operated once for a 48 hr period at each site. Ants were also collected by hand on an opportunistic basis at each site. The weather was fine throughout, with daytime maximum temperatures around 35 °C, and nighttime minimum temperatures about 20 °C. The sampling regime was designed to provide comparative information on species richness and the relative abundances of different ant species foraging on the ground at the study sites (see Andersen 1990), and not to assemble complete species lists for each site.

<table>
<thead>
<tr>
<th>Revegetation Age (yrs)</th>
<th>2</th>
<th>4</th>
<th>8</th>
</tr>
</thead>
</table>

**Recolonisation Source**

<table>
<thead>
<tr>
<th>Distant</th>
<th>2A</th>
<th>4A, 4B</th>
<th>8A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>4C</td>
<td>8C</td>
<td></td>
</tr>
</tbody>
</table>

(a) Revegetation at all sites except 4B was heavily dominated by fast-growing species of Acacia, producing a dense shrubland. Site 4B underwent a management burn and included a variety of plant taxa (see text for details). Two sites undisturbed by mining operations (sites C1 and C2) were used as controls.

Ant species in traps were scored according to a five point abundance scale: 1 = 1 ant, 2 = 2–5 ants, 3 = 6–20 ants, 4 = 21–50 ants, 5 = >50 ants. Species richness and species composition at each site were determined by compiling records from traps and hand collections, and species relative abundances were calculated by summing abundance scores over the 15 traps. Species were then assigned to functional groups according to Andersen (1990), and the abundance of each functional group determined for each site.
Results

A total of 66 species from 21 genera were recorded during the study. Species richness was highest at the two control sites (35 and 33 species), compared with 4–21 at the disturbed sites (Fig 1). Comparing sites distant from undisturbed vegetation and dominated by Acacia, species richness increased from 4 after 2 years (site 2A), to 7 after 4 years (4A) and to 12 after 8 years (8A). Sites located close to undisturbed vegetation (4C, 8C) had considerably more species (both 21). Site 4B, which had undergone a management burn, had 12 species recorded, compared with 7 at adjacent (unburnt) site 4A.

There was a clear succession of ant species across sites (Fig 2). At site 2A, the entire ant fauna consisted of four abundant species of Iridomyrmex. Their large populations appeared to be almost entirely supported by honeydew from sap-sucking homoptera that were abundant on the young plants, as little insect prey was available. Of the species at site 2A, only I. sanguineus occurred at site 4A, where the tropical tramp species Paratrechina longicornis represented 46% of total pitfall catches. Tetramorium lanuginosum was also abundant. Neither P. longicornis or T. lanuginosum were recorded at all at the control sites. All the common species at site 4A were also common at sites 4B and 8A, but here several additional species also occurred.

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FIGURE 1 Total numbers of ant species recorded, and total ant abundances in pitfall traps, at each study site.

(a) Revegetated sites are placed in order of increasing ant species richness. The contributions of the major functional groups (Dominant Iridomyrmex, Opportunists, Generalised Myrmicinae, Hot climate specialists) are shown.
"Ant Species (1-66)"

**Figure 2** Distribution across sites of the 66 ant species recorded during the study (a)

(a) Sites are ordered as in Figure 1.

_Paraatrechina longicornis_ was less common at revegetated sites located close to undisturbed vegetation (sites 4C and 8C), representing about 13% of total catches in each case. Species composition at these sites was very similar, with _I. sanguineus_, _P. longicornis_, _Rhytidoponera reticulata_, and _Iridomyrmex_ spp 2 and 14 being the most abundant ants, and similarly so, at both sites.

Individual species showed a variety of responses to different levels of revegetation (Fig 3). Some, such as the meat ant _Iridomyrmex sanguineus_ and to a lesser extent _Iridomyrmex sp 14_ and _Monomorium sp 24_, were widely distributed across sites. _Iridomyrmex sp 14_ was most abundant in the open habitats of site 2A and the controls, whereas the reverse was true for _Monomorium sp 24_. A few species, notably _Paraatrechina longicornis_ and _Tetramorium lanuginosum_, were found only at revegetated sites (Fig 3). On the other hand, very many (28) species were recorded only at control sites, including all the seven species of _Melophorus_ that were collected.

Functional group composition also varied markedly across sites (Fig 1). The initial stage of revegetation (site 2A) was exclusively colonised by dominant species of _Iridomyrmex_, which were then replaced by opportunists and generalised myrmicines as vegetative and litter cover attained high levels (sites 4A and 8A). Site 4B had sparser litter than did sites 4A and 8A, and sites 4C and 8C had numerous patches of bare ground — these differences were all reflected in the abundance of dominant _Iridomyrmex_.

The abundances of dominant _Iridomyrmex_, opportunists, and generalised myrmicines at revegetated site 8C were all comparable with those at the control sites (Fig 1). However, hot climate specialists (primarily species of _Melophorus_) were absent entirely from site 8C, and other functional groups were poorly represented. Moreover, the major opportunist at site 8C was _P. longicornis_, which was absent from control sites. The functional group profiles of the control sites were therefore markedly different from those of revegetated sites.
FIGURE 3  Abundances of the major ant species in pitfall traps at each site
Discussion

Recolonisation by ants at sites 2A, 4A and 8A suggests the following successional sequence. Sites are initially colonised by species of *Iridomyrmex*, which attain high population densities. Their success appears to be due to an ability to exploit honeydew from homopterous insects, as well as their well-documented preference for open habitats. As vegetative cover and litter development increases (sites 4A and 8A), species of *Iridomyrmex* become replaced by opportunists and generalised myrmicines. Ant recolonisation is very slow, with only 12 species present after eight years. Species richness, species composition, and the composition of functional groups all bear little resemblance to that occurring at control sites. The major species at revegetated sites, *Paratrechina longicornis*, is an introduced species associated with human disturbance throughout the tropics (Wilson & Taylor 1967), and is absent from control sites.

Results from sites 4C and 8C suggest that ant recolonisation is markedly accelerated when revegetation occurs close to relatively undisturbed vegetation. Twenty-one species occurred after four years (site 4C, compared with only seven species at site 4A). However, species richness and composition at site 8C was almost identical to that at site 4C, indicating that little further succession had occurred after four more years. This is probably because floristics and vegetation structure had remained largely unchanged during this period, and it is likely that the ant communities at these sites represent the end-point of ant succession under the prevailing vegetation. Further change in ant species richness and composition would be expected with significant changes in vegetation.

There can be little doubt that a major factor limiting recolonisation by ants of revegetated sites is the heavy shade and litter cast by acacias. The ant fauna of Australia’s tropical savannas consists primarily of arid-adapted species requiring well-insolated conditions, such that they are usually absent from heavily shaded habitats (Andersen & Major 1991). This is especially true for species of *Melophorus* (Greenslade 1979), which were prominent components of the control sites but absent from all revegetated sites. The heavy shade and dense litter of revegetated sites also restricts the establishment of other plant taxa; it is therefore likely that the above situation will not change, at least until the acacias die (possibly after 10–15 years).

The conclusion of this study is that revegetation dominated by fast-growing species of *Acacia* is not conducive to ecosystem restoration at Ranger uranium mine. Data from site 4B, where the site was burnt and a variety of plant taxa were established, gave improved results, although the longer term fate of this site is currently unknown. It is recommended that ERA establishes an extensive series of experimental plots at Ranger, where the effectiveness of a wide range of management treatments is systematically tested.

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References


CHAPTER 26

INTEGRATING CONSERVATION AND DEVELOPMENT:
AUSTRALIA'S RESOURCE ASSESSMENT COMMISSION
AND THE TESTING CASE OF CORONATION HILL

Brian Galligan and Georgina Lynch

Introduction

The politics of environmental dispute resolution are particularly volatile and contentious because they involve powerful groups and well entrenched interests that are passionately committed to opposing courses of action. Politics in pluralist societies typically work by means of incremental adjustments, tradeoffs and compromises. As much as possible, the claims of contending interest groups are partially accommodated through integration into, or marginal adjustment of, established policy and symbolic frameworks. This traditional politics of incremental adjustment tends to break down for environmental disputes, however, because of the character of those disputes and the nature of the groups involved. Environmental disputes tend to be zero-sum games requiring an either/or, develop or not-develop outcome. Some development is often not a feasible compromise because of the nature of the development which destroys the natural condition; for example, damming a wild river like the Franklin tames the river, or felling mature trees in a native forest changes its pristine status. There are of course many instances when controlled development can be married with environmental preservation or even enhancement, but such tradeoffs are made more difficult by the character of environmentalists and their politics. Environmentalists or ‘greens’ epitomise the ‘new politics’: they form a single interest group; they tend to have a fundamentalist dedication to their purpose and do not easily accept compromise which is the stuff of traditional politics; and they are well organised with developed institutional structures, large membership and sophisticated media and lobbying capacities. Hence, in Australia as in many other countries, the politics of environmental dispute resolution has put great stress on established political institutions and policy processes which have not responded well to the new challenges (see Papadakis 1989, 1990).

Nor has the usual fall-back on the judiciary and court system been very effective in Australia or overseas. ‘Given the incapacity of executive and legislative branches of government to resolve such fundamental disputes,’ one American commentator reports, ‘the courts have become a dominant force in American environmental policy’ (Rabe 1988, 583). But these too are poorly equipped to fill the political breach because of their rigid procedures and inability to deal flexibly with broader issues of economic growth and social impact or to handle complex issues involving the physical and social sciences. Dissatisfaction with the courts has led to a mushrooming of ‘environmental dispute resolution’ (EDR) alternatives. The emphasis in EDR is on avoiding litigation by bringing contending parties together in a less adversarial context to explore possible ways of accommodation and settlement. This alternative, however, also has limited scope because it is appropriate only for disputes between contending parties and tends to exclude other parties and remove the issue from the public domain to an arena of private tradeoffs (see Rabe 1988, 590–8 for a critical discussion of shortcomings in EDR).

There has been a comparable, although less pronounced, move away from courts to experimentation with alternative methods and forums of environmental dispute resolution at the state level in Australia where the courts have been traditionally relied upon for resolving environmental disputes. Probably the most notable instance was the appointment by the Queensland government of Tony Fitzgerald as commissioner to inquire into the conservation, management and use of Fraser Island (Fraser Island Environmental Inquiry 1991). This was in turn the occasion for a major conference on alternative methods of dispute resolution sponsored jointly by this Commission and the Queensland government. ¹
The most notable Australian innovation in the politics of environmental dispute resolution, however, has been the creation of the Resource Assessment Commission (RAC) by the Hawke government in 1989. Established 'to bring a new level of rigour and sophistication to the Government’s decision-making processes related to resource use issues', the RAC constitutes a major step forward in providing governments with the results of an analysis of the likely implications of proposals for the use of Australia’s natural resources. At least that was the claim of the Chairperson of the Commission, Justice DG Stewart, in presenting the RAC’s first inquiry report on the Kakadu Conservation Zone, and more particularly on mining Coronation Hill, in May 1991. Stewart boasted that the initiative puts Australia at the forefront of developing a more objective and enlightened process for dealing with these important issues' (Resource Assessment Commission 1991, v).

This paper examines Australia’s brave new experiment in institutional design for establishing a process for enhanced assessment of the conservation and development aspects of major projects, and the testing case of Coronation Hill which was a baptism of fire for the new organisation and its procedures. As we shall see in the next section, the politics of enhanced rationality which is embodied in the RAC process of systematically exploring options tended to be brutalised at the decision making stage by a Prime Minister and Cabinet enmeshed in larger power struggles. Nevertheless, the outcome of banning mining and incorporating Coronation Hill within the Kakadu National Park was the outcome preferred by the RAC, and for which its thorough assessment and report had prepared the ground.

The Resource Assessment Commission

Genesis

The Resource Assessment Commission (RAC) was established by the federal government in 1989 to deal with highly contentious environmental and resource allocation issues. The passing of the Resource Assessment Commission Act by the Commonwealth Parliament on 16 June 1989 followed the announcement by the then Prime Minister, the Hon Robert Hawke, of a series of new principles to guide decision-making in future conservation and development disputes. These were enunciated by Mr Hawke in a joint news conference with Senator Graham Richardson, Minister for the Arts, Sport, the Environment, Tourism and Territories, and the Hon John Kerin, Minister for Primary Industries and Energy, in November 1988. The government’s purpose, claimed the Prime Minister, was to discharge to this and future generations of Australians the responsibilities that we have for both sustainable and appropriate economic development on the one hand and the obligation that we have to this and future generations to protect the Australian environment. This would entail establishing a formal policy framework which was much more ambitious than the ad hoc approach typical of decision-making to date.

Up to this point there had been a proliferation of conflicting rhetoric and claims advanced by both business and environmental groups, each sides endeavours to ‘balance the green debate’ in ways which were congenial to their particular interests. At one end of the spectrum, business and industry groups recognised the growing political clout of burgeoning green lobby groups and saw the need to establish a coherent policy direction. The Wesley Vale Pulp Mill experience, which saw the plans of a private corporation frustrated and delayed due to a conservation controversy, motivated a number of industry groups to lobby collectively for a defined policy from the government (Chapman 1989). At the other end, environmental groups could not afford to ignore empirical studies which indicated that, as economic conditions deteriorated, concern for the environment could be out-weighted by the necessity for economic development. With such convergence, the time was ripe for the establishment of a cohesive policy framework.

The political protagonists, Richardson and Kerin, welcomed a climate responsive to striking a balance between development and environment groups. The consummate political operator, Senator Richardson, had become the ‘born again greenie’ who was clearly capable of advancing the cause of environmental groups, while John Kerin, the solid economic rationalist, was considered as the saving hope for a frustrated business community. There was no doubt that the electoral consequences of alienating one, or conceivably both, of these groups would be damaging for the Hawke government. In the face of such a dilemma, the idea of an independent body with the capacity to weigh the value of competing claims was advocated as the ideal instrument for achieving a solution. In a show of unprecedented (but in view of the climate, perhaps not unpredictable) cooperation, representatives from Industry Groups and the Australian Conservation Foundation supported the idea of an independent body with the capacity to consider all sides to the debate. The RAC was heralded as an appropriate
vehicle for balancing economic needs with preservation of the environment for future generations (Conservation: A Time for Co-operation, The Canberra Times, 31 January 1989). It is noteworthy that the Wilderness Society, the largest self-funded Australian Conservation Group, boycotted participation in the RAC inquiry process (Green Group Split, Courier Mail, 21 July 1990). The group claimed that they could not participate in the RAC inquiry process unless a moratorium was placed on tree felling in areas which were the subject of the Forest and Timber Inquiry. 4

Rules of passage

The passage of the RAC legislation through Parliament was not an easy process. The opposition was under considerable pressure from business groups to support the legislation, but, in the tradition of partisan politics in Australia, an agreement could not be reached between the two major political parties. Ian Sinclair, leading the debate for the opposition, proposed that the RAC bill was nothing more than an extra layer of bureaucracy, adopted by the government to 'avoid making hard decisions' (House of Representatives, Hansard, 10 May 1989, 2431). Sinclair condemned the government for favouring minority view points in resource management issues, and for 'using the RAC concept to atone for public reaction against the government's last minute intervention on the Wesley Vale Pulp Mill' (HOR, Hansard, 10 May 1989, 2431). Moreover, the opposition objected to the RAC Bill on federal grounds that land use was the responsibility of the states and, accordingly, the states should have a clearly defined role in the RAC proposal. The opposition fuelled the states rights issue by moving that the government 'be condemned for failing to ensure consultation with the States before the appointment of special Commissioners to the RAC' (HOR, Hansard, 10 May 1989, 2431).

While not succeeding with their proposed amendments, the opposition's negative stance ensured that the passing of the RAC legislation was contingent upon the support of the Democrats who held the balance of power in the Senate. Democratic spokesman, Senator Norm Sanders, conceded that the Bill was a step in the right direction, but initiated a package of amendments designed to 'put the environment first'. Essentially, the amendments were to ensure the following: that in matters relating to a National Estate, the Australian Heritage Commission would have the right to give evidence about the matter to the inquiry; that witnesses who testified before the Commission were reimbursed for expenses and, in certain cases, remunerated for the development of data; and that the concepts of 'ecosystem integrity and sustainability' and 'ecological sustainability' be included in the RAC Act (Senate, Hansard, 16 June 1989, 4222-4). To secure the support of the Democrats, the government agreed to review the RAC legislation, and included the amendments proposed by the Democrats in the final draft. From this legislative compromise, the RAC was born.

An ambitious purpose

From a very early stage it was apparent that the genesis of the RAC belonged to Kerin and his Department of Primary Industries and Energy. Indeed, Kerin attributed the idea of the RAC to a former senior private secretary from his department. Kerin also explained in a paper, 'Making decisions we can live with', that he had welcomed the proposal for the RAC as a means of 'trying to accommodate my frustration with endless public inquiries' (Kerin 1990, 18). Through the RAC, he hoped to achieve a balanced approach.

The lack of common ground between the disparate development and environmental groups had become starkly apparent in the negotiated settlement in the Lemanthyn and Southern forests Inquiry in Tasmania. Kerin suggested that an important environmental area with an equally significant economic benefit did not have to be resolved in terms of 'either/or' outcomes ('Green Luddites derail policy creation', Australian Financial Review, 8 November 1989). The findings of the Helsham Inquiry, set up to look into the conflict between forestry groups and conservationists over Tasmanian forest management, were abandoned after the Commission of Inquiry failed to provide a unanimous result. This in turn led to a series of intergovernmental negotiations between the Commonwealth and Tasmanian government (Tsamenyi et al 1989). In the short term, the result was a complex arrangement of compromises and consultations which had little, if any, resemblance to the actual findings of the Helsham Inquiry. In the long term, there was no doubt that the Commonwealth government could not afford another Helsham, hence a transparent body with the authority to consider complex issues of resource management seemed to be the solution. Kerin saw the alternative as an independent review body with a systematic methodology and transparent process of investigation. With the capacity to 'sort out some of the wood from the trees literally', the RAC might prove to be an invaluable addition to the decision-making process in Australia (Kerin 1990, 20).

From bitter experience, the federal government had come to recognise the glaring need to link the policy
problems associated with the development/environment debate with an institutional framework. Clearly, the task of translating policy formation into policy implementation is not an easy one, as commentators such as Pressman and Wildavsky (1984), Dunshire (1978), Sabatier and Mazmanian (1981) have recognised. This is especially the case where developmental and environmental issues are involved together. Indeed, the difficulties associated with policy implementation in environmental policy making characterised the final report of the World Commission on Environment and Development (1987), chaired by Mrs Gro Harlem Bruntland. In a report titled Our Common Future, the Bruntland Commission flagged the need for institutional innovation in developing an appropriate framework for dealing with matters that raised both economic and environmental issues:

The integrated and interdependent nature of the new challenges and issues contrasts sharply with the nature of the institutions which exist today. These institutions tend to be independent, fragmented and working to relatively narrow mandates with closed decision processes. Those responsible for managing natural resources and protecting the environment are institutionally separated from those responsible for managing the economy. The real world of interlocked economic and ecological symbols will not change; the policies and institutions concerned must (WCED 1987, 9).

Kerin's approach to establishing the terms of reference for the RAC were in keeping with the spirit of Our Common Future (HOR, Hansard, 3 May 1989, 1822–3). The objective of the Commission was to enquire into and report not only on environmental and economic considerations but on the cultural, social, industrial, and any other aspects of resources and their uses. The Policy Principles for resolving competing claims for the use of resources were set out in schedule 1 of the RAC Act and emphasised a qualitative approach.

1. There should be an integrated approach to conservation (including all environmental and ecological considerations) and development by taking both conservation and development aspects into account at an early stage.

2. Resource use decisions should seek to optimise the net benefits to the community from the nation's resources, having regard to efficiency of resource use, environmental considerations, ecological integrity and sustainability, ecosystem integrity and sustainability, the sustainability of any development, and an equitable distribution of the return of resources.

3. Commonwealth decisions, policies and management regimes may provide for additional uses that are compatible with the primary purpose values of the area, recognising that in some cases both conservation and development interests can be accommodated concurrently or sequentially, and, in other cases, choices must be made between alternative uses or combinations of uses.

Clearly, the terms of reference for the Commission indicated that the expected impact of the RAC far exceeded merely determining the 'value' of a particular area. There were hopes that the RAC would be capable of developing a prudent, but forthright, policy framework for handling questions of environmental and developmental significance. This would entail working out a comprehensive strategy to assist the federal government in integrating environmental and economic factors into its decisions about the use of Australia's natural resources. If it succeeded in its lofty but difficult purpose, the RAC would be a major institutional and policy innovation of the Hawke government, and a political godsend to boot.

An approximate model: the IAC

While the attempt at integrating environmental and economic factors into a workable policy framework was unique for Australia, an integrative approach to policy decision making has important precedents in industry policy. Tariff protection for manufacturing which was the central pillar of Australian industry policy from federation until the 1960s always had an independent body charged with assessing applications for increased protection and to which the minister could refer matters for investigation. This was at first the Interstae Commission until it was rendered impotent by a jealous High Court, replaced by the Tariff Board through its various protective and corrective phases from 1921 until the 1970s, then the Industries Assistance Commission and, finally, its mutant the Industry Commission in 1989. Australia's propensity for using independent state institutions to develop and monitor government policy is as old as federation. In the early 1970s, the Whitlam government had restructured the Tariff Board as the Industries Assistance Commission (IAC) to free it from the clutches of the protectionist Department of Trade and Industry. The IAC was charged with a broader mandate of assessing the
economic impact of protectionism in general and tariff levels for particular industry sectors in particular.

When the idea of the RAC was first mooted in Cabinet in 1988, the Prime Minister proposed that the RAC amalgamate with the IAC. This suggestion was resoundingly defeated, however, as there was an existing apprehension that the IAC was overwhelmingly an economics industry oriented body (see note 2). The Australian Conservation Foundation (ACF) supported this resolution, claiming that a body such as the IAC did not have the capacity to deal with issues of a complex environmental nature.

Although the Prime Minister was unable to amalgamate the two Commissions, the guidelines for the RAC process were modelled on those of the IAC (Cuthbertson 1990, 62). The RAC, like the IAC, is a permanent body. However, except for the Chairperson of the Commission, Justice Stewart, 'special' commissioners are only appointed for the duration of the inquiry, rather than on a permanent basis. This differs from the IAC's strong emphasis on permanent staffing which has been justified in these terms: 'The IAC's reputation for professionalism in the Australian community and internationally could not have been achieved without some sort of consistent staff presence around an integrity of structure and identity' (Cuthbertson 1990, 62).

The guidelines articulated in the RAC Act emphasise the need for an integrated, independent approach to the inquiry process, which is similar to that of the IAC. Further to this, the proceedings of the RAC, like those of the IAC, are not adversarial or legalistic in nature in order to facilitate public participation at all levels of the inquiry process. Because of this emphasis on a transparent process of public inquiry, some commentators have drawn close parallels between the IAC's review of tariffs in the 1980s and the RAC's processes for assessing economic and environmental issues in the 1990s.

Federal dimensions

While the RAC does not have a role to play in deciding the nature of the terms of reference for a particular inquiry, the contributions of state governments in the inquiry process are vital. Section 16(2) of the RAC Act requires, firstly, that state governments be consulted, and secondly, that reasonable steps be taken to consult with persons who are interested in the resource matter. In practice, section 16(2) means that before a recommendation can be passed to the RAC, the governments of the states must be consulted on the terms of reference for a particular inquiry. The precise nature of the 'consultation' process with affected states and the process for determining the desired terms of reference for a particular inquiry were not specified, so there is obvious room for flexible development, but also for challenge and dispute.

So far the RAC has received the terms of reference for three recommendations: the first concerned the Forest and Timber Inquiry where terms of reference were decided after a successful consultative process with the relevant state governments; the second, which was completed first, was the Kakadu Inquiry, under the auspices of the Northern Territory government, which fell within the authority of Commonwealth jurisdiction, and the third, the Coastal Zone Inquiry, for which consultation with the relevant states and interested parties was particularly delicate and lengthy.

In the last two decades, a number of controversies have involved disputes about the respective powers of the Commonwealth and the states. Disputes over the constitutionality of certain Commonwealth decisions in relation to environmental policy and land use management have led to Court battles and bitter political stand-offs between the Commonwealth and state governments. Examples include the extraction of mineral sands from Fraser Island (Murphyores Inc Pty Ltd versus The Commonwealth & Others (1976) 136 CLR 1), the Dams dispute in South West Tasmania (The Franklin Dam case (1983) 46 ALR 625), the Pulp Mill proposal in Wesley Vale Tasmania, the Lemonthyme and Southern Forests Inquiry in Tasmania (Richardson versus The Forestry Commission (Tasmanian Forests case) (1983) 62 ALJR 158), the destruction of rainforests in Queensland and NSW, bauxite mining in the jarrah forests of Western Australia and uranium mining in the Northern Territory. In the past the legislative framework for environmental policy and management has been of little assistance in trying to resolve these tensions. Both the Commonwealth and the states have enacted legislation in the arena of environmental protection and resource management in an attempt to define more clearly lines which are hazy.

The states have strong jurisdictional claims in this area, as Bruce Davis points out:

natural resources, utilisation, land use planning and nature conservation programs are all the prerogatives of the States, with the Federal role limited to suasion for
common standards, research assistance of the provision of funds for some resource conservation activities. In addition, the Commonwealth jurisdiction includes Federal sites and buildings within States and all Federal Territories, including some offshore islands and Antarctica (Davis 1985, 2).

But as concern for the environment has increased in the past twenty years, too has the Commonwealth's desire for direct involvement in environmental protection and resource management initiatives. Thus, it has come as no surprise that some Commonwealth proposals in the field of land management have impinged upon what the states considered to be their jurisdiction. The result has been an underlying tension and, in some cases, an innate suspicion that the Commonwealth is trying to erode state rights in resource management issues. It has been argued by numerous commentators that the fact that the constitution does not make any express provision to empower the Federal Parliament to make laws with respect to the environment encourages federal/state antagonism in the area. However, the Constitutional Commission found that an express environmental head of power for the federal government was not necessary (Constitutional Commission 1988, 757). Indeed, closer examination of relevant constitutional provisions indicates that the Commonwealth, in practice, has considerable power to influence environmental policies of the states.

Constitutional basis

Section 51(1) of the constitution, the trade and commerce power, has been used by the Commonwealth to prohibit the export of minerals unless the express approval of the appropriate federal minister is obtained. The High Court in Murphysores Inc Pty Ltd v. The Commonwealth & Others (1976) 136 CLR 1 approved of the intervention of the Commonwealth in preventing the mineral sand-mining of Fraser Island, indicating the extensive practical scope of section 51(1). In addition, the commerce power confers a plenary authority on the Commonwealth to prohibit imports absolutely and conditionally (Zines 1985, 15).

The constitution also provides that power with respect to foreign corporations, and trading or financial corporations, section 51(xx), falls within the ambit of the Commonwealth. This power has proven to be of considerable significance since the Concrete Pipes case in 1971 (Strickland versus Rocla Concrete Pipes Ltd (1971) 124 CLR 468). The Tasmanian Dam case has widened the possible ambit for the operation of the power significantly. The corporations power is now considered to be the main vehicle for federal commercial regulations in Australia. Essentially the Commonwealth may control, having regard to environmental considerations, all manufacturing, production or extractive processes conducted by corporations for the purpose of trade (The Franklin Dam case (1983) 46 ALR 625).

Another potent source of Commonwealth power for intervening in state resource development issues is the section 51(xxix) external affairs' power. As the number of International Agreements dealing with the preservation of world cultural and natural heritage sites increases, the utilisation of section 51(xxix) widens the Commonwealth's base of authority in addressing issues regarding the environment and its resources. Following the decision of the High Court in the Tasmanian Dam case, the existence of a treaty obligation is sufficient to bring the matter within the external affairs power. As a result, the Commonwealth has a significant role to play in a World Heritage Listing issue which has the potential to affect the environmental policy of any state (Constitutional Commission 1988, 758). As Mason CJ commented: 'Entry of a property in the World Heritage List supported by the protection given by the Act, constitutes perhaps the strongest means of environment protection recognised by Australian Law' (Queensland v. The Commonwealth (1988) 77 ALR 291, 296).

While not as pervasive as the commerce and corporations powers, the races power is relevant to the protection of Aboriginal relics and sacred sites which are an integral part of Australia's cultural environment (Constitution of Australia Act, section 51(xxvi). In the Tasmanian Dam case, the High Court also approved of the Commonwealth's providing legislation for the protection or conservation of a site which is of particular significance to people of Aboriginal race (Zines 1985, 23).

In addition, there are a number of financial powers which the Commonwealth can use for environmental objectives. Section 96 enables the Commonwealth to give financial assistance to the states on the terms and conditions it prescribes. Such incentives can be used to ensure that states adopt certain practices, for example, Soil Conservation programs (Soil Conservation (Financial Assistance) Act, 1986). So too, sections 51(ii), 51(iii), 90 and 99 concerning taxation, bounties and excise, are useful tools for the Commonwealth to grant depreciation allowances for appropriate environment protection developments.
and bounties for products produced by pollution free means (Constitutional Commission 1988, 758).

Finally, it should be noted that section 109 of the Constitution provides that when a Commonwealth and state law are inconsistent, the Commonwealth Act will prevail, and the state law, to the extent of the inconsistency, will be invalid (Constitution of Australia Act, section 109). Thus, while states do control the use of land and own the mineral resources of the land, in practice this power effectively means that the Commonwealth may exert paramountcy over legislative arrangements for the environment in Australia.

Against this background, it can be seen that underlying the consultation process between the Commonwealth and the states for determining terms of reference for RAC inquiries is a complex constitutional framework which gives the states extensive jurisdictional powers but the Commonwealth most of the trump cards. However, the states can seriously jeopardise the whole process because litigation before the High Court is a most unsatisfactory way of proceeding. By withdrawing from involvement in the RAC process which is, after-all, a Commonwealth government initiative, a state might in practice be able to scuttle the whole exercise.

Where constitutional jurisdiction is so divided between semi-sovereign governments, the appropriate way forward is not litigation but cooperation. There were positive signs of this in the Special Premiers’ Conference process for the review and practical reform of intergovernmental arrangements during 1990–91. At the first of a series of Special Premiers’ Conferences held in November 1990, the Commonwealth and state governments agreed to develop an Intergovernmental Agreement on the Environment through a cumulative process. The communiqué from the Conference indicated that such an agreement would involve a cooperative national approach to the environment: be based upon better definitions of the roles of the respective governments; and hopefully lead to a resolution in the number of the disputes between the Commonwealth and the states and territories on environmental issues. Such an agreement would in turn produce greater certainty of government and business decision-making and better environment protection (Special Premiers’ Conference 1990, 10). Under the umbrella of this type of ‘co-operative’ approach, the requirements for state consultation pursuant to 16(2) of RAC Act would be easily met. Hawke’s New Federalism, however, was derailed by Keating’s accession to the leadership in late 1991.

Coronation Hill

The inquiry process: some lessons

Some important lessons can be drawn from the Final Report on the Kakadu Conservation Zone Inquiry, tabled in Parliament on Tuesday 7 May, 1991. In assessing the effects of mining in the Kakadu conservation zone, the Commission found that the environmental effects of mining the Coronation Hill site would not threaten the fine environmental balance of the fragile wetlands of Kakadu. More specifically, thorough examination of relevant material by the inquiry found that the impact of mining at Coronation Hill would not cause significant harm to the water flow levels in the South Alligator River. However, the final report did signal that the extractive industry at Coronation Hill would threaten the integrity of the park’s world heritage listing, and irrevocably damage Aboriginals’ spiritual values, as the area sought for mining is claimed by the Jawoyn tribe to be a sacred site.

After the final report was handed down, the RAC came under considerable fire from the media for failing to provide a ‘conclusive’ decision, and thereby throwing the decision back in the federal government’s lap (McGuinness 1991). These criticisms reflect a misunderstanding of the Commission’s inquiry process. The RAC is not a decision-making forum but has a purely advisory role. The purpose of the Commission is to analyse and order various options to provide informed recommendations. Accordingly, the methodology of the Commission is geared towards providing a thorough systemic analysis, not providing a winner-takes-all answer (Stewart 1990, 104).

Ultimately, the success of impartially weighing the claims of interested parties depends upon the effectiveness of the Commission in facilitating a comprehensive and consistent inquiry process.

The RAC Act outlines the forms and limits of adjudication which direct the course of the inquiry process. The object of the Commission is to balance competing interests between conservation and development groups, and this needs to be tackled by integrating environmental and economic factors in assessing resource management issues of national significance. This process involves addressing the environmental, economic, industry, cultural and social implications of major natural resource proposals. Justice Stewart, as Chairperson of the RAC, has emphasised this factor as a major concern of the Commission, commenting that in an
integrated assessment process the Commission must identify all the factors and synthesise them in a comprehensive, consistent and balanced way' (Stewart 1990, 102).

Section 16(1) of the RAC Act provides that the Prime Minister can initiate an inquiry in relation to a resource matter, and refer the matter to the RAC to conduct an inquiry into the issue. The Commission does not have the authority to initiate its own inquiries. Moreover, the terms of reference for a particular inquiry are determined by the government. The Commission has no input into the specification of the matter, the scope or time frame of the inquiry, nor the priorities to be observed by the Commission in investigating a particular recommendation. Hence, like the IAC, the RAC depends upon the political priorities of the federal government to determine the scope of its work (and indeed its life-span).

The process of recommending a resource matter to the RAC has already raised concern in various sections of the community. The environment/development debate is swathed in emotion because it affects the livelihood of many people with a vested interest in a particular outcome. Any political party runs the risk of alienating a crucial proportion of the electorate by advancing the cause of one particular group at the expense of another. To achieve the objectives outlined in Schedule 1 of the RAC Act, the Commission must ensure that the inquiry process is not subject to political interference. If the government recommends a political 'hot-cake', the chances of the RAC evaluating the benefits of a particular area with the active participation of all interested parties is severely restricted.

The RAC, to date, has been given three recommendations and already the problems of remaining impartial and independent have arisen. The referral of the Coronation Hill mining issue to the RAC took place amidst wide criticisms from the business community that the federal government has used the RAC as a 'cooling pond for hot environmental issues' (Wallace 1989, 32). In a joint statement nine industry groups, led by the Business Council of Australia, claimed that the decision to refer the issue of mining at Coronation Hill to a twelve month inquiry was a blatant attempt to delay making a politically sensitive decision. They concluded:

> While business supports the establishment of the RAC and hopes that it will remove the emotion which now characterises resource development decisions, the Government has yet to provide any undertaking that the process will replace short-term political expediency (Wallace 1989, 32).

Given such sentiments, it comes as no surprise that the final report on the fate of the Kakadu Conservation Zone did not take the 'heat' out of the Coronation Hill issue. In fact, the recommendations of the RAC had entirely the reverse effect. Commentators have proclaimed that the report was a 'litmus test' for business confidence in the Hawke government policies, the plight of Aboriginal people, and the validity of the RAC itself (Kelly 1991). These claims were made amidst loud protestations from the Prime Minister that the Kakadu Report represented no such test, as Coronation Hill was a 'special case' and should be interpreted in its natural isolation (Taylor 1991). The federal Cabinet was split as to whether the RAC recommendations on Coronation Hill should be implemented.

It should be noted, however, that in the Kakadu inquiry the Commission achieved what the RAC process was designed to achieve. All available information and resources were employed to ensure that the Commission gave impartial, comprehensive and informative advice about different ways to use resources. The Coronation Hill study illustrates the immense difficulty in weighing the competing values of all factors. Furthermore, it highlights the increased difficulty faced by an independent body, such as the RAC, when it is passed any issue which is already the subject of intense political wrangling.

The options clarified

In presenting the RAC report to the Prime Minister, Justice Stewart reitered that its aim was to 'better inform government decision making, but that decision making remains the province of government which will still have to make difficult decisions' (Resource Assessment Commission 1991, vii). The options, however, had been comprehensively and publicly canvassed through the RAC process of inquiry, research, public hearings and draft report exposure.

On the economic development side, the RAC report made clear that from a strict financial cost-benefit analysis the project would represent an efficient use of resources. But clearly it would be no economic bonanza, yielding only about $82 m in direct net economic benefits to the Australian economy (estimated in 1991 present value terms) (Resource Assessment Commission 1991, xx). The project would contribute substantially to the depressed Northern Territory economy, especially in the
construction stage, and to Australia's trade balance. It would also benefit financially the Jawoyn, a number of whom were in favour of mining which would boost their employment prospects and break the vicious circle of welfare dependency. Perhaps most significantly of all, a decision to forego mining would be interpreted by business as a failure on the part of government to deal with mining proposals in sensitive areas. The mining lobby was touting the line that 'sovereign risk' for investors was now primarily a matter of government fickleness, and this project was a 'litmus' test of the government's broader intentions.

On the environmental front, the RAC found that the Conservation Zone which included Coronation Hill was closely linked, ecologically as well as geographically, with Kakadu National Park, especially through the South Alligator River which served as a refuge and corridor for terrestrial and aquatic fauna. Mining development might, in the view of some, detract from the 'ecological integrity' of the combined Zone and National Park area, but the RAC concluded that 'a single mine, properly managed and monitored, would have a small and geographically limited direct impact on the known biological resources of the Conservation Zone' (Resource Assessment Commission 1991, xxii).

Hence, if economic development and protection of the environment were the only issues, there was not a great lot at stake in the decision, at least in substantive terms. The economic benefits were not so large, nor, with proper management, was the environmental impact very great. Of course, those facts did not decrease the symbolic significance of the decision for the opposing development or environmentalist lobbies, but they did enable the public and the government to discount the wilder rhetoric on both sides and put the issue into proper perspective. As one newspaper editorialised after the RAC report was made public, it was 'difficult to feel sympathy for the loud warnings of doom and gloom issued by either conservationists or miners in the controversy over mining Coronation Hill' (Financial Review, 10 May 1991).

The primary issue, therefore, for both the RAC and the government was the preference of the Aboriginal people and the status to be accorded their religious belief. The RAC report warned:

> If mining proceeds in the Zone it will be against the wishes of the senior Jawoyn men, who are supported in their view by many Jawoyn people and other senior Aboriginal people in the Region; further, mining will adversely affect the ability of Jawoyn people, particularly the senior men, to sustain cultural and religious values, beliefs and practices that are important to them (Resource Assessment Commission 1991, xxii).

The Conservation Zone was within Jawoyn territory; Coronation Hill (Gurata) was regarded by Jawoyn elders 'as being associated with Bula and as containing the essence of Bula' and mining would disturb that; and the three senior Jawoyn men who were acknowledged to speak with authority on the matter were opposed to mining (Resource Assessment Commission 1991, xxii–xxiii). Nothing was clear cut, however, since the Jawoyn religion was fluid and imprecise, and there was disagreement about the significance of Gurata and the permissibility of mining even among its senior custodians. In fact, two out of the three of these had indicated that the site was not significant, a fact that the RAC noted as an 'inconsistency' that 'cannot be easily explained' (Resource Assessment Commission 1991, xiii). The strong impression one gets from reading its report is that the RAC was highly sympathetic towards Aboriginal religious sensitivities and reservations about mining; for instance, 'The Inquiry took the view that underlying cultural and religious themes and trajectories of interpretation should be accorded primary importance in assessing the nature of Aboriginal cultural and religious interests' (Resource Assessment Commission 1991, 155–6). Whatever 'trajectories of interpretation' might mean, it is clearly not very precise.

Nor did the RAC beat about the bush in pointing up the Aboriginal issue for government decision making. 'The dilemma facing the Australian Government is clear', it said: 'should it set aside the environmental risk that cannot be eliminated and the strong views held by the Aboriginal people responsible for the Conservation Zone in favour of securing increases in national income of the order that seems likely from the Coronation Hill project and possibly from other mineral resources in the Zone?' As if to counterbalance the symbolic significance of the decision painted by the mining constituency, the RAC added the warning that 'a decision to permit mining may be seen as a further instance of reluctance on the part of the Australian government to take decisions in favour of retaining Aboriginal culture and religious values in the face of potential economic gains from mining' (Resource Assessment Commission 1991, xxiii–xxiv). Coronation Hill was indeed a special case, the RAC concluded. And quite clearly, it had loaded the dice against mining by its findings and emphasis on the Aboriginal issue. Quite simply, as the press
reported it, the RAC report 'backed Aborigines' (eg *Australian*, 6 May 1991, 'Mining Report Backs Aborigines').

**The politics of government decision making**

The Hawke government had been able to defer making a hard decision on mining at Coronation Hill for more than a year by referring the matter to its newly established Resource Assessment Commission. With the completion of the RAC's final report in May 1991, however, the government had to bite the bullet. Even the RAC, in the first of its recommendations, advised the government to make a decision 'as soon as possible' (Resource Assessment Commission 1991, xxi).

That was always going to be difficult but was exacerbated by leadership instability in the government. Treasurer Keating, for long the Prime Minister in waiting, made his challenge the very day that Cabinet was scheduled to make its decision on Coronation Hill so the matter had to be deferred. Prime Minister Hawke survived with the support of most of his senior ministers and strong backing from Labor's Left faction. Significantly, the Left faction included current Aboriginal Affairs Minister, Robert Tickner, and his predecessor, Gerry Hand, who played a key role in delivering the Left's numbers for Hawke. Hawke survived easily enough, but it was widely perceived that the Left had strengthened its influence in the government when Brian Howe, the Left's senior minister, became Deputy Prime Minister.

The day before the rescheduled Cabinet decision on Coronation Hill, the Prime Minister came out strongly in favour of respecting Jawoyn religious beliefs about Bula and that disturbing Bula would unleash destruction. Hawke said: 'I think it's an enormous presumption for us to say about 300 people, you are irrational, fancy believing that Bula is there. I mean where is our God?' (reported in the *Age*, 18 June 1991). Although Hawke's outburst was before an audience of Catholic girls at a Sydney school, it was immediate headline news. He had told the students that they would not be hard put to work out his position on the issue. Hawke's statement was interpreted as preempting Cabinet because, in this first major issue after a wounding leadership challenge, a defeat would signal chronic lack of authority.

In such dramatic circumstances, the decision on Coronation Hill was hardly in doubt as Cabinet met. Previously, it had been reported that the Centre Left faction that could be expected to have the swing vote favoured mining, and that the Labor caucus favoured leaving it to the Jawoyn people to decide whether they wanted mining or not (*Age*, 28 & 30 May 1991). It was also widely reported both before and after the Cabinet meeting that a majority of Cabinet, including the senior economic ministers, favoured mining. The issue was put to Cabinet in terms of two broad options: for a complete ban on mining, or mining subject to approval by the Jawoyn Aborigines (*Financial Review*, 19 June 1991). Bob Collins, Minister Assisting the Prime Minister on Northern Australia, put the case strongly for the second option, arguing that he was more familiar with Jawoyn views than the RAC through his political and personal ties in the Northern Territory. But Collins was opposed by the Left ministers, especially Bolkus and Hand. The decision was taken without a vote which is usual practice for Cabinet, but only after Kim Beazley, a Hawke supporter in the recent leadership battle but a supporter of the mining option, is reported to have said: 'It's your government. You make a decision. We'll support you' (*The Australian*, 20 June 1991). In typical hard-headed fashion, Graham Richardson, a Keating supporter but an opponent of mining, summed up the outcome: against the background of the leadership challenge and Hawke's anti-mining remarks the previous day, Cabinet had no choice but to give the Prime Minister 'a win' on the issue (*The Australian*, 20 June 1991).

So, as it turned out, the government's decision on Coronation Hill was in accord with the RAC's specification and weighting of options. But that was chiefly as a consequence of the charged leadership issue and factional politics within the government rather than as a result of the triumph of enhanced rationalism in government decision making. Hawke won by making it a make-or-break leadership issue that swamped the alternative preferences of his Cabinet and Labor caucus. Additional factors that likely tipped the balance were Hawke's own personal commitment to the rights of the Aboriginal position and his determination to win on their behalf, and popular support for a decision against mining. This last matter, however, was controversial and had been clouded by a public storm over the RAC's contingent valuation finding. Because of the manner in which the decision was made, little public attention was focused on, nor credit given to, the RAC for its background work. More damaging was the pledge of the Liberal Coalition opposition to revoke the decision when in government, and abolish the RAC as 'yet another layer to the already over-layered decision-making process' and an excuse to delay action without adding significantly to available information (Fred Chaney, Shadow Minister for the Environment, Media Release, 9 August 1991). Nor has the mining company relinquished its determination to mine Coronation Hill: having tried unsuccessfully to
pressure the new prime minister, Paul Keating, into reversing the government’s decision, it has recently mounted a challenge in the High Court on the grounds that, in effect, the government deprived it of its property right without just compensation. Hence the RAC’s legitimacy and future are not assured, nor was it its Coronation Hill report the harbinger of an enhanced politics of environmental decision making (see Brennan 1991, 14-16). Nevertheless, its role was significant in publicly defining the options.

Notes
2. Transcript of Joint News Conference with Senator Graham Richardson, Minister for Arts, Sport, The Environment, Tourism and Territories and the Hon John Kerin, Minister for Primary Industries and Energy and the Prime Minister, the Hon. Robert Hawke, 18 November 1988, p 1.
3. The Sydney Morning Herald, ‘Public support for green issues strong, but fading,’ reporting a poll conducted in December 1989, which indicated that as economic conditions became harder, the scales of concern for the environment adjusted in favour of economic progress.
4. According to the Resource Assessment Commission, the potentially debilitating effect that non-participation by the Wilderness Society may have on the inquiry process has been, to a large extent, limited in practice by the Wilderness Society’s continued contribution to the Environmental Impact Assessment Process.
5. See the RAC Act, per sections 31, 38 and schedule 1 respectively.
6. Constitution of Australia Act, section 122, gives the Commonwealth plenary powers with respect to Territories.
7. RAC Act, Section 17 (a), (b) & (c).
8. The pro-mining camp was understood to include Senator Button, Mr Willis, Mr Dawkins, Mr Beasley, Mr Kerin, Senator Cook and Mr Griffiths, with the last 2 not having a vote in Cabinet. The anti-mining group was said to include Mr Hawke, Mrs Kelly, Senator Richardson, Mr Hand, Senator Boland and Mr Tickner (who did not have a vote on the issue).
10. For a close analysis of the Cabinet split on the day, see Glenn Milne, ‘Hawke’s bloodless victory reopens dangerous wounds’, The Australian, 20 June 1991.

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CHAPTER 27

MODELLING ENVIRONMENTAL CHANGE AND SUSTAINABLE DEVELOPMENT IN AUSTRALIA

Ian Moffatt

Introduction

The purpose of this chapter is to illustrate the way in which dynamic modelling can aid our understanding of ecologically sustainable development in complex, changing environmental systems. To put this paper into context, a brief description of environmental change in Australia over the past 200 years is given, followed by a description of some possible changes due to the greenhouse warming effect in the next 50 years. Obviously, this broad view of environmental change can only sketch some of the significant natural and anthropogenic processes which have affected the continent. It must, however, be stressed that whether we are examining past environments or speculating on possible future changes, we must deal with various degrees of uncertainty.

Another characteristic of environmental systems is that they are subjected to various forms of change. These changes can be due to exogenous factors such as sunspot cycles or due to endogenous events such as earth tremors. Furthermore, endogenous changes can be the result of both the actions of people and of natural events. The fluctuations in the international business cycles, for example, can have a major impact on the lives and landscapes of parts of Australia. To make matters even more complicated, these changes can also occur at different temporal and spatial scales and with varying degrees of magnitude. Clearly, the interactions of these endogenous and exogenous processes can result in diverse patterns of environmental responses which are exceedingly difficult to understand and explain. Yet, if we are to plan for ecologically sustainable development in Australia, it is essential that decision makers take note of the fluctuations in environmental systems.

The concept of sustainable development came into prominence in political affairs with the publication of the Brundtland Report (WCED 1987). Essentially, this report attempted to reconcile the problems of development with that of environmental conservation (Moffatt 1992a). One of the problems raised by the report is the diversity of definitions given to the term 'sustainable development'. A useful definition of sustainable development is that it attempts to meet the basic needs of all and to extend to all the opportunity to satisfy their aspirations for a better life without compromising the ability of future generations to meet their own needs. To date, however, there are no methods currently available to integrate these two aspects of reality (James 1991). It will be argued that one way to make progress in this area of research is to develop a dynamic model of sustainable development so that we can anticipate and plan for some possible impacts of environmental change in Australia.

In the following section some of the natural and anthropogenic changes to the Australian landscape over the past 200 years will be described. This section also includes a description of possible changes attributed to the greenhouse effect (Pearman 1988). In the third section a framework for modelling the environment as a dynamic system will be described. This framework illustrates different trajectories that a system may exhibit when parameters in a model cross critical thresholds. Even in deterministic models of the environment multiple states of dynamic equilibrium as well as chaotic dynamics can be exhibited. By introducing a stochastic element in a dynamic model, together with exogenous energy, it can be demonstrated that such models can then evolve rather than merely exhibit growth and decline. This type of model is known as a self-organising system or dissipative structure (Nicholis & Prigogine 1977; Prigogine & Stengers 1982).

In section four this dynamic framework can be applied to the concept of sustainable development by extending the pioneering work of Daly's steady-state concept (Daly 1977, 1980; Daly & Cobb 1989) and Georgescu-Roegen's ideas on entropy and economic laws (Georgescu-Roegen 1971, 1976). By re-introducing the environmental constraints which make up the equations of the model of
sustainable development, it is possible for us to appreciate the finite limits of the planet and some of the problems in attempting to manage complex, interacting environmental systems. It will be demonstrated by simulation modelling that it is possible, in theory, to achieve a sustainable form of development in Australia. Finally, some of the problems inherent in planning for a steady-state sustainable society for Australians are discussed.

Environmental change in Australia

Environmental change can be examined at a whole series of spatial-temporal scales. In this section there are brief descriptions of some of the major changes to the environment which have taken place in Australia over the past 200 years and a forward glance at probable changes in the environment, due to the greenhouse effect, by the year 2050.

Australia is an ancient continent which split from Antarctica some 54 million years ago. It is slowly moving northwards towards the Indonesian archipelago carrying with it a Gondwanic flora and fauna. Throughout the Tertiary period (65 to 2 million years BP, i.e. Before Present) most of the continent was covered by closed forests, which have gradually been replaced by more open vegetation over the last twenty million years (Clark 1990). This slow change in the vegetation cover was probably due to increased seasonality and greater variability in thermal and water regimes (Nix 1981). It has been estimated that by 2.5 million years ago a winter rainfall regime was established in the southeast, replacing the summer rainfall regime which had previously covered the landmass.

During the Quaternary period (approximately the last 2 million years) the continent was affected by colder and drier conditions than at present. Almost all of Australia remained unglaciated during the Quaternary; consequently the soils and landforms are very different from those of Europe and North America. As a result of its geological evolution, the continent has been subjected to erosion for an extended period. The geomorphological processes have resulted in the continent being reduced to a relatively low lying landmass with the mountain ranges rarely rising above 200 metres, with the obvious exceptions of the McDonnell Ranges in the arid centre and the Great Dividing Range on the eastern margin of the country. The continent is generally endowed with nutrient-poor soils and a unique Gondwanic flora and fauna as well as feral animals introduced in the past 200 years (Boyd 1990; Leeper 1970; Young et al 1990).

There is reliable evidence that the peopling of Australia began over 50,000 years ago with the migration of Aborigines into the northern coastal areas of the continent (Roberts, Jones & Smith 1990). In the central desert region artefacts dated some 20,000 years BP have been discovered. During this extended occupation of the continent it is clear that the Aboriginal groups were able to use fire as an early environmental management method for clearing small areas of ground for food collecting purposes. Inevitably, this practice would have caused some changes to the flora and fauna; however, the actual extent of these anthropogenic changes are both difficult to estimate and to disentangle from non-human causes. The Aboriginal groups showed great ingenuity and skill in living in an essentially sustainable way in the various ecosystems which make up the continent. All this was to change with the coming of the Europeans.

European settlement of Australia had profound impacts on both the landscape and the Aboriginal peoples who came into contact with these different economic and cultural groups. Powell, for example, indicates that the Europeans planted their own ideas of landscape design on an alien landscape and culture, showing scant regard for the Aboriginal peoples and their unique ways of coping with a harsh environment (Powell 1976).

The displacement of the Aboriginal peoples and their land is portrayed in Figure 1. In 1778, at the continental scale, the area occupied by non-Aboriginal people was insignificant. One century later, however, over half of the land was under European use with wheat cropping in the south and east and extensive pastoral properties in the centre, north and around Australia's coastal margin. Aboriginal lands were centred in the west of the continent and in Cape York Peninsula and Arnhem Land.

In addition to the confiscation of Aboriginal land, new ways of using the resource base were introduced, most noticeably in changes to the natural and quasi-natural vegetation of the continent. The use of inappropriate farming methods resulted in vast tracts of the land suffering degradation. In some of the marginal semi-arid lands, the hazard of land-degradation was 'first ignored, then harshly recognised and later only partly accepted' (Blakie & Brookfield 1987, 36). These and other environmental problems are now recognised in Australia and are being addressed especially in the Landcare decade. Nevertheless, Australia has had the problem of encouraging economic growth in a mineral rich but fragile
FIGURE 1 Human land use in Australia: 1788, 1888 & 1988

environment. Thus, in just two hundred years the European settlers and all subsequent non-Aboriginal people who have settled in Australia have caused great damage to both the Aboriginal populations and to the natural and quasi-natural landscapes of Australia. In some instances this was due to the Europeans, especially the British, attempting to transfer their own ideas of husbandry onto an alien landscape (Powell & Williams 1975; Powell 1976, 1988). Boyden et al (1990) have referred to this fourth ecological phase of exploitation of the environment as technometabolism (i.e. the input of resources and energy and the output of wastes resulting from technological processes). Some of the characteristics of this exploitative phase of Australian development are: a growing per capita consumption of resources and energy; a material standard of living, as manifest in income and in the acquisition of manufactured commodities, which is very uneven (This latter inequality of wealth and social provision is especially true of the Aboriginal population, although many non-Aboriginal peoples suffer deprivation in Australia); and an emphasis on environmentally damaging economic activities such as uranium mining and woodchipping simply to maintain employment.

One of the major areas of current and future environmental concern is the likely impact of the enhanced greenhouse effect on Australia. The details of the likely scenarios for Australia and the states/Territories within Australia have been well documented (Pearman 1988; Henderson-Sellers & Blong 1989; Moffat 1992a & b). The anticipated changes at the continental scale include: an inland temperature increase by 4–5 degrees Celsius; drier southern coastal areas, especially much drier around Adelaide; warmer, windier and possibly drier conditions around Hobart; and an uphfill movement of the snowline. On the Western and Eastern seaboard, the coastal temperature would probably rise by 2–3 degrees Celsius and the cyclone belt would move further south as would crocodiles and box jellyfish. In the north more flooding and erosion are anticipated as well as an increase in mosquito-borne disease (Park 1991).

Obviously, as we attempt to anticipate future changes to the Australian environment we will inevitably encounter greater uncertainties concerning both changes to the physical and human environment and in our responses to these probable changes. Attempting to produce policies for environmental planning and management is not easy in these circumstances, as noted in the ten volumes of the Ecologically Sustainable Development Working Group draft reports (ESDWG 1991). Nevertheless, as all political decision making is made in situations of some degree of uncertainty, it is important that scientists try to reduce the uncertainty in their climatic change scenarios and that politicians attempt to introduce preventative and adaptive responses to a greenhouse warmed earth.

Looking imaginatively into the future, Boyden et al (1990) argue that the technometabolic phase must end. They argue that there are three possibilities: the biosphere might collapse as a system capable of supporting human life; some fortuitous development(s) may bring a halt to the technometabolism before irreparable damage is done to Australia and elsewhere; humans might use their intelligence and their aptitude to move towards an ecologically sustainable society. It is possible that the third possibility is gaining momentum in Australia. In the last decade the federal and state/Territory governments together with various non-governmental organisations have become acutely aware of the fragile nature of the ecosystems upon which ultimately all life depends. The CSIRO report on Australia’s environment and natural resources noted that

> if Australia is to continue to prosper as a nation any increased production must not result in a continuing decline in the value of the nation’s renewable natural resource base, nor its biological diversity, nor its capacity to assimilate waste (Young et al 1990, 3).

One way of attempting to reconcile economic development within the constraints of ecological systems is to move towards integrated models of sustainable development.

**A framework for modelling ecologically sustainable development as a dynamic system**

One of the encouraging features of the current situation in Australia is the fact that many different individuals and institutions have embraced the idea of ecologically sustainable development. The recently released Ecologically Sustainable Development Working Groups’ draft reports are a welcome step forward in the promotion of an alternative society to the current phase of technometabolism (Boyden et al 1990). Before we get carried away on a wave of euphoria about the possibility of creating an ecologically sound, socially just and participatory society in Australia, it is worth bearing in mind that we do not have any method for deciding which form of development, if
any, is sustainable. As James notes, whilst there is general agreement between government, industry, conservation groups and the community to embrace a form of Ecologically Sustainable Development, ‘the current challenge is to find effective ways of operationalising the concept’ (James 1991, 19).

One way of making a positive contribution to this debate is to apply the methods of contemporary dynamic modelling in an attempt to cast some light on the problems of sustainability which are at the forefront of the conflict between economic developers and environmental conservationists. The purpose of such an effort is to develop some methods which allow us to differentiate between sustainable and non-sustainable development and to indicate the ways in which a sustainable path of development can be achieved; it could also highlight the difficulties in achieving sustainable development in Australia.

Dynamic models may be defined as a simplification of a real world system which changes through time and space. This apparently straightforward definition of dynamic models hides a bewildering array of dynamic behaviour found in such models (May 1976; Moffatt 1991). This dynamic behaviour includes: instabilities; locally stable or metastable systems; bifurcating behaviour; chaotic dynamics and self-organising or dissipative structures. Some of these modes of behaviour are illustrated in Figure 2, based upon a simple difference equation of the logistic type written as \( \Delta p_t = r p_t (1 - p_t/L) \) where \( p \) is the number in a population group, \( L \) is the carrying capacity of the system and \( r (1 - p_t / L) \) is the rate at which new members of the population are recruited into the system. This simple non-linear difference equation produces a variety of behaviour when its parameters cross critical thresholds. If, for example, \( 0 < r < 1 \) then the system converges monotonically towards \( L \). Oscillating convergence towards \( L \) is observed when \( 1 < r < 2 \). If, however, the condition where \( 1 < r < 2.57 \) applies, then a series of stable limit cycles can develop. When \( r > 2.57 \) then the logistic equation model exhibits chaotic behaviour, with the latter being defined as a non-recurrent time trajectory for the state variable \( P \). This type of behaviour occurs in a simple deterministic equation. In models which are characterised by three or more non-linear equations with an exogenous input of energy and a stochastic element, more complex patterns of self-organisation (dissipative structures) can be observed (Nichols & Prigogine 1977; Prigogine & Stengers 1982; Moffatt 1985, 1991). Clearly, if we are serious in our attempt to promote sustainable development, and use models to help us achieve this, we must be aware of the limitations, including chaotic regimes, which reside hidden and dormant in even simple models of environmental systems.

The major implication of this foray into dynamic modelling is to highlight the dangers involved in attempting to use models for planning and management; it is important that chaotic and bifurcation regimes be noted but avoided if we are to plan for an ecologically stable future. Yet, if we are to proceed to develop a strategy for promoting sustainable development, we need to ensure that in our attempts to move the current systems from an unsustainable trajectory we do NOT inadvertently prevent the possibility of evolutionary changes occurring. Bearing these important caveats in mind, we now turn to a more elaborate model of sustainable development.

The idea of sustainable development is a vague concept which attempts to reconcile economic development with ecological constraints. It has been endorsed in spirit, by several countries such as the United Kingdom, Canada and Australia. In Australia, the federal government, for example,

recognises the fundamental link between economic growth and the environment. It recognises that environmental aspects are an integral part of economic decisions. It is committed to the principle of ecologically sustainable development (Hawke 1989, 4).

Ecologically sustainable development means 'using, conserving and enhancing the community's resources so that ecological processes are maintained, and the total quality of life, now and in the future, can be increased' (Ecologically Sustainable Development 1990, i).

There are several problems associated with this attempt to promote sustainable development (Hare 1990). One of the problems with the concept of sustainable development is that it is ill defined. This lack of a clear definition is important; as Pearce notes, 'Single word objectives such as sustainability are deceptive and dangerous without rigorous thinking' (Pearce 1990, 322). Without clarification of the concept of sustainability there can be little progress in attempting to reconcile economic development and environmental conservation in Australia or elsewhere. Another problem associated with sustainable development is that it lacks methods which would enable it to be put into operation to help reconcile the demands of economic development with environmental conservation. Several researchers (for example Pearce et al 1991) have attempted to focus their attention on developing suitable tools for making
FIGURE 2 Various modes of behaviour in dynamic models

Source: Moffatt 1985, 229.
the concept of sustainable development operational but to date no satisfactory method has been produced.

A dynamic model of ecologically sustainable development

This section makes a preliminary attempt to clarify the concept and method of sustainability by reworking the ideas of a steady-state economy using dynamic simulation methods. The classical economist Mill is responsible for promoting the idea of a steady-state economy (Mill 1878). His ideas on the steady-state economy received scant attention until it was realised that humankind's market and state planned economies could not continue plundering the earth of its resources and polluting the planet without some major changes to these systems. Currently, as many of the planned economies are changing to a market system, the problem of environmental abuses has not receded. Indeed it could be argued, as Marx noted, that

*Capitalist production ... disturbs the metabolism of the man and the earth, is the return to the soil of its elements consumed by man in the form of food and clothing, and therefore violates the eternal condition for lasting fertility of the soil ... capitalist production, therefore, develops technology, and the combining together of various processes into a social whole, only by sapping the original sources of all wealth: soil and the labourer (Marx 1867, quoted in Daly 1977, 111).*

The idea that the capitalist processes are ecologically unsustainable reappears in Boulding's characterisation of the market economy as a cowboy rather than a spaceship economy. The image of a cowboy economy is,

*symbolic of the illimitable plains and also associated with reckless, exploitive, romantic, and violent behaviour, which is characterised by open societies. The closed economy of the future might similarly be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy (Boulding 1980, 258).*

Whilst Boulding noted the need to develop an economic system as a subset of ecological activities, it was Daly who provided the main twentieth century impetus to developing a steady-state economy. Daly has advocated a steady-state economy for many years (Daly 1977, 1980; Daly & Cobb 1989). The starting point for his analysis was an appreciation of both the materialistic basis of economic activity and a moral imperative that we need to embrace a form of stewardship of the planet rather than an uncaring exploitation. Daly's idea of a steady-state economy is shown in Figure 3. Note that emphasis is placed on the use of flows of energy in the system rather than on attempts to live on borrowed natural capital stock.

It is possible to extend the idea of a steady-state economy into a model of sustainable development by using both energy accounting and dynamic simulation modelling (see Slessor & Moffatt 1987). In Figure 4 a simplified flow chart of a macro-model of sustainable development is shown. This model consists of several positive and negative feedback loops which interconnect the major state variables in the model. These major state variables include: a demographic sector; crude industrial and resource base sectors; energy sector; and agricultural and vegetation sectors. The two major endogenous inputs not only include precipitation and temperature changes associated with enhanced greenhouse induced climatic change, but also economic and trade flows. As far as possible the material flows are expressed in energy rather than monetary units and several policy switches can be applied to some of the negative feedback loops so that the trajectory of the system can be guided onto a sustainable form of development.

The major state variables in the model were initialised for Australia for 1980 and a 'business as usual' base run was simulated. As can be observed from Table 1, the base run is not sustainable. By the time the simulation has reached 2020, the energy required by the system is exhausted and to compensate for this shortfall large imports of oil have to be made resulting in a massive trade deficit. The standard of living has an index figure of 19 compared with the 1980 index of 100. The population growth is over twice the sustainable population. Obviously, this would be an unhappy state of affairs for Australians. The federal, state/Territory governments and others would need to take decisive action to prevent this critical, simulated event from actually occurring.

Several simulation experiments were performed to try and steer the trajectory onto a sustainable path of development. This is achieved by introducing a
Figure 3: A steady-state economy

Source: Daly 1980, 20.

(a) Rectangle (E) is the total ecosystem, which contains the total stock (S) of wealth and people as one of its mutually dependent components. The ecosystem imports energy from outer space (sun, A) and exports waste heat to outer space (sink, Z). The stock contains matter in which a considerable amount of available energy is stored (e.g. coal, oil in oil tanks, water on high ground, living things, wood products, and the like), as well as matter in which virtually no available energy is stored. Matter and energy in the stock must be separately maintained. The stock is maintained in a steady state when B is equal to D and C is equal to F. In the steady state throughput equals either input (B plus C) or output (D plus F), since input and output are equal to each other. When input and output are not equal, then the throughput is measured by the smaller of the two.

From the second law of thermodynamics, we know that energy cannot be recycled. Matter may be recycled (R), but only by using more energy (and matter) to do it. In the diagram, energy moves only from left to right, whereas matter moves in both directions.

For a constant S, the lower the rate of throughput the more durable or longer-lived is the total stock. For a given throughput, the lower the rate of recycling (R), the more durable are the individual commodities. The optimum durability of an individual commodity is attained when the marginal production cost of increased durability equals the marginal recycling cost of not having increased durability further. Cost is total ecological cost and is extremely difficult to measure.

Both the size of the stock and the rate of throughput must not be so large relative to the total environment that they obstruct the natural ecological processes which form the biophysical foundations of wealth. Otherwise, the total stock and its associated throughput become a cancer which kills the total organism.

series of policies in the model via activating several negative feedback loops. By stabilising population growth and conserving energy requirements as well as altering the national goal to self-sufficiency in energy, using renewable resources and some fossil fuels, it is possible, in theory, to achieve a condition of dynamic equilibrium in the macro-model of Australia. Under this scenario the simulation shows a reduced population with an index of 111 and a sustainable population potential of 113, i.e. a population still within the bounds of sustainability. The nation appears to be self-sufficient in food and energy, although the standard of living is slightly reduced when compared with the 1980 index base. This simulated condition can be interpreted as a steady state or a state of ecologically sustainable development.

Obviously, the research reported here is only indicative of the possibility of developing a detailed macro-economic-ecological model of sustainable development in Australia. Much more detailed investigations into the sensitivity of the parameters of the model need to be carried out. Furthermore, there is a need to develop a larger data base and interconnect this to a geographical information system before more confidence can be placed in this dynamic model of ecologically sustainable development. At least this model merely indicates the potential of this approach to resolving some of the issues which surround the term 'ecologically sustainable development'. At the national level this simple model can illustrate the way in which a sustainable future for Australia may be achieved in theory; however, translating the model's recommendations into practice requires some careful ethical and political judgements.

Preliminary research with this overly simple model of sustainable development indicates that the current
FIGURE 4 A generic model of sustainable development

Source: Slessor & Moffatt 1987, 225.
TABLE 1 Unsustainable and sustainable simulations for Australia, 1980–2020

<table>
<thead>
<tr>
<th>Unsustainable trajectory (U)</th>
<th>Major state variables</th>
<th>Sustainable trajectory (S)</th>
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</thead>
<tbody>
<tr>
<td>2020* 1980* (U)</td>
<td>(S) 1980* 2020*</td>
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<tr>
<td>221 100</td>
<td>0.02 Population growth</td>
<td>0.00 100 111</td>
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<td>93 100</td>
<td>– Sustainable population</td>
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<td>– 100</td>
<td>0.24 Investment</td>
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<td>0 100</td>
<td>0.21 Energy self sufficiency</td>
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<td>42 100</td>
<td>1.00 Food self sufficiency</td>
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<td>100 100</td>
<td>0.50 Interest rate</td>
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<td>315000 100</td>
<td>– Imports</td>
<td>– 100 58</td>
</tr>
<tr>
<td>19 100</td>
<td>– Standard of living</td>
<td>– 100 89</td>
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</table>

* Based on index of 100 for year 1980

"business as usual" trajectory is unsustainable in the longer run. Obviously, by introducing some environmental policies such as energy conservation into the model, this would then delay the need for making major imports of oil. Single policy options, as simulated in the model, do not necessarily lead to an ecologically sustainable form of development, although it does delay the need for high imports of oil. By using several policy options in combination, however, it is possible to simulate a state of dynamic equilibrium to represent Mill's steady-state society. However, although it is relatively simple to change these policies in a model, it is often difficult to alter these in the real world. This is especially true when many environmental decisions require international agreements to be made before national/regional policies are implemented. However, there are signs that such international agreements can be made as some environmental conditions deteriorate and reach critical thresholds. Witness, for example, the case of controlling ozone emissions.

Clearly, some of the problems associated with environmental change are complex in both their scientific basis and their political economic context, causing difficulties for planning for environmental change.

Implications for planning sustainable development in Australia

The Australian environment has been subjected to intense development pressures for less than two hundred years. In that time Richardson notes that 70% of the plant communities which existed in 1788 have been modified in some way; over 65% of the original tree cover has been removed; and up to 75% of our rainforest has been cleared for grazing and agriculture ... 55% of arid lands and 45% of non-arid areas require treatment for land degradation; 4.2 million hectares are affected by salting; 78 species of plants and 17 species of mammals are believed to be extinct (Richardson 1990, v).

Clearly as a result of economic exploitation and poor environmental management practices, this continent has suffered large scale damage.

Given the damage already inflicted on Australia, there is a vital need to develop a national sustainable development strategy. Whilst some early steps to develop this are already underway, there are problems with developing sustainable development strategies for Australia and elsewhere. In particular, the second law of thermodynamics makes any idea of an indefinite ecologically sustainable development impossible. All that can be achieved is the promotion of sustainable development for the good of all sentient beings on this planet for as long as possible. It can be suggested that this time-span will be much greater if we adopt a spaceship Earth attitude rather than continue a cowboy approach to the earth's resources (Boulding 1980). The fact that the federal government, non-governmental organisations, industry and the community are becoming involved in promoting ecologically sustainable development gives some hope for the future. However, we need to address the problems
of inter-generational and intra-generational equity and ask how long will a steady-state sustainable future last?

If attention is turned to these two interrelated questions, namely of inter- and intra-generational distribution of goods and the duration of a sustainable society, it can again be argued that there is a degree of

*ethical attractiveness of the steady-state economy in that it provides an intertemporal world of equals in the basic goods of energy, materials, and space per capita ... if each generation is treated the same in terms of its basic opportunities, then, this may be fair enough from an intertemporal social choice perspective* (Georgescu-Roegen 1976, 123).

The basic idea of inter-generational and inter-temporal equality is argued by Rawls (1971) in his theory of justice. Briefly stated, if any individual could be born into the situation of any other and that everyone would be uncertain of when and in what situation they would be born, each person would argue for equality of income unless inequality was to the advantage of all. Whilst this Rawlsian position may be acceptable to humans, other sentient creatures may not accept it as fair. Nevertheless, it could be argued that this is an ethical goal worthy of pursuing in a world of increasing inequalities (see Lea, chapter 2 in this volume).

Another problem of any steady-state solution to environmental-economic interactions is that of duration. It is well known amongst astronomers that the life of our solar system and hence planet earth is finite — the solar system is estimated to end in approximately another 4.5 billion years from now. Despite this long time period it is clear that a 'steady state' or any other ecological-economic state is not forever, but as Page notes,

*there is a normative difference in choosing a path which leads to severe dislocations in 200 years and another which holds a much greater possibility of tenure for the next 300 million. It is easy to imagine a Rawlsian original position with the representatives from all potential generations choosing a steady-state path over a non-sustainable laisses faire one* (Page 1980, 317).

Whilst the mention of 300 million years is conjectural it is clear that it is better to promote a sustainable future than to continue along an unsustainable path similar to the past 200 years of environmental change and degradation (Heathcote 1990). It is imperative that we learn from history and realise that continuing a cowboy approach to running Australia's economy and ecology over the next two hundred years would be potentially disastrous for Australia.

From the above discussion it is obvious that any attempt to promote sustainable development in Australia needs to incorporate both economic development and ecological conservation within one conceptual framework. There are, however, several major difficulties with this task, including the role of models in the planning process and the problem of persuading those with economic power to redirect their efforts into a more sustainable productive direction even if this is a less profitable enterprise in the short term. There is also an urgent need for academics to develop a sophisticated theory of environmental-societal interactions in the historical process (Redclift 1988).

From a more orthodox planning perspective it is clear that modern policy analysis is not simply devoted to single function maximisation or optimisation criteria but has become increasingly multi-dimensional in nature (Nijkamp & Sproonk 1982). The reason for this shift in emphasis in planning and policy forum is a recognition of the fact that until the 1980s much planning designed 'to control or influence environmental systems has been made with reference to goals which were deeply held only by small, articulate and influential groups of society, in order to generate incremental changes in certain aspects of system operation' (Ahmad & Muller 1982, 31). Planning for sustainable development necessarily includes altering complex environmental systems but also needs to incorporate effectively the wishes of the population as a whole. Further work on defining the appropriate criteria for evaluating sustainable development from a multi-dimensional perspective is also urgently required. It is also important to try and interface dynamic models of ecological-economic systems with general equilibrium and optimisation models (Braat & Van Lierop 1989; Dixon 1990a&b; Young 1990). Similarly, there is a need to involve both a top-down and bottom-up approach to planning if ecologically sustainable development is to become a way of life.

In many countries the question of sustainable development becomes one of whether the country is to continue in its efforts to increase total output with scant regard for the ecological damage and assimilative capacities of the environment or whether individual nations are going to redirect their focus towards the enhancement of ecologically sustainable economic development. It should,
however, be realised that no analytical method can ever force a powerful elite to act in an ecologically sensible manner if they do not wish to. Convincing those powerful elites needs to be pursued through political action, intellectual argument and moral persuasion.

Summary

This chapter has briefly described some of the changes in the Australian environment which have occurred over the past 200 years and looked forward some 50 years to possible environmental changes due to the greenhouse effect. It has been argued that whilst the Aboriginal peoples altered the Australian landscape with their tradition of burning, they were able to live in an essentially sustainable manner in a harsh environment for many tens of thousands of years. The invasion of Europeans into Australia brought both new cultures and economic activities to Australia. The Aboriginal peoples' lands were expropriated and, in many cases, their traditional way of life was severely damaged; in some cases, such as in Tasmania, the Aboriginal people were exterminated. In a very strict sense the pattern of development over the last 200 years in Australia has been unsustainable for both the people and the landscape.

One of the ways in which sustainable development can be explored is by using dynamic modelling incorporating a resource/energy accounting. This particular framework has been described for modelling environmental systems which not only change, for example by growing or declining, but also permits a system to evolve. This idea draws upon Prigogine's concept of self-organising systems or dissipative structures (Prigogine & Stengers 1982) which has been used in open systems which are far from thermodynamic equilibrium. It is suggested that this approach may be useful for examining the concept of sustainable development since it acknowledges the role which free solar energy plays in maintaining the life support systems on the planet and the role of history in the evolution of people's use and abuse of the Earth.

One of the impacts of the movement to promote ecologically sustainable development in Australia is that it frankly recognises the role of human management in environmental systems. Furthermore, it assumes that some form of environmental management can be introduced in order to try and promote long-term sustainability of the ecosphere. The duration of sustainable development will be enhanced by adopting a more caring attitude to the abiotic and biotic species on this planet rather than an uncaring attitude. There is no certainty that the changes we are making to the planet, if left to unbridled market forces, will lead to a more sustainable world but there is a greater likelihood of creating a life of material comfort and dignity by ensuring the economic systems are controlled so that they operate safely within the ecological constraints of the planet.

This chapter has examined one way of modelling sustainable development in Australia's changing environment. In a sense, the relatively simple model developed above reinforces and extends Daly's statement that, 'all economic systems are subsystems within the biophysical system of ecological interdependence. The ecosystem provides a set of physical constraints to which all economic systems must conform' (Daly 1980, 24). Clearly, if we accept this sensible environmentalist premise then there is a need to try and steer Australia's current non-sustainable development trajectory onto a path leading to a sustainable future. This future is contingent on what we do now rather than on no action at all. It is always possible that our species becomes extinct but, unlike other species, at least we have a certain degree of choice over our fate rather than having to adapt to one which is imposed upon us. There is, of course, no guarantee that our efforts to promote sustainable development will succeed, yet the possibility of failure should not deter us from the task of promoting a just, participatory, sustainable and harmonious life on Earth. It is towards promoting that goal that some of our research efforts should be committed.

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CHAPTER 28

ENVIRONMENTAL AUDITING: A SUMMARY

Andrew Read

Introduction

An important tool needed to balance conservation and development strategies is 'environmental auditing'. No matter what policies are adopted, or how good our environmental planning or understanding of the environment is, there will always be lessons to be learnt and practical refining required to balance a forever changing conservation and development equation.

Today there is an increasing amount of effort being directed by governments towards evaluating the effectiveness and efficiency of environmental management practices and processes (ICC 1989). Environmental auditing is the formal means by which the performance of an environmental management program can be evaluated and adjusted (Margolis 1985).

As is the case for most environmental management tools, environmental auditing predates its name. It is important to be aware that the principles and methods of environmental auditing have been used by better forward thinking developers and environmental practitioners long before the actual name caught on (Margolis 1985).

Essentially, environmental auditing can be defined as the systematic examination of a project and process performance in satisfying and achieving environmental goals. It generally involves the search or verification of records, including verification of compliance, the accuracy of impact predictions, and the effectiveness of the mitigation measures. Without this necessary feedback, environmental impact assessment (EIA) is only a static exercise, whose beneficial influence is directed towards and ends with the early stages of development. The fundamental concept that is often overlooked is that environmental assessment is an on-going process; it should not stop once the approval has been granted (Sadier 1988).

Auditing therefore provides continuity between both the assessment and development phases and can be undertaken at any stage of the EIA process. Sadier (1988) emphasises that auditing should not be perceived as yet another stage of the EIA process but should be an integral element, providing the ongoing feedback necessary to continuously improve the EIA process, understanding environmental management, and thus protection of the environment.

The main objectives of this chapter are to discuss aspects of auditing objectives, and the issues and problems associated with its application both overseas and in Australia.

Terminology, objectives, and benefits

Of continued concern to environmental auditors is the amount of confusion associated with the terminology of environmental auditing. This concern is illustrated by the large proportion of text (in any published paper on the topic) dedicated to defining terms, relative to the proportion of text reporting, actual findings or new information on environmental auditing. The two areas that present the most problems are the differences between environmental auditing and environmental monitoring, and the differences between the types of environmental audits.

There is a distinct difference between environmental auditing and environmental monitoring. Bisset and Tomlinson (1988, 406) define environmental monitoring to be

concerned with the identification and measurement of impacts from developments, it is a process of repetitive observation of one or more elements or indicators of the environment according to pre-arranged schedules in time and space in order to test postulates about potential impacts on the environment.

In an attempt to resolve the continuous academic confusion and the lack of consistency in audit
terminology, Tomlinson and Atkinson (1987) published an article dedicated to achieving some sort of standardisation of environmental audit terminology. They also identified seven or so different types of environmental audits. It is now the most well quoted paper in the environmental audit literature.

The following year, Sadler (1988) argued that the basic principles of environmental auditing were the same for all environmental audits and, in practice, terminology was not as important as adequately describing the objective of the audit study. This approach to environmental auditing has been adopted by CCNT, as well as by the Western Australia Environmental Protection Agency (Bailey & Hobbs 1990; Read & Wright 1989). Because of the confusion still remaining in audit terminology, it is important when undertaking an environmental audit to make sure the objectives are defined unambiguously. The most well-known environmental audit objectives are as follows:

1. To evaluate the effectiveness of compliance requirements and compliance monitoring, and recommend changes where appropriate (Palmisano 1989; Bailey & Hobbs 1990);

2. To evaluate the effectiveness of surveillance and environmental monitoring programs, and recommend changes where necessary (Bisset & Tomlinson 1988);

3. To determine the state of the environment;

4. To determine whether the commitments by the developer in the EIS were implemented (Tomlinson & Atkinson 1987);

5. To determine actual impacts and compare these with predicted environmental consequences, to assess the accuracy of predictions made during the EIA process (Sadler 1988; Buckley 1989);

6. To further the environmental understanding of impacts and improve predictive capability (Sadler 1988);

7. To determine the effectiveness of the mitigation procedure for minimising any adverse impacts associated with projects (Tomlinson & Atkinson 1987);

8. To provide early warning of undesirable change (Kiell et al 1985);

9. To improve design and performance of future similar projects (Tomlinson & Atkinson 1987); and

10. To evaluate the efficiency and effectiveness of the EIA process (Culhane 1987; Bailey & Hobbs 1990).

It is important to understand that the above objectives can be and often are performed concurrently rather than as separate audits. Indeed, all audit conclusions in the ‘final wash’ should be used to improve the Environmental Impact Assessment process itself (objective 10). EIA improvements might be accomplished through better guidelines for EIS preparation, the adoption of revised and improved standards and or criteria, better understanding of potential significance of impacts for decision-making purposes and improvements in methods of impact prediction (Tomlinson & Atkinson 1987; Sadler 1988).

The objectives listed above suggest that the primary benefit of environmental auditing is that it facilitates positive feedback into an imperfect EIA process. This feedback in turn enables the performance of the process and environmental management to be evaluated and, as a result, the environmental decision-making capabilities are substantially improved; the process becomes more efficient; and the objective of ecological sustainable development is within reach.

Through environmental auditing and feedback, improvements can be made in approval conditions, project design, and project execution. Overall reductions of tangible and intangible costs can also be achieved in the planning and assessment process, engineering and technology and day-to-day environmental management. For example, information at hand at the time development proposals are reviewed may indicate that expensive specifications need to be met by the developer to reduce predicted environmental impacts. If subsequent environmental auditing finds that environmental impacts are well below acceptable limits, then less-costly equipment or procedures could be adopted and criteria used in EIA process appropriately adjusted (Bisset & Tomlinson 1988).

An important benefit of environmental auditing, which is often overlooked, is the increase in social and government acceptance of the EIA process and its credibility (Sadler 1988).

**Application in Australia and overseas**

To date, most environmental auditing in Australia and overseas has been conducted for compliance verification. Objectives for these ‘compliance audits’ usually include: determining a facility
compliance status at a given date over time; determining the costs of compliance with environmental requirements; assessing future compliance requirements; determining whether required reports have been submitted in a timely and accurate manner to control agencies; and determining existing or contingent liabilities (this last example is important for facilities involved in a prospective sale) (Penna 1983; Palmisano 1989). Most 'compliance audits' are undertaken internally with the aid of consultants (Coopers & Lybrand Consultants 1991).

Most firms that have completed audit programs conclude that the benefits of being able to correct environmental problems in this manner far outweigh any harm that may come from eventual disclosure of the existence of an environmental problem (Guida 1982).

In the United States, the adoption of 'closure audits' has become a major trend over the last 5 years. Many States now have laws that have changed the way industrial properties terminate operations. For example, there are provisions that require sellers to remove hazardous wastes and residues prior to real estate transfer. In New Jersey, owners are now subject to liability and clean up responsibilities regardless of the circumstances of ownership (under the New Jersey Environmental Clean-up Responsibilities Act and Resource Conservation and Recovery Act). The Transfer Act in Connecticut, now requires an owner to certify that the property is clean prior to transfer (Palmsiano 1989).

Coopers and Lybrand Consultants (1991) recently completed a survey of 1000 major Australian companies regarding their environmental management practices. Of the 352 respondents to the survey, 82% advised that they had introduced environmental policies in the last 5 years and 39% had undertaken a formal environmental audit of their organisation or part thereof (75% of the chemical companies and 59% of mining companies had undertaken audits). The survey showed that the main objectives of these audits included:

1. Compliance with legislation (100%);
2. Monitoring systems and procedures (79%);
3. Site contamination (79%);
4. Product use and disposal (76%); and
5. Looking at future legislation requirements (60%).

When asked by Coopers and Lybrand Consultants (1991) the reasons for undertaking the audits, the main answers by the responding companies were:

1. Parent company requirements (35%);
2. Clean image (22%);
3. Internal organisational pressure (14%); and
4. Legal advice (12%).

Environmental auditing practices by State Government agencies in Australia vary from ad hoc to routine, depending on the audit objectives. Most State Government environmental auditing programs, in one way or another, look specifically at the conditions of compliance, which are usually restricted to 'compliance monitoring', rather than 'compliance auditing' (Buckley 1990).

However, the lack of consistency with environmental audit implementation and methodology in Australia could change. With efforts now being focused towards Ecologically Sustainable Development (ESD) and the establishment of the first Intergovernmental Agreement on the Environment, consultation is currently taking place towards establishing national principles for EIA in Australia. These principles include environmental auditing. A draft document on the National Principles of EIA in Australia suggests that authorities responsible for assessment address the following objectives:

1. Ensure predicted environmental impacts are monitored, results assessed and feedback provided to improve the environmental management of proposals;
2. Properly monitor the efficiency and effectiveness of EIA process to learn from the past, streamline requirements and help maintain consistency; and
3. Review, adapt and implement techniques and mechanisms which can improve the process and minimise uncertainty and delays (ANZEC 1991).

Victoria is now actively involved in environmental auditing, and provision has been made specifically for environmental auditing in the Victorian Environment Protection (General Amendment) Act 1989. In Victoria, however, environmental auditing concentrates on site contamination (objective 3, p 2) and physical risks and hazards (Buckley 1990). The Act provides for the formal appointment of 'Environmental Auditors' which prepare audit reports and decide on the granting of 'Certificates of Environmental Audit'. Under the Regulations, auditors must refuse the issuing of certificates 'if the condition of the relevant segment of the environment is potentially detrimental to any beneficial use of the segment'.
As part of Victoria's Environmental Protection Authority (EPA) industrial waste strategy, 'waste auditing' is recognised as a first step towards waste minimisation. In this regard, the EPA has sought industry co-operation in introducing self auditing procedures for waste management, and have prepared a document to assist industries in carrying out the audits. The main goal of the waste audits is to identify areas where waste reduction can be incorporated into an existing plant's process or equipment (EPA 1990). Very recently (July 1991) Victoria held a workshop on environmental auditing which included, amongst other things, proposals for developing national guidelines for environmental auditing.

Following work by Bailey and Hobbs (1990) on auditing artificial waterways and other coastal developments in Western Australia, the WA Environment Protection Authority introduced an audit program. Primarily, the audit program is designed to assist the Authority in matters relating to conditions of approval and compliance monitoring.

Western Australia's audit program, however, goes beyond compliance issues and examines the state of the environment in relation to predictions made in the EIS and, where possible, examines the performance of the EIA procedures (Treloar J, pers comm, August 1991).

Western Australia and the Northern Territory appear to be the only State or Territory in Australia that have looked at auditing the performance of the EIA process including the effectiveness of environmental safeguards and impact prediction. Other States have specifically focused on compliance auditing and site contamination.

The Northern Territory Government recognised the need for some form of formal feedback mechanism in the environmental assessment process when it passed the Environmental Assessment Administrative Procedures in 1984. Clause 15 of the Administrative Procedures specifically gives broad powers to the Minister for Conservation to review and assess the environmental aspects of any proposed action, including effectiveness of safeguards or standards for protection of the environment and accuracy of forecasts of environmental effects.

The Conservation Commission of the NT has researched approaches needed to integrate environmental auditing into the assessment process, and recently, commenced the development of a framework for conducting effectiveness review of the environmental assessment process. An interdepartmental project team has been established to conduct a series of trial audits on selected projects. Results from the trial audits will be used to identify the need for improvement in environmental management and project design, including, improvements in future assessment, decision-making, and management and supervision of projects at the time of construction.

Of the environmental audits undertaken in the Northern Territory, most have been implemented by developers, due to parent company requirements or part of their environmental management policies.

Environmental auditing issues and problems

Probably the major factor that limits effective environmental auditing is inadequate environmental assessment and poor documentation. Auditing overseas has shown the need for a higher level of linkage and integration between actions involved in EIA (Culhane 1987; Elkin & Smith 1988).

Impact predictions are generally poorly presented and are of little value in making decisions or recommendations. Auditing, therefore, must be kept firmly in mind during the development of guidelines for EISs and in the design of baseline studies, formulation of impact description and predictions, and the implementation of monitoring programs. Bisset and Tomlinson (1988, 417) consider that auditing can be effectively achieved only when monitoring data allow statistically valid interpretation of cause-effect relationships to be derived: 'The acquisition of baseline data should be iteratively linked with impact prediction and the likely requirements for impact monitoring'.

To overcome the deficiencies in the way predictions are formulated and phrased, Bisset and Tomlinson (1988) suggest that they be treated as hypotheses which can be tested. Such hypotheses would force those preparing EISs to specify a number of aspects relating to the time-scale, magnitude, significance, probability of occurrence, and geographic extent of impacts (Tomlinson & Atkinson 1987; Bisset & Tomlinson 1988).

Follow-up activities, such as surveillance and monitoring, are also generally poorly outlined, if mentioned at all. Such programs should be specifically outlined including the reporting procedures.
Although mitigation measures (environmental safeguards) are generally well described in the NT, they are not often formulated in practical terms. This can be improved through the preparation of guidelines that prompt developers to answer mitigation information, similar to those suggested by Elkin and Smith (1988). For example:

- Can parts of the project be reduced or eliminated?
- Can impacted resources be repaired or rehabilitated? How is this achieved?
- Can affected resources be replaced or compensated for?
- Can on-going management procedures be instigated to reduce damage?
- Can project design, timing, equipment used, or site management be modified to reduce effects?
- Can effects be monitored?
- What provisions are made for future mitigation (eg incorporate contingency plans)?

Limitations and problems affecting implementation of environmental auditing are numerous and, like EIA, relate specifically to the circumstances of the development itself. Some of the common problem areas are described below:

1. The EIS is generally written and formatted as a static document and does not cater for progressive changes in design, environmental safeguards, or knowledge of the potential impacts;

2. Predictive techniques need to be referenced or documented;

3. EIA procedure — the EIA process is often seen as an approval requirement and in many countries EIS’s are orientated towards project approval rather than environmental management for the project. Environmental audits are essentially management tasks and are of little use to the decision making process (Tomlinson & Atkinson 1987);

4. Resources limitations, especially staff and time;

5. Poor understanding of responsibilities between Government departments. Institutional problems can result in duplication of effort and reduction in the amount of information obtained;

6. Inadequate and/or inappropriate follow-up techniques;

7. Decision-making — once a decision has been made to proceed with a proposal there is seldom any political will to encourage audits. Issues of confidentiality and access to data may occur. Audits might be seen or regarded as being a tool for criticising the decision-making or management process (Tomlinson & Atkinson 1987);

8. A positive program of information feedback from audits is essential (Canter 1984). Without a mechanism to feed information gained from audits back into the system, the objective of auditing cannot be achieved; and


Conclusion

Environmental auditing is not a new concept. Auditing and associated research studies have passively taken place by most resource managers and developers since the EIA concept was first introduced. As a result, there have been considerable advances in environmental understanding, both in planning and management areas over the last 10 years. Today, it is recognised, however, that through formalising the process of environmental auditing as an integral part of EIA (as a feedback management tool), the learning process will be greatly enhanced. This is seen as particularly important in relation to the implementation and development of Ecologically Sustainable Development strategies in the future, and managing a dynamic, forever changing environment.

Planning for environmental auditing must be commenced early in the EIA process. 'Early planning enhances the ability to generate the circumstances that are conducive to the ease and success of follow-up' (Sadler 1985). To do this, commitments from developers, environmental consultants and Government authorities are required.

Once an environmental audit has been undertaken, it cannot be considered complete until follow-up action is taken. As mentioned before, without a mechanism to feed information gained from audits back into the EIA process, the objective of environmental auditing cannot be achieved.
Acknowledgments

I wish to especially thank Dr Janice Warren for her valuable comments on the discussion paper.

References


CHAPTER 29

ENVIRONMENTAL ASSESSMENT AND PLANNING LAW IN THE NORTHERN TERRITORY: IS THERE A NEED FOR LAW REFORM?

Freya Dawson

Improving the democratic process by greater public participation has been a critical factor in the emergence of modern environmental law in all Australian jurisdictions. This chapter will assert that it should be an essential component in environmental law in the Northern Territory. Northern Territory environmental legislation, such as the Environmental Assessment Act 1982 and the Planning Act 1979, does not reflect the emphasis on public participation which has developed in other Australian jurisdictions. The Northern Territory Government has expressed a commitment to reviewing these laws (NT Dept Lands & Housing 1989; Anderson 1990) and in this context it is proposed to explore the arguments supporting increased public participation and to consider various reform options.

Introduction

Planning law first appeared in Australia at a time when the term environmental law had never been heard of. It emerged early this century when middle class reformers began to press for a better physical environment in towns and cities (Parrier 1988). Planning law involves government in the development of land use plans for cities or regions, decisions about the use of particular pieces of land in the context of those plans and the resolution of conflicts which can arise out of this process. Australian cities have developed so too have the importance and complexity of town planning laws.

Environment impact assessment (EIA) legislation is a more recent development. EIA applies to specific, proposed developments. The primary objective is to identify the likely impacts and risks to the environment inherent in any proposed development so that these matters are considered in the decision-making process. EIA is not necessarily linked with planning laws, however, in some jurisdictions such as New South Wales, planning and EIA laws are integrated in one Act. All States and the Northern Territory now have environmental assessment requirements, however they differ significantly between jurisdictions (Bates 1987).

Environmental assessment and planning law in the Northern Territory

The Planning Act 1979

The planning system in the Northern Territory is broadly similar in style to that of the States but with some significant differences. In the States, planning is administered largely by local authorities. In the Northern Territory, planning is administered by two tiers of planning administration (NT Dept Lands & Housing 1989).

The Act sets up the Northern Territory Planning Authority which exercises a local planning function not dissimilar to municipal councils elsewhere in the country. The Authority is responsible for the preparation of draft planning instruments which are submitted to the Minister for approval. Once the Minister formally 'makes' the planning instrument, the Authority is authorised to enforce it. Planning instruments may specify either the Planning Authority or the Minister as the 'consent authority' for particular types of developments. The Authority exercises control only in designated areas of the Territory, which include the Darwin, Alice Springs, and Katherine town areas.

The second tier of planning administration is carried out by the Department of Lands and Housing. The Department has taken up the task of 'strategic planning'. Strategic planning includes the preparation of long-term plans such as the Darwin Regional Land Use Structure Plan 1990 (NT Dept Lands & Housing 1990). The Planning Authority is authorised under the Act to prepare both town plans and regional plans at the direction of the Minister, however, the preparation of regional plans is also carried out by the Department of Lands and Housing. The activities of the Department appear to
be carried out pursuant to section 66A of the Act which gives the Minister the power to 'publish the planning and development objectives of the Territory'.

The Planning Act also sets up the Planning Appeals Committee which hears and determines appeals against consent decisions of the Planning Authority. Following the decision of the Committee, further rights of appeal on questions of law only exist to the Northern Territory Supreme Court. There is no appeal to the Planning Appeals Committee where the Minister is the consent authority. Only the applicant for the development consent has the right to appeal the decision to the Committee.

**The Environmental Assessment Act 1982**

The long title of this Act states that it is an Act 'to provide for the assessment of the environmental effects of development proposals and for the protection of the environment'. The objects of the Act are set out in section 4. This provision specifies that 'matters' which are: capable of having a significant effect on the environment shall be taken into account in relation to certain decisions and actions, namely, the formulation of proposals, the carrying out of works, the negotiation of intergovernmental agreements, the making of decisions and the incurring of expenditure in both the private and the public sphere. The environmental significance of proposed actions is determined by the Minister for Conservation.

The Environmental Assessment Act does not set out an administrative process to achieve the stated objects of the Act, rather, it authorises the preparation of Administrative Procedures which contain all of the substantive provisions (s. 7). The placing of the substantive provisions in Administrative Procedures mirrors the Commonwealth Environmental Protection (Impact of Proposals) Act 1974. The enforceability of Administrative Procedures (which do not have the same legal status as legislation or regulations) has not been determined by the courts (Bates 1987).

The Administrative Procedures (cl. 6) require that a report, commonly referred to as a Preliminary Environment Report (PER), be prepared as soon as possible after the formulation of a proposal. The PER is prepared by the proponent of the proposed action. The proponent is the company, individual or government department who wishes to undertake the development. After receiving a PER, the Minister for Conservation may direct the preparation of a draft Environmental Impact Statement (EIS) (cl. 8). If an EIS is prepared there is a requirement in the Procedures that the draft be made available for public comment (cl. 10). Having received public comment, the proponent then prepares the final EIS and submits it to the Minister for Conservation who must examine it and may make comments or recommendations.

The comments of the Minister for Conservation are forwarded to the 'responsible Minister' who must make the decision as to whether the development should proceed and, if so, under what conditions. Who the 'responsible Minister' is will depend on the nature of the development, so, for example, the Minister for Mines would make the final decision about mining developments.

**The relationship between the Planning Act and the Environmental Assessment Act**

The rationale for combining a critique of the Planning Act and the Environmental Assessment Act in this paper is not so much that they are closely related pieces of legislation, but that they *should* be. The lack of integration of planning and environmental assessment laws is a real limitation on the effectiveness of environmental protection in the Territory.

To be effective, environmental impact assessment should operate in the context of 'environmental planning', that is, planning that gives primary consideration to the environmental sensitivities of the subject land. The Planning Act does not provide for the assessment of the environmental sensitivities or capabilities of the land as a priority in the planning process.

'Town planning' under the Planning Act, would be more effective if it accurately anticipated the environmental impacts of various land use options. Under the current legislation there is no mechanism whereby information flowing from the EIA process can be fed back into the planning process. If this did occur, it may increase the usefulness of environmental assessment as a tool for environmental protection while at the same time providing more information and certainty to prospective developers.

Despite the lack of integration, both Acts will apply to many development proposals in the Northern Territory, particularly those in urban areas. However, some developments which may have a significant effect on the environment, escape regulation under either Act. Developments on land not covered by a planning instrument do not require consent from the Planning Authority. In some cases there is no consent required from any government.
authority. These developments will avoid the requirements of the Administrative Procedures under the Environmental Assessment Act unless the Minister for Conservation finds out about them by means other than the normal process (cl. 4) and makes a direct request for a PER (cl. 7). Clearing of trees on private land for pasture improvement comes into this category of developments. It was recently confirmed that crocodile farming is also in this category as it can proceed in a rural area without development consent (D’Rozario 1991).

The development of a national approach to environmental assessment in Australia

A number of States are comprehensively reviewing environmental assessment and planning laws. The Northern Territory, Queensland, Tasmania and South Australia currently have environmental assessment legislation under review. In some jurisdictions, for example, South Australia and the Northern Territory, this is being accompanied by a review of planning laws. In other States there has been reform in recent years. However, greater uniformity in environmental assessment and planning laws across Australia has not been an objective of this process. It is in this context that attention is now being given to a consistent, national approach to the development of environmental laws.

EIA law is included in an Intergovernmental Agreement on the Environment which was due for consideration at a Special Premiers’ Conference in November 1991. In preparation for the Special Premiers’ Conference, the Australian and New Zealand Environment Council (ANZEC), has prepared a draft document entitled A National Approach to Environmental Impact Assessment in Australia. The objectives of developing a National Approach stated in this document can be summarised as follows:

a) to reach a common understanding and agreement on principles and the practice of EIA in Australia;

b) to improve the EIA process;

c) to promote public understanding and both provide and facilitate consistent opportunities for public involvement;

d) to improve consistency between jurisdictions responsible for environmental impact assessment, and to avoid duplication.

It is outside the scope of this paper to consider the initiatives in detail, however, one aspect of the draft National Approach stands out in the context of a review of Northern Territory legislation.

An emphasis on public participation

The draft National Approach emphasises the role that the public should have in the EIA process. It identifies the public as key participants in the EIA process along with the assessing authorities, government and the proponents. It recognises that the public has an important role in the evaluation of proposals and in monitoring the administration of the EIA process. Emphasis is placed on the positive input that public comment can provide, for example, through the provision of local knowledge. The point is made that public participation will be most effective if it occurs from the earliest stages of the process, extending back into the policy and planning stages. The public can also have a role in the outcomes of the EIA process such as monitoring and compliance audit activities.

With one exception, the recognition of public participation is reflected in the principles applicable to the assessing authorities and the government. Assessing authorities should provide public participation opportunities in a proactive manner and report publicly on the assessment of proposals. Government should provide support to community groups to enable better and informed involvement. Public and proponent objections should be allowed on decisions made regarding the requirement for and level of assessment, adherence to due process, and the environmental advice given to decision-makers. An exception is made where decisions are made by Ministers. It will be argued below that this exception represents a significant weakness in terms of the objects and effectiveness of public participation.

The emphasis on public participation in the draft National Approach reflects the direction of law reform in many Australian States. For example, the South Australian Government has just released a Discussion Paper entitled Proposal for a South Australian Environmental Protection Authority and a Charter on Environmental Quality (1991, 33). It states that ‘new environmental protection legislation will need to incorporate principles of openness, public disclosure and consultation and accountability’. The NSW Environmental Planning and Assessment Act 1979 is an example of legislation which already includes a high level of
public participation consistent with the principles being put forward at the national level (Farrier 1988).

Why is public participation Important?

It is clear that increased public participation is firmly on the agenda in the area of environmental law, however, there are still vocal opponents and some reluctance on the part of governments to allow for it. Some industry groups see public participation as increased opportunity for environmental groups to influence government decision-making that has traditionally been in the developer's favour. Governments may be prepared to support increased public participation in principle, but when it comes to actually implementing the principles, they have been less enthusiastic. It is not surprising this is the case, as participation necessarily includes increased scrutiny. The experience in some Australian jurisdictions, particularly NSW, is that government has been taken to court on a number of occasions over environmental decision-making. In that State, a recent response has been an angry attack against the Land and Environment Court and suggestions that its powers to review government decision-making be reduced (Conservation News, September 1991).

In the context of government reluctance or opposition, it is important to look closely at the arguments which support greater public participation. Some environmentalists, for example, the NT Environment Centre (Jackson S, pers comm) demand that public participation in environmental decision-making should be a right that is recognised in all environmental legislation. Unfortunately, a rights-oriented approach does not find much support in the Australian system of law.

At a very basic level, Australian law requires that individuals should be able to have some involvement in decisions which affect their private rights. It is common for legislation to provide for objections, hearings, and appeals where a decision affects an individual's private rights, for example, the right to develop private property. However, the calls for participation coming from environmentalists are much broader than this basic protection of private rights or interests.

The law is less likely to provide participation rights when the decision affects some public right, ie a right that a person enjoys in common with other members of the public. An example might be a public right to enjoy a public park or a beach. More difficulty arises when you seek to broaden the category of public rights to assert a more general right such as the right to a clean environment. Such general rights are not specifically recognised in Australian law. This is a hurdle that may need to be overcome if we want to recognise participation in environmental decisions as a right rather than a privilege.

By way of contrast, in Canada and the USA there has been a concerted attempt to have environmental rights embodied in statute law and this has occurred in some jurisdictions (Emond 1981). Recognition of a general right to a clean and healthy environment can support increased access to the courts, access to government information, greater government accountability to the public, and public participation in various aspects of the decision-making process to enforce the right. This rights-oriented approach is one option for supporting further law reform in Australia.

An alternative approach to the issue of broadening public participation in environmental decision-making is based on the principle that decisions about the environment should be made in the public interest. Public participation is one mechanism for ensuring that the decision-making process is accountable to the public interest. Of course, the public interest is not monolithic and conflicts will arise between groups representing different aspects of the public interest. Public participation can ensure greater equity of access to different interest groups. If participation is combined with greater openness in the decision-making process, it may discourage governments from deciding in favour of powerful groups with a vested interest in a project. Decision-makers need to get a feel for the needs and aspirations of the community, particularly in an area where public consciousness is developing so rapidly.

The Westminster system of government supports the traditional view that once elected by the people, government has the mandate to make these decisions in the public interest without further consultation. Governments are accountable to the parliament, and through the parliament to the people, at the next election. It is now widely accepted that this traditional approach is not sufficient to ensure adequate accountability or participation in the democratic process (Thynne & Goldring 1987). In our increasingly pluralistic society it cannot be sufficient for the voice of the people to be heard only once every three or four years.

Once it has been acknowledged that traditional theory may not fully meet the needs of
accountability and participation in our modern democracy, the principle that decisions should be made in the public interest can be used to support the widest possible participation by the public in environmental decision-making. A fact which adds weight to this argument is that these decisions most often concern public resources; for example, our coastline, waterways, crown land and mineral and forest resources. Many major resource exploitation developments are justified in terms of State/Territory or national public benefit. If the public interest in environmental decision-making requires increased public participation, the issue then becomes one of time and resources and of achieving equitable access to participation for various public interest groups. The question is whether we are prepared, perhaps, to pay for more open and democratic government and improved environmental decision-making.

From a more pragmatic viewpoint, public participation in a decision-making process will increase the chances that the ultimate decision is acceptable to the community (Pain 1989). For example, an environmental planning exercise (such as a regional or local environmental plan) is more likely to be accepted by the community which it affects if they feel they have some ownership in it. As is pointed out in the ANZEC draft National Approach, public participation can also bring benefits for decision-makers by providing useful local and expert knowledge. The public can provide different outlooks on the possible impacts of a proposal as well as alternatives that the decision-makers or the developers have not thought of. Time and resources will be saved if controversial issues are highlighted and widely discussed early in the decision-making process. Often, acceptable compromises can be found. Even if a compromise is not made, at least everybody is made aware of the reasons for a particular decision and this may help them to accept it.

As mentioned above, increasing public participation may require a commitment of resources in terms of time and money. The argument is also put forward that decision-making will become bogged down, particularly if there is a broadened right of appeal. There tends to be a fear on the part of governments that the floodgates will be opened to a wave of litigation. The experience in other jurisdictions has proved this fear to be unfounded. In NSW, for example, the opportunity for public interest litigation has been taken up by the public, but the courts have by no means been swamped with litigants (Pain 1989). The reality of the cost and time commitment involved in litigation is enough to deter most people. In terms of other mechanisms of participation, such as a right to make submissions or to be heard at a public meeting, difficulties can be avoided by providing adequate information to prospective participants about the purpose and parameters of the decision-making process, and by carefully structuring the process.

The arguments in favour of increased public participation are gaining increased acceptance in Australia and the public is becoming more vocal in demanding these rights. The question now needs to be asked; is there adequate provision for public participation under Northern Territory environmental laws?

Public participation under the Planning Act

The avenues for public participation under the Planning Act are very limited.

During the process of preparing a draft planning instrument, the Planning Authority only has an obligation to consult with the public when they are directed to do so by the Minister (s. 41). Once prepared, a draft planning instrument must be publicly exhibited (s. 45) and any person may make a written submission to the Authority in relation to that draft instrument (s. 49). The Authority may invite a person who has made a submission to appear before the authority in support of his or her submission (s. 50). The authority is only obligated to hear a person if they are the owner of land to which the draft plan relates (ss. 50(2)). The Authority must then prepare a report on the submissions which is sent to the Minister along with the draft plan (s. 59). There is no right of objection or appeal against the decision of the Minister in relation to the final planning instrument and there is no obligation on the part of the Minister to make public the reasons for a decision.

One of the effects of the two tier administrative arrangements described above between the Planning Authority and the Department of Lands and Housing is that the planning carried out by the Department of Lands and Housing is not subject to statutory procedures for public participation described above. The Act does not provide for any type of public participation in the planning and policy development carried out by this department under section 66A. This is a very significant limitation on participation in the planning process as a whole, given the amount and type of planning and policy work they undertake.
The only party with participation rights in relation to applications for subdivision or development consent before the Planning Authority is the applicant. There is no provision in the Act for public notification of development applications. No opportunities exist for third parties to be heard by the Planning Authority or to comment on an application. As noted above, appeals against the decision of the Planning Authority are only available to the party who made the application.

Public participation under the Environmental Assessment Act

The only opportunity for public participation in the Administrative Procedures of the Environmental Assessment Act is for public comment on a draft Environmental Impact Statement (cl. 10). Even this is qualified, as a proponent may request that parts of the draft statement not be released for public comment (cl. 10). Once public comment has been received, it must be taken into account by the proponent in the preparation of the final Environmental Impact Statement (cl. 12). The public has no access to the assessment of the EIS made by the Conservation Commission and there is no way that the public can know whether their comments have influenced this assessment or the outcome of the final decision. No rights of appeal are provided for under this legislation.

In the history of the administration of the environmental assessment process in the Northern Territory, only a small number of Environmental Impact Statements have been prepared compared with the number of proposals assessed in some way (CCNT Annual Reports 1984–1990). The great majority of proposed actions are assessed on the basis of the initial notification document which is referred to the Minister for Conservation. This is known in the Conservation Commission as the Notice of Intent. In a relatively small proportion of cases a preliminary Environment Report is requested by the Minister (CCNT Annual Reports 1984–1990). These documents are not available to the public. There is no provision in the Act or Procedures for the public to be notified that an environmental assessment is being carried out in relation to a proposed development unless a full EIS is requested.

The fact that the Northern Territory has no Freedom of Information legislation compounds this lack of public access to information. The result of this situation is that many developments which may be detrimental to the environment are in the construction phase before the public finds out about them. For example, a number of large mining developments in the Top End were approved on the basis of a PER which was not made public (CCNT Annual Reports 1984–1990). The only other provision which may allow some public participation is if the Minister directs that an inquiry be held under section 10 of the Act. This provision has not yet been used (CCNT Annual Reports 1984–1990).

Will there be law reform in the Northern Territory?

Clearly, if the principles outlined in A National Approach to Environmental Impact Assessment in Australia are supported by the Northern Territory Government, and are adopted as part of the Intergovernmental Agreement on the Environment, the Environmental Assessment Act will have to be comprehensively reviewed. The arguments in favour of increased public participation in decision-making under this Act apply with equal force to the Planning Act. In fact, both of these Acts are currently being reviewed by the Government.

Rather than being linked to federal initiatives, the pressure for this reform in the Northern Territory has arisen from community frustration and dissatisfaction with the administration of these laws. This was recognised by the Minister for Lands and Housing in July 1989 when the Government released A Discussion Paper on the Proposed Revision of the Planning Act (NT Dept Lands & Housing 1989). A number of the issues identified in this discussion paper are relevant to the level of public participation. These include the composition of the Planning Authority, third party appeal rights, the obligation to advertise development proposals and the standing of objectors to a development application to appeal. Public comment was sought on these issues. It is understood that the process of reviewing this legislation is still continuing.

Also in 1989 a report was commissioned from an independent environmental consultant on the Environmental Assessment Act. The report, titled Review of the Northern Territory Environmental Assessment Act and Administrative Procedures (Anderson 1990), was released to a select number of community groups in February 1990. One of the recommendations of this report is that 'public participation should be seen as a right rather than a privilege'. To some extent the report recommends changes which would improve the level of participation, but it does not go as far as the more recent draft National Approach. No further
information has been released to the public concerning the directions or timing of the review of this Act other than that the review is continuing.

In the light of the draft National Approach and the emphasis placed on public participation in that document there should be more public discussion and debate about the directions of law reform in the Northern Territory. The government can not expect the public to wait indefinitely for change. To be effective, any proposed legislative changes must be made clear to the community. If the Government rejects the nationally agreed principles or is reluctant to put them into effect in the Territory, the reasons for this should be made clear and the response of the community sought. The willingness of government to embrace increased public participation in relation to the review of these environmental laws will be shown in the approach taken in a number of key areas.

**Policy and planning**

In order for government regulation to be effective and acceptable to the community, the public should be involved from the earliest stages in policy development and environmental planning (Emmon 1981). Ideally, the broad policies should be made clear in the legislation, through statements of objectives which are then reflected in the body of the Act. If the objective is thus stated, any further policy development carried out by a government authority must conform to these objectives.

An efficient form of public participation in policy development and planning is to allow written submissions, perhaps supplemented with public hearings on more controversial issues. In the case of the Planning Act, the role of the Department of Lands and Housing will have to be reviewed and formalised in legislation if an appropriate degree of public participation in policy and planning is to be guaranteed. In the case of strategic planning and local and regional planning instruments, the right to make submissions and to be heard should extend beyond the owners of affected land to any concerned member of the public.

The public should also be involved in the development of guidelines and criteria relevant to decision-making under the Environmental Assessment Act. An example are the criteria used to determine the appropriate level of assessment of a proposal under that Act. These criteria will reflect the policy on what is considered to be a significant effect on the environment. This threshold question is crucial to the effectiveness of the legislation in protecting the environment in the public interest.

Currently these matters are in the discretion of the Minister for Conservation.

**Access to information**

Access to information is an area that is certainly in need of urgent reform. The lack of public access to preliminary Environmental Reports under the Environmental Assessment Act is a good example. There is no possibility for members of the public to make an independent assessment of the likely effects of a proposed development as they have no way of knowing what has been proposed. Under the current Procedures, concerned members of the public must make 'stabs in the dark' to try and provoke a response that will yield information. Often a heated public debate will occur after the development has already commenced. Early access to information may encourage a more informed and timely discussion of contentious issues.

The public should also have access to the reports of the Conservation Commission on the assessment of development proposals. It is important for the public to be able to judge whether or not their comments have been taken into account, and what other factors have influenced decision-makers. The same principle applies to the final decisions of the planning or EIA process. The reasons for decisions, whether made by a government authority or the Minister, should be made public. Publication of the reasons for decisions will have an obvious impact on the ability of the public to participate effectively, and on the accountability of decision-makers. It can have a very positive effect on the quality of government decision-making.

**Enforcement**

One of the principles for public participation outlined in the draft National Approach is that the public should monitor the administration of the EIA process. This principle is very much connected to increasing the accountability of decision-makers to the public. 'Monitoring' by the public can only be effective if it can be enforced. Unless procedures are laid down by legislation or by regulations passed under the authority of legislation, they are not likely to be legally binding and enforceable. Administrative Procedures such as those under the Environment Assessment Act have an uncertain legal status. This mechanism is designed to avoid judicial scrutiny of the administration of this legislation (Bates 1987, 87). If environmental laws are to be adequately enforced the procedures for environmental assessment should be included in the Act itself. Regulations can provide details as to penalties for breach of the Act and similar matters.
Even if the procedures are enforceable, the common law places very significant legal hurdles in the way of members of the public who want to enforce the performance of a public duty by administrators. A person will only be able to bring an action against the administrator of legislation if they can show 'a special interest in the subject matter'. This rule has been used to deny environment groups access to the courts to challenge the legality of government decisions under environmental legislation in a number of Australian jurisdictions (Bates 1987, 272). In line with a policy of increased public participation, the NSW Environmental Planning and Assessment Act provides that any person may bring proceedings to enforce a breach of the Act (s. 123). This applies to breaches by individuals as well as government. Only a small amount of litigation has proceeded under this provision, but it has arguably had a significant effect on environmental protection in that state (Pain 1989).

The right to appeal

Appeal rights are non-existent under the Environmental Assessment Act and are very limited under the Planning Act. This lack of appeal rights is inconsistent with the degree of public participation suggested above. Providing for public participation in the decision-making process creates rights and expectations in the public that their comments, objections or information will be taken into account. These rights and expectations should be protected by widening appeal provisions to include groups or individuals seeking to appeal in the public interest (known as third party appeals).

The issue of third party appeals under these Acts has been repeatedly raised by community groups in the Northern Territory, a fact which has been recognised by the NT Government (NT Dept Lands & Housing 1989). It is also an issue which has been brought to the attention of the Northern Territory Law Reform Committee. In their 1991 Report on Appeals from Administrative Decisions the Law Reform Committee recommend that third parties and persons with a direct personal stake in proceedings should have a right of appeal from most administrative decisions. This recommendation encompasses many of the decisions made by the Planning Authority, the Department of Lands and Housing, the Conservation Commission and Ministers in the administration of the Planning Act and the Environmental Assessment Act. The report recommends that the appeal should be to an independent tribunal rather than the Minister and should not be restricted to questions of law, leaving it open for the Tribunal to consider the merits of a case. The Northern Territory Government is currently considering these recommendations.

If the government rejects the recommendation to set up a general appeals tribunal there are a number of other options which they should consider. For example, the role of the Planning Appeals Committee could be augmented to cover appeals over a broad range of decisions under both the Environmental Assessment Act and the Planning Act. The ability of a specialist tribunal to develop an expertise in an area is a considerable advantage in the area of environmental law. The procedures of such a tribunal can also be adapted to cope with expert evidence and a degree of formality appropriate to public participation. Another similar option is to set up a specialist court such as the NSW Land and Environment Court. This option is currently being explored in South Australia (SA Dept Environment & Planning 1991).

The role of the Minister

In both the Environmental Assessment Act and the Planning Act there is a concentration of decision-making power in Ministers. The Ministers are also given very broad discretions. Both of these factors can cause problems for public participation and accountability (Thynne & Goldring 1987, 56–75).

Ministers generally want to have control over 'political' decisions. Ministers also tend to be reluctant to exposing themselves to direct public input and scrutiny in the name of accountability. When questioned about the accountability of Ministerial decision-making, government is likely to reply that Ministers are responsible to Parliament, not directly to the people. Unfortunately, party politics has greatly reduced the effectiveness of Ministerial responsibility as a mechanism for accountability in all Australian governments (Thynne & Goldring 1987, 56–75). A reliance on this traditional mechanism is not consistent with a desire that environmental decision-making respects or is answerable to the public interest.

Giving Ministers broad discretions can hinder accountability. It is very difficult to challenge the lawfulness of a decision made under a broad discretionary power. There is no way for the public to know that their concerns in relation to a decision have been taken into account, or that the decision was made in conformity with the object of the statute. A broad discretion may be appropriate where Ministers are involved in questions of broad policy, but will be less appropriate in the case of individual application of policy to the facts (Emond
1981). Even in relation to policy decisions, criteria can be stated in the legislation so as to confine the decision to considerations which are specifically relevant to the purpose of the Act.

Despite these widely recognised problems, a reliance on Ministerial decision-making is implied in the Draft National Approach. The fact that ANZEC is a council of Ministers may be one of the reasons for this approach. Not only are final decisions to be made by Ministers, but they are not going to be subject to appeal. This will inevitably frustrate members of the public who have participated actively at other stages of the decision-making process. Apart from any other factors, the time constraints on Ministers make public participation in decisions made by them impractical. Alternative decision-making structures should be considered which sit more comfortably with the goals of increased participation and accountability.

In the case of the Environmental Assessment Act the most obvious option is to have more decisions made by an independent statutory authority such as the Conservation Commission. If adequate attention has been given to policy and planning with direct Ministerial involvement, then the application of these policies and plans by an independent statutory authority should not cause political problems for the Minister. The same principles apply to planning. In the case of the Planning Act it may be appropriate to vest more decision-making power in the Planning Authority, or in local councils. Increased public participation such as rights to object and appeal sits more comfortably with decision-making at this level. These authorities should be flexible enough to encompass increased participation, provided that they are adequately resourced.

Conclusion

This chapter has highlighted one aspect of planning and environmental assessment laws that is in urgent need of reform, however, the concern with increasing public participation also applies to other areas of environmental law in the Northern Territory. This is not to suggest that other major issues do not exist in relation to these Acts and to other environmental laws which require attention, but I believe that public participation will be critical to the success of environmental regulation. An increased role for the public in environmental decision-making will help to focus attention on the successes and failures of our attempts to protect environmental quality and perhaps facilitate a resolution of some of the broader issues. In the long run, the only way that we can preserve our environment is if every member of our community becomes actively involved in that process. It will never be enough to expect governments to do all the work. Public participation in environmental decision-making will foster both community and government responsibility in this area.

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