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Australasian Marine Science Consortium

Central Queensland
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'MANGROVES – A RESOURCE UNDER THREAT?'

An Issue for the Central Queensland Coast

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Edited by:

David Hopley & Lesley Warner

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PROCEEDINGS OF A SYMPOSIUM HELD

Friday 27 October 1995

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Lecture Theatre
Gladstone Campus
Central Queensland University

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Australasian Marine Science Consortium

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- A RESOURCE UNDER THREAT'

An Issue for the Central Queensland Coast

PROGRAMME

A Symposium organised by AMSC

at the

Central Queensland University
Gladstone Campus

1995

PROGRAMME

8.30am	**Registration**	
9.00am	**Welcome:**	Professor Ray Golding Vice-Chancellor, James Cook University
9.10am	**Opening of Conference:**	Mrs Coral Marxsen Councillor, Gladstone City Council

Morning Sessions Chaired by:

Professor David Hopley
James Cook University of North Queensland

SESSION 1: OVERVIEW

9.15am **An Australian Perspective - Resources and Potential Problems**
Dr Alan J Butler, Department of Zoology, Adelaide University

9.45am **Ecology of Mangroves of Port Curtis, Regional Biogeography, Productivity and Demography**
Professor Peter Saenger, Centre for Coastal Management
Southern Cross University

10.15am **Discussion**

10.30am **Morning Tea/Coffee**

SESSION 2: RESOURCES

11.00am **Commercial and Ecological Values of Mangrove Habitats**
Dr Barry Clough, Acting Project leader
Sustaining & Restoring Mangroves, AIMS

11.30am **Changes to Mangrove Ecosystem Distribution in Port Curtis, 1941 to 1989**
Mr Donald B Arnold, Department of Environment & Heritage, Gladstone

12.00pm **Discussion**

12.15pm **Lunch: Gladstone Campus, CQU**

PROGRAMME

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Associate Professor J Greenwood
Queensland University

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1.45pm	**Water Quality, is it a Problem in Mangrove Communities?** Mr Laurie Cook, Senior Lecturer, Biology, Central Queensland University
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SESSION 4: MANAGEMENT

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3.30pm	**Management: What Can GBRMPA Do?** Mr Clive Cook, Manager, Impact Assessment & Major Projects Great Barrier Reef Marine Park Authority, Townsville
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5.00pm	**Social Gathering hosted by CQU**

INTRODUCTION

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WELCOMING ADDRESS

by

Professor R.M. Golding

Vice Chancellor
James Cook University of North Queensland

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OPENING ADDRESS

by

Councillor Coral Marxsen

B bus ASA FAIM

Gladstone City Council

WELCOMING ADDRESS: PROFESSOR R.M. GOLDING

Welcome to the 1995 Annual Symposium of the Australasian Marine Science Consortium which today will examine a major environment issue for the central Queensland coast, namely the conflicting pressures which are being placed on the extensive mangrove resources of the region.

This is the ninth regional symposium of its kind organised by the Consortium which in addition last year was the main host for PACON '94, the biennial meeting of the Pacific Congress for Marine Science and Technology which attracted almost 600 delegates from Australia and overseas.

Obviously our regional symposia have attracted fewer delegates but their focus on local issues and more importantly their attempt to find resolution has attracted attention around Australia. Regions as great as the whole of southeast Australia or the Australian tropics, and the marine and coastal issues associated with them, have formed the focus for the Consortium in earlier years. At other times, we have focussed in on smaller regions but with problems just as great. These have included the waterways of Sydney, Jervis Bay, Moreton Bay, Tasmania and southern New Zealand.

Our meeting today is in one of the foremost industrial ports along the eastern coast of Australia. The deepwater port of Gladstone handles approximately 30 million tonnes of cargo a year and is the second largest on the Australian eastern coast. It has been the catalyst for rapid industrial growth and industrial investment exceeding $6 billion.

Although the channels into the port are now dredged to allow the entry of ships of greater draft, it is a natural harbour sheltered to the north by the Australian Heritage Area of Curtis Island and to the east by the equally impressive Facing Island. Shelter however also has its natural responses and Port Curtis and the adjacent area of the narrows between Curtis Island and mainland are the sites of extensive and important mangrove forests which have a national, if not international, significance and have been the location of long term monitoring studies. The days when mangroves were regarded as expendable and valueless have long since gone and the juxtaposition of harbour, industry and high value heritage areas obviously places a great deal of pressure on those whose job it is to manage the region.

The Australasian Marine Science Consortium which is also the Australian Chapter of PACON International has 17 institutional members. Whilst many of these are universities with strong research interests in the coast and marine environment, also represented are research organisations with a strong interest in applied research such as the Australian Institute of Marine Science and the CSIRO Division of Oceanography and management organisations such as the Great Barrier Reef Marine Park Authority. Industry is also represented in the Consortium membership through our latest member the Australian Maritime Engineering Co-Operative Research Centre based in Tasmania.

Just as our membership represents a balanced cross section of Australian interests in the coastal and marine environments so do the topics of our regional symposia. It is worth noting that the comprehensive program which Assoc. Prof. Lesley Warner has organised for us today will be addressing the issues of sustainable development and sustainable industry and the utilisation of the coastal environment. The fact that our Consortium represents so many institutions in which marine and coastal science, technology and development are represented gives our deliberations today an importance which I hope will be noted by all tiers of government which have a responsibility for this area.

I congratulate Lesley Warner and the Central Queensland University for putting together such an interesting program and being able to attract the group of very prominent speakers from whom we will no doubt learn a great deal during the day. Opportunity will be given for discussion and I hope that you, the audience, will contribute your opinions to give a balanced view of the issues facing development on the central Queensland coast.

I would now like to invite Councillor Coral Marxsen, of Gladstone, to open the symposium.

OPENING ADDRESS: COUNCILLOR CORAL MARXSEN

It is my pleasure to open your conference. Your topic today is Mangroves - A Resource Under Threat: An issue for the Central Queensland Coast.

Gladstone is a very important city on the Central Queensland Coast.

Some interesting economic facts about Gladstone are:

- 28.4% of Queensland's exports go out of our port
- 7.5% of our nation's exports go over our wharves
- Gladstone has a strong tourism industry concentrating on reef tourism, eco-tourism, industrial tourism and we are the southern access to the Great Barrier Reef
- We have a sound industrial base with further development proposed
- Gladstone has a rich hinterland with mining, agriculture, pastoral and fishing industries
- We are the Port City to the World with world class port facilities

Gladstone's natural attractions are:

- We have a beautiful deep natural harbour protected by numerous islands
- There are miles and miles of golden sandy beaches, interspersed with the occasional rocky headland
- Our vegetation includes: scrubland, savanna, subtropical rainforest and mangroves
- The land is traversed by creeks and rivers of both salt and fresh water
- We enjoy incredible fishing
- This area is just so rich and so bountiful and yet it would be so fragile if it was abused

We must respect that we hold all this in trust for future generations.

Gladstone City Council addresses these responsibilities both in its Corporate Plan and in its Operational Plans. All councillors consider this to be very important.

In one address I gave to council I referred to Gladstone as being 'An Industrial City with a Green Heart'. The long drought we have been suffering has made me think again about this statement. However, the statement reflects what we are trying to do.

We are a clean town, a tidy town and Council puts its money where its mouth is. We have repeatedly won the Tidy Towns competition for Queensland.

Council in this year's budget dedicated 1.4 million dollars to a clarifier to upgrade our sewerage treatment facilities. This is a considerable commitment from such a small rate base. We have spent considerable parcels of money on our garbage dumps.

We are currently working on Environmental Management Plans for all our small businesses. Also we have started on Environmental Management Plans for our sewerage pumping stations. The city has a successful recycling program that has increased the quantities recycled by more than 400% over our initial program.

Gladstone has an Open Space Study that is a plan for the City right out to our existing boundaries. This plan protects our ridges and the many natural water courses that flow through our hilly city. It encourages native animals and birds into the city and belts of natural woodland separate the suburbs and act as buffer zones between residential and between other zoned areas.

We have a Tree Planting Program. Our goal is to plant 100,000 trees in the city. There is a plan with recommended plantings for the different streets, differing in plant variety and size to accommodate utilities such as power lines etc and to suit whether the location of the planting is in a valley or on a ridge.

Other projects in which we have included extensive tree planting area; Australia Remembers, a grove of trees in Memorial Park; and beautification of the cenotaph and Kin Kora roundabout. CES job opportunity programs included tree plantings with the bicycle and walkways.

Our Botanical Gardens are exceptional for their type. These gardens have areas dedicated to the natural vegetation you will find in the different areas around our region. I strongly recommend you visit our gardens.

Industries in our City are lifting their game in relation to pollution. For example the Power House rung by NRG will have all chimneys fitted with special filters that will remove all visible pollution by 1997.

We are proud of our city and we believe we are doing a lot of the right things to make our city an industrial city with a green heart.

Welcome to our city. Enjoy our city.

Gain all you can from your conference.

It is my pleasure to open your conference – Mangroves, a Resource Under Threat.

SESSION ONE

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OVERVIEW

AN AUSTRALIAN PERSPECTIVE - RESOURCES POTENTIAL PROBLEMS

Dr Alan J Butler
Department of Zoology
University of Adelaide
SA 5005

ABSTRACT

I ask two rhetorical questions: are mangroves a resource, and are they under threat? My focus is on the kind of information needed to answer those questions, whether we have it, and how we can get it.

I will argue that they are an important resource, but that we need better information about the nature of the resource and its importance.

The threats to mangroves are diverse and, aside from the most obvious physical threats, very difficult to document. The 'state' of the mangroves is correspondingly difficult to document on a large scale.

I will suggest that potential problems arise because Australia has a science–based economy without a deeply scientific culture. Our approaches to management of systems like mangroves need to be based on the process of science, not merely on its recent findings.

INTRODUCTION

I feel honoured but humbled to be giving this talk; I have not done research work in mangroves for years. I have, however, been involved in the Marine and Estuarine Reference Group for Australia's State of Environment Report, being prepared by DEST, using the OECD's favoured Pressure–State–Response framework.

As a result, perhaps I can make some comments about 'an Australian perspective'; (because that Reference Group was charged with trying to do so), and some comments about the challenge ahead in doing it better.

What I find myself really talking about is the relationship between science and management which, as ***processes***, have more in common than people generally realise.

MANGROVES - A RESOURCE UNDER THREAT?

I will argue that mangroves are indeed resources – not a resource, because mangroves differ – that they are under threat, though many of Australia's mangroves are still relatively unspoiled, and that 'potential problems' include not only the ones usually listed but also a difficulty in understanding how science really works and of how it can contribute to solving environmental problems.

A resource? The importance of mangroves

THE CONVENTIONAL WISDOM

Mangroves are commonly credited with being:

- species rich habitats
- nursery areas for commercial and recreationally important species of fish and invertebrates
- highly productive
- important inshoreline and riverbank stabilisation
  important in floodwater assimilation
- important in waste assimilation

and I would strongly argue that they are of

- educational
- recreational
- aesthetic importance

and that for these reasons (even without all of the above) Australia is custodian of something valuable.

This together clearly makes them a *resource.*

They are threatened in a range of ways, mostly by clearance for alternative land-uses. Threats include:

- clearance for alternative land-uses
- upstream catchment clearance
- inappropriate land-use upstream, hence nutrient inputs, sedimentation, etc
- sewage effluents
- oil spills
- other industrial pollution
- climate change, both *per se* and through sea level changes

THE EVIDENCE

This paper is not a formal review of the literature, but I make a few remarks on the nature of evidence for the 'conventional wisdom'. Some sources are listed at the end.

Species-rich habitats
"Mangroves ain't mangroves ....." There are 39 species of vascular plants in the tropics, grading to only one in South Australia (where, instead the saltmarshes are becoming more speciose); *Avicennia integra* appears to be the only endemic species. Mangroves are most locally diverse in the wet tropics (up to 35 species, in some estuaries on Cape York).

The composition and form of mangrove associations vary with temperature, rainfall, river run–off, sediment type, tidal range and coastal landform.

This needs to be stressed at the outset ... there's no such single thing as a mangrove swamp or forest, any more than there's a single kind of grassland or rainforest.

There are numerous species of animals associated with mangroves, again more obligately and in greater numbers in the tropics. In some arid areas mangroves from the only closed–canopy forest available for birds.

In general, biological inventories at 'list' level are good (though there is still work to be done in some areas). There is also an impressive body of information at the level of descriptive plant ecology. Finally, there is *some* dynamic plant ecology, especially for certain areas in Queensland and NSW. There's less information on animal ecology, either descriptive or functional.

Nursery areas
Juveniles of numerous species of fish and invertebrates are found in mangroves, again more species in the tropics; eg 197 species of fish in northern Australis, 65 near Brisbane, 46 around Sydney.

For example, the early life cycle of the banana prawn appears to be linked to mangrove–lined estuaries; CSIRO work has shown that the post–larval and juvenile phases are restricted to mangroves and mangrove–lined creeks. During the late dry and early wet season, juveniles are only found in mangroves.

In general, though, there has been limited study of what such species are doing there; there are interesting, partly competing hypotheses to explain the role of the habitat in the ecology of juveniles. The trouble is, the hypotheses are so plausible it hardly seems worth testing them, but without testing we are just being doctrinaire. We need studies that make and test predictions.

A common, usually implicit prediction is that because fisheries depend on mangroves, reduction in mangroves should reduce fishery yield. Hence, studies relating fishery yields to presence or extent of mangroves would be an obvious approach. There are some such data for penaeid prawns in the Gulf of Carpentaria and in Indonesia and Malaysia, but they are lacking in many parts of Australia, so generalisations are out of order.

But even those studies are often merely correlative, and therefore studies of *mechanisms* are needed, eg by analogy with some of the work on fish in shallow seagrasses, we need studies on the diets, behaviour, etc of those organisms.

Productivity
Productivity is said to be high in mangroves. There are measurements from various parts of the world and of Australia in terms of above–ground biomass, wood production, leaf production and the surprisingly important benthic algal production. But a system can have high productivity without exporting much of it and the popular wisdom that mangroves are 'highly productive' implies directly or indirectly that mangroves do export a lot of fixed

carbon which is important for adjoining systems. The data on this are variable and have been shown in various studies to be dependent on all the things you would expect -plant species, degree of tidal inundation, etc. Some studies have shown very impressive amounts of export which contribute to the inshore supplies of carbon and nitrogen and have complex, rather unstable relationships with benthic animal communities (poor nutritional quality of mangrove detritus, storm events and tidal scour all contribute to the 'oligotrophic' and 'pioneering' nature of certain mangrove communities); in AIMS studies in the Central Great Barrier Reef region, bacterial standing stocks have been found to be high but meiobenthos generally low, inhibited perhaps by tannins in the mangrove litter or by low availability of nitrogen; the macrofauna, too is low compared, eg with bare mudflats and seagrass meadows nearby. Nonetheless, some animal activity in the mangroves and neighbouring waterways *is* important (eg certain benthic crustaceans and gastropods and zooplankton).

If organisms arrive small, grow, then leave, this could be a form of export that may be both quantitatively and economically significant. I think the evidence for it is very weak in the south of Australia but quite substantial in the tropics (various fish, penaeid prawns).

Queensland work has shown that mangrove forests are sinks for nutrients (notably nitrogen and phosphorus).

Other ecological processes

There is increasingly solid evidence on population dynamics of particular species of mangrove trees (notably in northern Queensland and New South Wales) as well as on physiology, productivity, detritus outwelling, etc, but there are still many species, and perhaps more importantly many places, where such work has not been done.

The evidence from such demographic and physiological studies might lead to more sensitive ***indicators*** of mangrove 'health' – eg. given an understanding of the regeneration niche of a species at a site, a reliable indicator of stand health may perhaps be devised in terms of numbers of seedlings present and number of saplings being established. I think that may be the way ecological indicators are going to have to be developed. It is possible to envisage indicators such as flowering seasons, insect herbivore loads, infrared reflectance, use of remote sensing to map mangroves and hence to indicate not only areas but shifts in distribution.

Shoreline and river-bank stabilisation, floodwater assimilation

There is good reason to consider these important on short time-scales, though there is equally evidence that mangroves will not resist a determined, directional process such as erosion at a creek mouth or change in local sea level.

Waste assimilation

There is evidence that mangrove swamps can assimilate more added nutrients and organic matter than some other systems. They appear to be limited by nitrogen and phosphorus and are very efficient at taking them up.

They do not, however, have infinite capacity to absorb nutrients, as indicated by experience near Port Adelaide, where mangrove roots are blanketed by massive growth of *Ulva* attributed to nutrient enrichment, mainly from secondarily treated sewage.

Scientific, educational, recreational, aesthetic importance including biosphere preserves
This is the argument for rainforest and other unspoiled natural systems. I think it a mistake to defend any habitat *only* on the grounds that it might be worth a lot of money; it is more honest and arguably more important to say it is part of our heritage (and by all means may also be worth money, might harbour valuable genetic resources, etc). This is a heritage which many other Indo–West–Pacific countries are rapidly losing. Mangroves are very special vascular plants, occupying a habitat in which their immediate ancestors did not evolve. (*cf.* marine mammals) and having fascinating physiological and ecological adaptions to salt, waterlogging, anoxic soils, reproductions and dispersal, some of which are poorly understood (eg. viviparity) as well as some population and community dynamics that are not spectacularly different from those of terrestrial assemblages but still of interest. Along with the structure–forming vascular plants, whole communities of more–or–less committed species live. One example: the existence of *A. marina* in Adelaide region is difficult to explain in terms of past sea levels, and the genetics of SA mangroves are there fore of particular interest. These are questions in pure science, every bit as exciting and culturally important as say, unearthing the Globe Theatre or raising the *Mary Rose*. I think we ought to defend mangroves on those cultural grounds, as well as for any economic value they may have. Despite recent hype by those who take simplistic and myopic view of economics, I continue to believe that one of Australia's greatest assets is its wonderful, *relatively* unspoiled nature. And what little information we could glean during the State of the Environment exercise suggests that the mangroves (nationwide) are indeed relatively little spoiled. We should look after this asset.

Conclusion ... a resource?

Yes, but 'mangroves ain't mangroves' and we do need to keep getting good data, critically and open–mindedly, about the nature of the resource.

Mangroves - Under Threat?

Kinds of threats

Mangroves are extensively cleared and filled near major population centres. Port construction, dredging etc. have major direct effects (habitat removal) and indirect effects (changing flow patterns). These habitats are hydrologically the sorts of places that will trap sediments, rubbish, pollutants etc.

There has been a surprisingly wide range of uses made of mangroves in Australia, but mostly on small scales and many of them now discontinued. So far, pressures in Australia do not include farming, clearing in order to grow rive, much timer–gathering, use for fodder, etc.

Being estuarine organisms (in many areas) mangroves are threatened by the kinds of forces that threaten estuaries; pollution, land reclamation, engineering works, clearance of catchments, inappropriate development within catchments, oil spills, other forms of pollution.

More subtle threats may exist. Sea level change has been discussed, eg. in SA. Other consequences of climatic change (notably temperature and rainfall) may also be important.

Most lists of threats make little comment about plant 'health', except in extreme cases such as oil spills and blanketing of roots by nutrient–induced algal blooms. But mangroves have leaf damage due to insects and fungi are known to be prone to stress from high salinity, drought, cold, and are presumably not immune from effects of other pollutants.

Extent of threats

Generally the threats are greatest around the major population centres. There has been extensive clearing for land reclamation near coastal cities such as Sydney, Newcastle, Brisbane, Cairns, Adelaide – and Gladstone – and there have been modifications such as breakwaters, channel dredging, flood mitigation works, which can affect mangroves indirectly. I understand the significant additional areas in Cairns and Gladstone are now under threat from development.

There are indirect effects – eg. Saenger and colleagues estimate that 37% of NSW estuaries had more than half of the catchment cleared, 60% of Victorian, 86% of South Australia but only 3% of Western Australia estuaries – the score was 0% for the Northern Territory and there was not enough information to decide for Tasmania and Queensland. Despite the encouraging condition of some tropical areas, however, we need to watch out for areas where new development will occur, to ensure that it is done more wisely than that of the past (eg the Pilbara coast of WA and parts of the Qld coast).

Regrowth of mangroves can occur, especially where sediment is building up (often this is human–induced, perhaps due to some environmentally–unwise action elsewhere).

Desirable data

We would like information on each of the perceived threats, but some are not even well enough understood or defined that we could say what to measure. What, for example, should we measure to monitor some perceived, possible threat to mangrove physiology from heavy metals? A research study is implied, in advance of any monitoring program.

In short, we'd like data on health, on degradation of mangroves, but we can really only get data on their presence or absence.

Actual data available

There is extensive data of a biological 'inventory' kind – mappings of species occurring, zonation, etc. These are impressive achievements, but they still do not cover all Australian mangrove areas. There are documented patterns of species richness with latitude, climatic conditions, tidal amplitude, estuary size. Within a site, the explanations for distribution patterns are complex; simple ideas of zonation stand up under scrutiny here about as well as they do on rocky shores! Sure, there are zones, as long as there is a very strong, simple environmental gradient, but generally the picture will be more complex than that. But most of the biogeographic studies simply tell us what is where. We assume that what is there is what (in some sense) belongs there, except in areas where we know we have done some damage but we have explanations for the observed patterns.

In the end, the only data we found we could present for an Australia–wide assessment of mangroves for Australia's State of the Environment Report was on areas. The total is about 11,500 km^2 for Australia (Zann 1995). The function of reporting such an estimate will be that we can ask in five years whether the area has gone up or down. So, biologists will ask, what??

In certain places the information about areas alone is telling. For example, Moreton Bay is commonly cited: the figure changes but it seems that some 17% of mangrove stands have been removed from Moreton Bay. We might usefully ask how the figure has changed five years hence. But area is the crudest possible ecological indicator ... suppose it is increasing because of sediment deposition due to degradation of catchments; is that a good thing?

I suggest that an Australian perspective on ***areas*** would say that we are not doing too badly. Further, we have both legislation and public pressure established in such a way that we will hold the present situation pretty well. What of other aspects of the 'health' of this resource?

One clear point about mangroves is that they are dynamic (and not only because people clear catchments!). There are numerous cases documented of changes in relative sea level in mangrove stands over decades, or of mangrove sediments having been overlain, in only a few thousands of years, by sand–dune systems such as those at Glenelg in South Australia where the English settlers landed in 1836 (and which are themselves now under threat); we are talking abut systems that are very dynamic on short time scales.

Responses – Management

There are reserves of various kinds, in some mangrove areas, but generally *not* a whole–ecosystem approach.

About 8% of Australia's mangrove forests are included in some kind of reserve. Queensland has the most extensive reserve system. However, mangroves differ from on another, and there is no indication that all types of mangrove forests are protected; large areas, such as those abutting the World Heritage areas of the Great Barrier Reef and wet tropical forests, enjoy inadequate protection, as is true of arid–zone mangroves in the West.

Some States have blanket protection of mangroves – various kinds of legislation and regulations require permission at chief executive officer level to cut, clear or otherwise damage a mangrove plant. And some, eg. WA Government, have a 'no net loss of mangroves; policy but again, since mangroves very, it is not clear what such a policy can achieve.

SCIENCE AND MANAGEMENT

As noted above, Australia was presented with a State of the Marine Environment Report (Zann 1995) early this year and is now working on a report on the State of the Environment (all components, not just marine) which should appear early next year. Such reporting is required under OECD arrangements. When I tried to use the experience to prepare this talk, it prompted some reflection on the relationship between scientists, science, and environmental management which has evolved over 20–30 years and which now presents and enormous challenge.

The environmental movement was largely led by scientists 20+ years ago (names like Paul Ehrlich spring to mind, whilst locally, in my State at least, it was practising scientists, mostly members of university departments, who formed the first environmental lobby, pressing for national parks, controls on the clearance of native vegetation, pollution control and so on).

I felt then that if the movement was successful it should do itself out of a job, because its concerns should become mainstream. I was right and wrong. There *are* now Departments of Environment, EPA's, etc. There *is* an identified profession of environmental management, distinct from the profession of scientific biology or ecology. The important issue with many environmental problems is no longer to draw attention to a problem, but to urge that action be taken about it. There is still a place for the non–governmental environmental lobby but it is a political, lobbying role, not a role of expertise (I simplify the case, of course, for the sake brevity). But where are the scientists, *as* scientists?

Scientists do seem collectively to have felt that we are not longer needed at the barricades of the 60's. Wilson & Barnes (1995) examined scientists' participation in environmental policy. They reported that we are not great participators; we are concerned about environmental problems but either feel it is not out duty, or that we are not competent (or perhaps that it is not wise or safe) to take part in policy formation, criticisms of policy, lobbying, etc.

Anyway, I suggest that the major difference between the 60's and the present is that now, it is political people – both within government and on various fringes – who are making substantial decisions about environmental matters that were simply not on their agenda 20–30 years ago. There have been international conferences – Stockholm, Rio – at which governments have signed agreements. Suddenly, there is a new role for scientists for which we are largely ill–prepared.

Governments are now making quite substantial commitments which we scientists implicitly said they ought to make 20–30 years ago ... and then asking us how to get on with the job! We may or may not get involved politically in environmental matters, but we now have a new, qualitatively different and appallingly difficult *scientific* role in these matters.

We are being asked for scientific advice about how to achieve **'ecologically sustainable development'**, about how to proceed to adopt the **'precautionary principle'** in the management of fisheries, for example, a 'whole eco–system' approach to management has long been advocated by scientists (in the sea, the current buzzword is **'large marine ecosystems'**) and enthusiastically supported by lobby groups. For the time being, we can get away with (correctly) complaining that there are appalling political barriers to adopting such management (too many local councils, etc, etc.) but in fact there is a risk that at any moment the political and administrative experts will solve all and that then they will ask us how to do it!

Whole–ecosystems management provides a good example of the new scientific challenge to which I refer.

I think that the job of advising on how to do it has been better faced, so far, by those concerned with catchment management than in other ecosystems, but it is a challenge that most scientist either ignore (retreating to various smaller scales) or preach about (I use the word pejoratively, intentionally, to imply the purveying of beliefs rather than tested hypotheses).

The State of Environment Reporting exercise was another example of the challenge of being asked for advice that we are not ready, in theory or practice, to give. It is easy to cry that we need; more data' or 'more studies', but what data? what studies? I suggested above some of the kinds of data we might seek in reporting on the stat of mangroves. Perhaps, in addition to the *areas* which were all we could manage on a national scale for the SoE Report, we could seek data on ecological or physiological *function*, some of which might not be too demanding, to obtain. However, I suggest this should be done *only where there is some reasonable hypothetical reason to be interested.* There is a wealth of techniques that could be applied, but none are cheap, and why should we use any one of them? This is a scientific question. Scientists are taught that science is not a matter of gathering data in the hope that some understanding will emerge; similarly, State of Environment reporting should not be a matter of measuring whatever we can simply because we can. This, then, brings me to the problem I identified as most important.

POTENTIAL PROBLEMS?

I was asked to speak about potential problems. I could allude to issues in planning, problems of jurisdiction, etc. These are real problems, but there has been plenty said about them (eg. by the Resource Assessment Commission and every report on coastal management that preceded it). I want instead to draw attention to a class of problems arising from a subtle misunderstanding of how science works.

There is no escaping the use of scientific methods; they have got us where we are, without enormous population, powerful technology, etc and there is no turning back. We are a scientific society. We need to use science in management. But management cannot be based on science as it is commonly understood – that is, on a body of knowledge obtained as a result of some methodical and dispassionate process of investigation which is ideally done *in advance of* management. Instead, I want to argue that there is a view in which science becomes *part of* management, or management literally becomes science.

In other words, the mangroves (like the rest of our environment) are under threat because we have a science-based economy without a scientific culture. *A true understanding of science is not common property yet, even amongst many people with science degrees, managers and those concerned about threats to resources! Only the trappings of science are widely understood. The real nature of the thought processes, the testing of ideas, hence the status of the results, are not second-nature to most of us and are easily over-ridden by superficial views. Science is still largely thought of as a body of knowledge, not as a process.*

I want to argue that science is, in fact, all about doubt. Those who would base their actions on it need to embrace doubt or uncertainty.

In order to weave science into management, we must recognise the need for information. 'Both sides' (I use quotes because there are rarely only two sides) in any debate about management options need to recognise that there is uncertainty. 'Both sides' need the *confidence* to acknowledge doubt, the *courage* to expose ideas to critical test, and the *goodwill* to agree on actions contingent on the results of the tests. This is a tall order, but ways are being developed to facilitate it. This is no place for a detailed account of those ways, but I'll try to indicate their spirit.

For a start, we must give up the idea of 'studying first, then managing'. Scientific work is never finished; there is always uncertainty. 'Management decisions are gambles' (Walters 1986). The approach called ***adaptive management*** embraces uncertainty by acknowledging its existence, seeking to identify the key uncertainties, and then agreeing on procedures to reduce uncertainty *in the course* of management.

Faced with uncertainty, scientists set up a range of alternative *hypotheses*. These are *possible* models of reality; they all fit the known facts but the scientists do not know which is correct. So, they make predictions from the hypotheses - *critical* predictions, such that each hypotheses predicts a different outcome. And they test the predictions against the facts - *critical* facts, gathered for the purpose of disproving some hypotheses, thus leaving the scientists more confident than others. Management can do exactly the same thing; this is why I claim that science and management should become one. If there is uncertainty, then identify it, agree on the alternative models, make predictions from them and manage in such a way as to gather the necessary data to test the predictions.

The approach is described by Walters (1986, 1993) and illustrated in Grayson & Doolan (1995). It is not applicable to all kind of problems, but I think it is needed for many problems concerning mangroves.

SOME SOURCES

This is an introductory paper for a symposium, not a fully-referenced review of the literature. The following are some sources of further information:

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ECOLOGY OF MANGROVES OF PORT CURTIS: REGIONAL BIOGEOGRAPHY, PRODUCTIVITY AND DEMOGRAPHY

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ABSTRACT

Port Curtis and the Narrows comprise a large submerged valley formed by rising sea-levels during the Quaternary. An outer series of barrier islands protects the enclosed water and results in large areas of low energy coastline. Four rivers discharge into the bay, each with a large stream sediment load of silts and muds. Tidal circulation dominates the hydrographic features of the area and determines the deposition of the fluvial sediment load while the scouring effects of the tidal currents, particularly at ebb tides, maintain a relatively stable balance between deposition and erosion in all tidal channels.

At present there are approximately 8Okm^2 of subtropical mangroves in Port Curtis comprising approximately 3.8% of the mangroves of the entire Queensland coastline. In addition, approximately lOOkm^2 of salt marsh, salt flat and mud flat communities occur in Port Curtis and the Narrows. The biogeography of these ecosystems indicate their regional significance including rare and endemic species as well as several significant species limits.

Leaf production data for two species of mangroves are presented and compared with leaf production data from other areas. Regional leaf productivity patterns reflect the highly seasonal subtropical conditions within Port Curtis.

Data will be presented on the establishment, survival and growth of mangroves within Port Curtis, collected during a study of the effects of the Gladstone Power Station during 1974–83. This demographic data set represents one of the longest continuous mangrove studies in Australia which allows the percentage survival, expected time for complete turnover and percentage annual mortality to be reliably calculated for the four most abundant species.

INTRODUCTION

Port Curtis and the Narrows comprise a large submerged valley formed by rising sea-levels during the Quaternary (Conaghan, 1966). An outer series of barrier island protects the enclosed water and results in large areas of low energy coastline (Figure 1). Four rivers discharge into the bay – the Boyne River in the south, the Calliope River and Auckland Creek in the centre and Munduran Creek in the north. As these rivers drain a hinterland of mostly argillaceous rock (Jardine, 1925), they carry a large stream sediment load of predominately silts/muds of albite and quartzite. Conaghan (1966), who studied the sedimentary processes within Port Curtis, concluded that the tidal circulation dominates the hydrographic features of the area and determines the deposition of the fluvial sediment load. The scouring effects of the tidal currents, particularly at ebb tides, maintains a relatively stable balance between deposition and erosion in all tidal channels. The mud content of the sediments in general is highest in low energy areas, where land masses provide shelter from wind and/or wave action.

Climatically, the area is subtropical with a mean annual rainfall of 944mm, of which approximately 50% falls from December to February. At present there are approximately 80km^2 of mangroves in Port Curtis from Boyne Island to Ramsey's Crossing (Figure 1). This comprises approximately 3.8% of the mangroves of the entire Queensland coastline. In addition, approximately 100km^2 of saltmarsh, saltflat and mudflat communities occur in Port Curtis and the Narrows. Immediately to the north, associated with the estuary of Raglan Creek and the Fitzroy River, additional substantial mangrove areas occur.

REGIONAL BIOGEOGRAPHY

The following physiognomic (structural) littoral vegetation types have been described from the Port Curtis area adjacent to the Calliope River and Auckland Creed (Saenger and Robson, 1977; Saenger, 1988).

Mudflats occur in areas where fine sediments have accumulated between mean sea-level (MSL) and mean low water spring (MLWS) level. These mudflats usually consist of more or less uncompacted fine silt, mud or clay and they do not form a suitable substrate for macrophyte colonisation. Algae of the genera *Rhizoclonium* and *Monostroma* commonly occur, especially during the winter months, as well as various species of diatoms. Outside the mouth of the Calliope River, mudbanks sometimes have considerable calcareous material of marine origin, forming a suitable substratum for numerous algal species (Saenger, 1982; Saenger and Wollaston, 1982).

The phenomenon of vegetation-free high tidal saltflats was first described in detail from the Central Queensland coastline (Fosberg, 1961). The factors responsible for their formation generally include clayey soils with poor internal drainage, high evaporation rates and a low, highly seasonal rainfall. High tidal salt flats occur at levels where they are inundated only by extreme springtides and the only plants observed were fine algae which form surface mats in moist depressions. These factors combine to give soil conditions (aeration and salinity) unsuitable for macrophyte colonisation.

When core samples of soils from Gladstone saltflats were compared with soils from adjacent stands of the mangrove *Ceriops tagal*, marked waterlogging in the soils of the saltflats was noted which, in turn, was likely to lead to poor soil aeration. The surface chloride concentrations were higher on the saltflats than among the *Ceriops* and they increase with depth. X-ray fluorescence analyses of the saltflat soils indicated that the concentrations of two major soil components - calcium and iron - were around 50% those of the *Ceriops* soils.

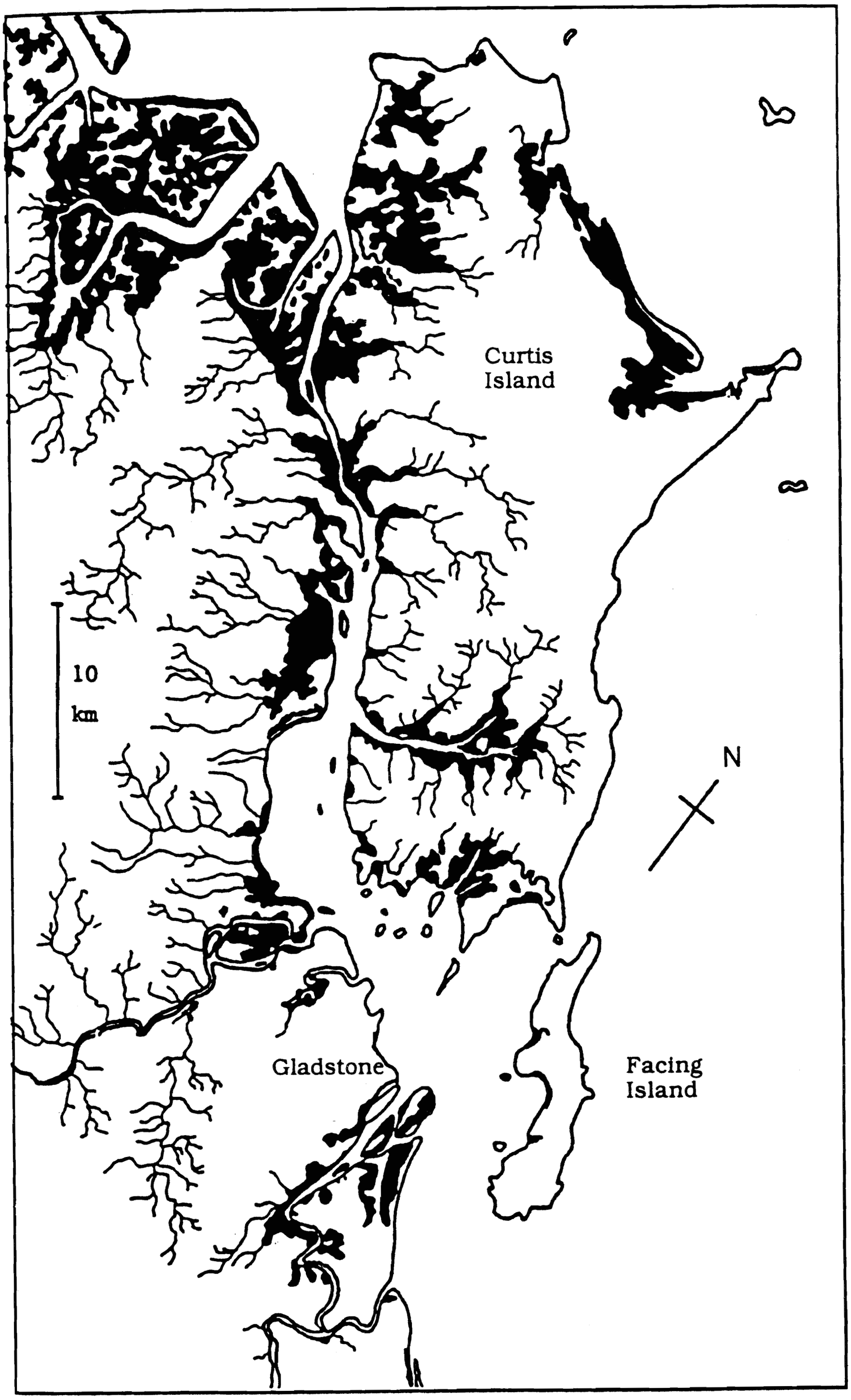

Figure 1: Showing extent of mangroves in Port Curtis and the Narrows

Compared with the saltmarshes south of Gladstone (Saenger et al., 1977), those of the study area are poorly developed in species diversity, height and density of the vegetation. Factors responsible for this include the highly seasonal rainfall and the high evaporation rates with the consequent short growing season, as well as the adverse edaphic factors (aeration and salinity). Saltmarsh species recorded are given in Table 1. The saltmarshes can be classified as low shrubland or as low open shrubland, with the latter predominating; where grasses (eg. *Sporobolus virginicus*) and/or herbs (eg. *Limonium australe)* occur, a herbland formation can be recognised. Despite their poor development, the Port Curtis saltmarshes contain the endemic *Suaeda arbusculoides* and the rare *Portulaca napiformis*.

Table 1:
Saltmarsh plants recorded from the study area

TABLE 1: SALTMARSH PLANTS RECORDED FROM THE STUDY AREA

SHRUBS

Diospyros ferrea var. geminata	Salsola kali
Enchylaena tomentosa	Sarcocornia quinqueflora
Halosarcia halocnemoides	Suaeda arbusculoides
Halosarcia inica var. leiostachyum	Suaeda australis
Myoporum acuminatum	

GRASSES AND HERBS

Aristida calycina	Limonium australe
Brachyscombe basaltica	Paspalidium gracile
Bulbostylis barbarta	Portulaca napiformis
Cyperus polyustachyos	Scirpus litoralis
Cyperus scariosus	Sesuvium portulacastrum
Eleocharis geniculata	Spergularia media
Emilia sonchifoliacus	Spergularia rubra
Epaltes australis	Sporobolus virginicus
Eragrostis elongata	Veronia cinerea
Fimbristylis ferruginea	Vittadinia triloba sens. lat.
Fimbristylis punctata	

ALGAE

Anabaena torulosa	Lyngbya aesturii
Anacystis marina	Microcoleus lyngbyaceus
Calothrix crustacea	Oscillatoria nigro–viridis
Chroococcus turgidus	Phormidium angustissimum
Hormidium subtile	Thizoclonium capillare

Mangrove vegetation extends over a vertical range from approximately MHWN to HWS levels. Along the shores of Port Curtis and including the island near the mouth of the Calliope River, a tall fringe forest (7m high) occurs. Within the Calliope River, as well as the smaller creeks, the types of mangrove communities are more variable and not well developed in terms of height or density, reflecting the low, highly seasonal rainfall and the high evaporation rates during the drier months. The mangroves and associated species in the study area are listed in Table 2.

Table 2:
Mangrove and associated plant species from the study area

TABLE 2:
MANGROVE AND ASSOCIATED PLANT SPECIES FROM THE STUDY AREA

MANGROVES	
Acanthus ebrecteatus *	– Holly–leaved mangrove
Aegialitis annulata	– Club mangrove
Aegiceras corniculatum	– River mangrove
Acrostichum speciosum	– Mangrove fern
Avicennia marina	– White mangrove
Bruguiera exaristata *	
Bruguiera gymnorrihiza	– Black mangrove
Ceriops tagal	– Yellow–spurred mangrove
Exoecaria agallocha	– Milky mangrove
Lumnitzera racemosa	
Osbornia octodonta	– Myrtle mangrove
Rhizophora stylosa	– Red mangrove
Xylocarpus australasicus	– Cannonball mangrove
Xylocarpus granatum *	– Cannonball mangrove
MANGROVE ASSOCIATES/EPIPHYTES	
Amyema mackayense ssp.mackayense	– Mangrove mistletoe
Myoporum acuminatum	– Boobiella
Lysiana subfalcata ss. maritima	– Mistletoe

* *Recorded only in northern part of study area, between Narrows and Raglan Creek*

Three or more–or–less deciduous mangrove species occur in the area Saenger and Moverley, 1985) including *Xylocarpus moluccensis, Excoecaria agallocha* and *Lumnitzera racemosa.* Leaf loss in these species coincides with the dry season ie. July to September.

The southern limit of *Bruguiera exaristata* occurs in the northern part of Port Curtis in Barker Creek, while the most southerly occurrence of *Xylocarpus moluccensis* (formerly *X. australasicus*) is in the Calliope River; this species does not occur in Auckland Creek. Similarly, *Xylocarpus granatum* is absent from the mainland coast south of the mouth of

Raglan Creek although small stands occur on Fraser Island. The most southerly occurrence of *Acanthus ilicifolius* is in Raglan Creek, immediately north of the Narrows.

With these species limits in and around Port Curtis, this area comprises an important biogeographical region on the east coast which compares in significance with other regions where a number of species occur at their most southerly limits eg. the Herbert River and Port Clinton (Bunt et al., 1982).

PRODUCTIVITY

While no direct productivity measurements are available for the mangroves of the study area, leaf production rates have been reported by Saenger and Moverley (1985). In addition, leaf fall rates were measured for two species of mangroves at two sites as part of a national leaf fall study (Bunt, 1995). The Gladstone data are given in Table 3 together with the annual totals for August 1982–83. For Ceriops tagal, leaf litter production appears to be lower in the Calliope River site (near the lower end of the anabranch) than at the Curtis Island site. In addition, these data show the seasonal pattern of leaf fall in these two species. Thus litter fall is minimal during May to July when low temperature are limiting. This is followed by maximal litter fall during August to September, which are the driest months when leaf shedding may facilitate the removal of tissue salts. While considerable variation exist in these data, these litter values reflect the highly seasonal conditions within the study area and are comparable with other values from dry subtropical areas around the world (Saenger and Snedaker, 1993).

Table 3:
Leaf litter fall rates for mangroves in the study area in g/m^2 (dry weight)

Table 3: Leaf litter fall rates for mangroves in the study area in g/m^2 (dry weight).

	Rhizophora stylosa		*Ceriops tagal*			
	Curtis Island		Curtis Island		Calliope River	
Trap No.	198	199	198	199	200	201
Aug 82	33.8	2.1	73.4	133.5	101.4	142.7
Sep	3.6	4.8	73.9	68.4	51.5	87.5
Oct	10.4	1.2	38.8	35.2	25.1	27.6
Nov	63.8	58.8	37.2	53.0	34.6	38.4
Dec	20.8	2.7	36.4	16.0	13.1	29.9
Jan 83	23.0	17.3	29.3	18.6	8.6	10.2
Feb	57.4	47.9	28.6	33.9	5.4	14.0
Mar	81.1	6.7	34.5	43.4	11.8	10.8
Apr	56.7	25.4	16.3	33.1	6.0	2.3
May	6.0	4.2	8.2	22.4	4.0	5.0
Jun	10.1	8.2	5.2	16.3	3.7	4.0
Jul	13.1	14.7	22.3	22.2	4.8	4.8
Aug	22.0	11.9	63.4	90.1	12.9	15.5
Sep	85.4	4.0	82.1	107.6	29.2	39.8
Annual Total	**401.8**	**205.9**	**467.5**	**586.1**	**282.9**	**392.7**

MANGROVE DEMOGRAPHY

While only limited demographic studies have been conducted on mangroves, those from the Australian region (Burns and Ogden, 1985; Clarke, 1995) have relied on relatively short-term studies of 1.5 and 3.5 years respectively. This account of the mangrove vegetation of the Port Curtis district is based on observations collected during a study of the effects of the Gladstone Power Station on the estuarine communities during 1974–83. As such, it represents one of the longest continuous mangrove study in Australia and allows the reliable calculation of selected demographic parameters.

Three large permanent plots were initially selected (Figure 2) to study any changes in mangrove growth rates, germination rates and seedling survival. A fourth plot was established early in 1979 after the destruction of one plot during bridge construction over the Calliope River.

The areas were selected to represent typical mangrove areas and were laid out to cover all the various mangrove zones from the vegetation-free saltflats to the extreme low water mark. As a result, the plots are of variable lengths but all are 10m wide.

In February/March 1975, all trees and seedlings were identified and mapped, tagged with aluminium tags and numbered. Heights and girths-at-breast-height (GBH) were measured in addition to a number of environmental factors such as soil salinities, soil types, texture and height above the Gladstone Harbour Datum.

Each year between 1976 and 1983 inclusive, new height and girth measurements were taken on the numbered trees, and the death of existing trees noted. any seedlings were tagged and measured and added to the stored data. Retrieval functions allow data retrieval on :

- a particular tree by number or position
- information about a group showing some property
- information about the variation in a property common to a group of trees

Contour plots of tide levels and soil salinity can be superimposed on the vegetation plots.

The data on growth and mortality rates for the whole plots have been analysed following the techniques of Sarukhan and Harper (1973). The percentage survival, expected time for complete turnover and percentage annual mortality of all individuals have been calculated for the four species common to Plots 1, 2, 3 and 4 and the results are given in Tables 4, 5, 6 and 7.

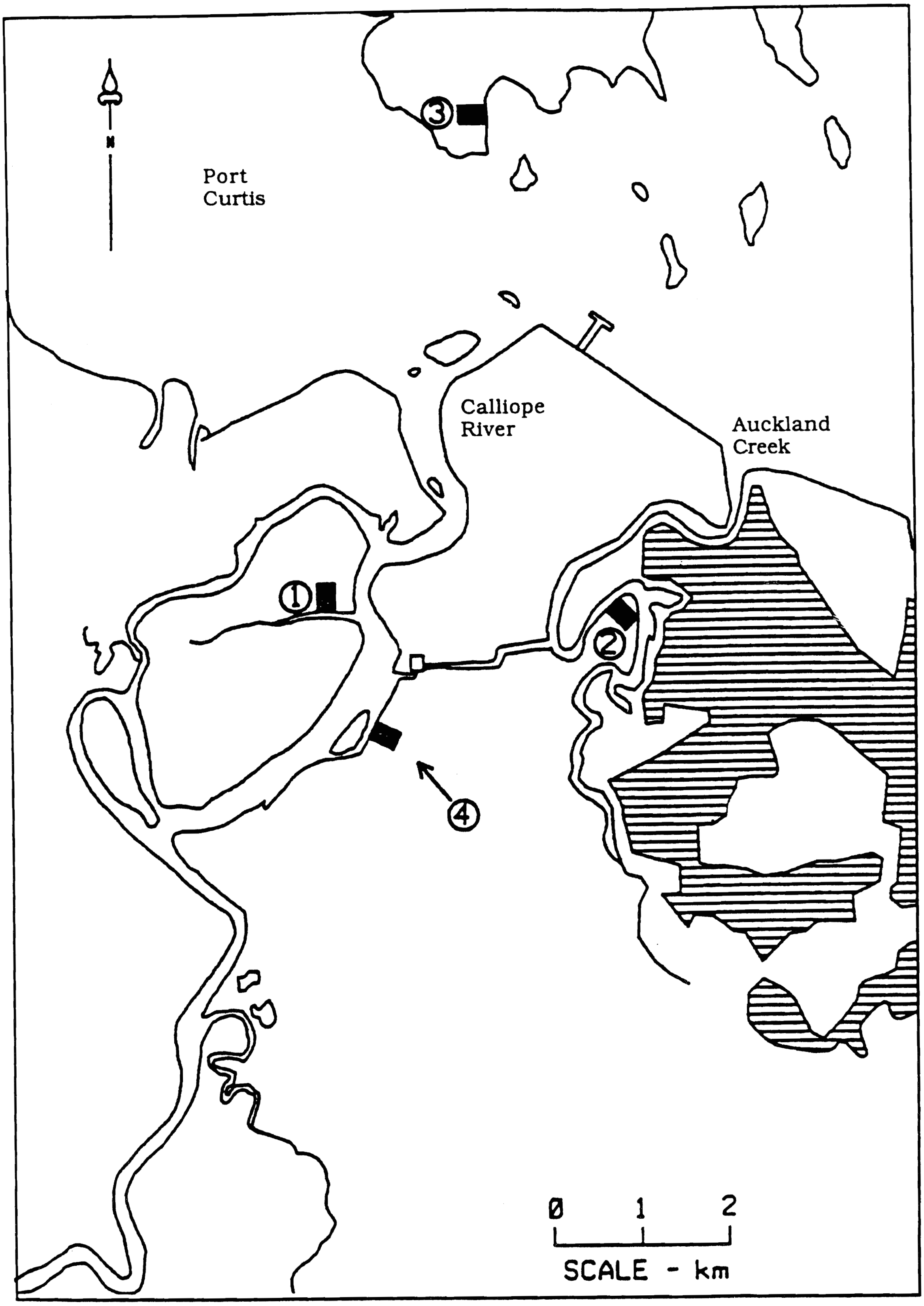

Figure 2: Showing locations of permanent mangrove study sites

Table 4: Population flux in Ceriops tagal at Plots 1, 2, 3 and 4 from March '75 to March '83

Table 4: Population flux in *Ceriops tagal* at Plots 1, 2, 3 and 4 from March 1975 to March 1983.

		Plot 1	Plot 2	Plot 3	Plot 4
a.	No. of plants in 1975*	417	20	20	13
b.	1983**	393	20	19	19
c.	Net change (b-a)	-24	0	-1	6
d.	Rate of increase (b/a)	0.94	1.0	0.95	1.46
e.	Arrivals 1975* and 1983**	5	1	3	11
f.	Losses 1975* and 1983**	29	1	4	5
g.	Survivors 1975* and 1983**	393	20	17	10
h.	% survival of plants in (a)	94.2	100	85.0	76.9
i.	Expected turnover (years) (No. of years) x 100 / 100-h	87.0	-	53.3	13.0
j.	Total plants recorded	422	21	23	24
k.	% Annual mortality	1.37	0.60	2.17	6.94

* 1980 for Plot 4 ** 1980 for Plot 1

Table 5: Population flux in Avicennia marina at Plots 1, 2, 3 and 4 from March '75 to March '83

Table 5: Population flux in *Avicennia marina* at Plots 1, 2, 3 and 4 from March, 1975 to March 1983.

		Plot 1	Plot 2	Plot 3	Plot 4
a.	No. of plants in 1975*	143	156	7	53
b.	1983**	76	72	10	35
c.	Net change (b-a)	-67	-84	3	-18
d.	Rate of increase (b/a)	0.53	0.46	1.43	0.66
e.	Arrivals 1975* and 1983**	2	22	10	0
f.	Losses 1975* and 1983**	69	106	7	18
g.	Survivors 1975* and 1983**	76	66	6	35
h.	% survival of plants in (a)	53.1	42.3	85.7	66.0
i.	Expected turnover (years) (No. of years) x 100 / 100-h	10.7	13.9	56.0	8.8
j.	Total plants recorded	145	178	17	53
k.	% Annual mortality	9.52	7.44	5.15	11.32

* 1980 for Plot 4 ** 1980 for Plot 1

Table 6: Population flux in Rhizophora stylosa at Plots 1, 2, 3 and 4 from March '75 to March '83

Table 6: Population flux in *Rhizophora stylosa* at Plots 1, 2, 3 and 4 from March 1975 to March 1983.

		Plot 1	Plot 2	Plot 3	Plot 4
a.	No. of plants in 1975*	29	67	220	12
b.	" 1983**	29	78	187	9
c.	Net change (b-a)	0	11	-33	-3
d.	Rate of increase (b/a)	1.0	1.16	0.85	0.75
e.	Arrivals 1975* and 1983**	20	41	255	0
f.	Losses 1975* and 1983**	20	30	288	3
g.	Survivors 1975* and 1983**	21	65	110	9
h.	% survival of plants in (a)	72.4	97.0	50.0	75.0
i.	Expected turnover (years) (No. of years) x 100 / 100-h	18.1	267.6	16.0	12.0
j.	Total plants recorded	49	108	475	12
k.	% Annual mortality	8.16	3.47	7.58	8.33

* 1980 for Plot 4 ** 1980 for Plot 1

Table 7: Population flux in Aegiceras corniculatum at Plots 1, 2, 3 and 4 from March '75 to March '83

Table 7: Population flux in *Aegiceras corniculatum* at Plots 1, 2, 3 and 4 from March, 1975 to March 1983.

		Plot 1	Plot 2	Plot 3	Plot 4
a.	No. of plants in 1975*	12	53	94	118
b.	1983**	6	50	105	104
c.	Net change (b-a)	-6	-3	11	-14
d.	Rate of increase (b/a)	0.50	0.94	1.12	0.88
e.	Arrivals 1975* and 1983**	0	3	46	0
f.	Losses 1975* and 1983**	6	6	35	14
g.	Survivors 1975* and 1983**	6	48	86	104
h.	% survival of plants in (a)	50.0	90.6	91.5	88.1
i.	Expected turnover (years) (No. of years) x 100 / 100-h	10.0	85.1	94.0	25.3
j.	Total plants recorded	12	56	140	118
k.	% Annual mortality	10.00	1.34	3.13	3.95

* 1980 for Plot 4 ** 1980 for Plot 1

These data show that while the plots were similar in composition, there is considerable variability in each of the demographic parameters. Means and standard deviations of parameters for each of the four species common to all permanent plots are given in Table 8.

The major characteristics of the four common mangrove species to be noted include:

- all species, *Rhizophora stylosa* in Plot 3, had extremely low recruitment rates
- all species show a rate of increase close to unity ie. low recruitment is matched by low mortality
- all species, except *Avicennia marina*, showed survival rates in excess of 70% over the 8 year period with annual adult mortality of less than 7%
- all species, except *Avicennia marina*, showed a turnover time exceeding 50 years
- *Avicennia marina* was affected by mangrove die–back during the study period and the demographic parameters clearly demonstrate that effect
- all species showed high seedling mortality during their first year, ranging from 36% to 77, with the species with the highest recruitment (*Rhizophora stylosa*) also showing the highest first–year seedling mortality.

Table 8: Mean demographic parameters with standard deviations for all species for Plots 1, 2, 3 and 4 from March '75 to March '83

Table 8: Mean demographic parameters with standard deviations for all species for Plots 1, 2, 3 and 4 from March 1975 to March 1983.

Parameter	*Aegiceras*	*Avicennia*	*Rhizophora*	*Ceriops*
Rate of increase	0.86 ±0.26	0.77 ±0.44	0.94 ±0.17	1.09 ±0.24
Annual recruitment	1.5 ±2.8	1.1 ±1.2	10.3 ±14.6	1.3 ±1.6
% Survival	80.1 ±20.0	61.8 ±18.7	73.6 ±19.2	89.0 ±10.2
Turnover Time (yrs)	53.6 ±42.1	22.3 ±22.5	78.4 ±126.1	51.1 ±37.0
% Annual Mortality	4.61 ±3.76	8.36 ±2.66	6.89 ±2.30	2.77 ±2.85
% Seedling mortality in 1st year	59.3	51.1	76.9	36.1
Total Plants recorded	326	393	644	490

What these data indicate is that the mangrove populations of the study area are in a state of dynamic equilibrium where recruitment is matched by mortality but where turnover times are extremely long.

DISCUSSION

Port Curtis and the Narrows form one of only two channel landscapes in Queensland (Hinchinbrook Channel is the other!). In that sense, the area is very unusual. It was undoubtedly highly considered and exploited for its marine resources by the indigenous inhabitants; Matthew Flinders described numerous fires around the shore of Port Curtis during his visit in 1802 and he met a hostile, stone throwing reception when landing of the southern end of Curtis Island.

As has been mentioned earlier, the Port Curtis region represents a significant biogeographic node pint in terms of mangrove distributions on the east coast of Australia. When this is combined with the extensive sheltered waters of this channel landscape, the Port Curtis mangroves comprise a significant portion of Eastern Australian mangrove systems. There are indications that the region is currently infilling while becoming somewhat more arid at the same time. The mangroves reflect this trend in their highly seasonal patterns of growth and deciduousness, their highly seasonal leaf litter production, and in the fact that most of the species find their southern limits in this region are generally species of more humid habitats. It should be noted that, of the four main species in the region, only *Ceriops tagal,* the species characteristic of high tidal elevation in arid areas, shows a rate of increase in the area of greater than one (Table 8).

These interpretations allow speculation concerning the future of the mangroves of this region. Present natural changes suggest that, if the current trends of increasing aridity and infilling continue, then some of the species at their southern limits may be lost from this area. On the other hand, the remaining species and the systems they support can be expected to maintain themselves and the marine productivity which they underpin.

Probably of far greater concern are future changes that might result from human activity in the region. A number of threats can be recognised including foreshore development, water pollution, water diversion and oil shale ming to name a few. Undoubtedly others could be added to that list. Given that the mangroves of the region support a significant fishery, provide considerable coastal protection and provide ample recreational opportunities, it would seem desirable to minimise human–induced effects as an integral part of planning for the region.

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SESSION TWO

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RESOURCES

MANGROVE PRODUCTIVITY

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ABSTRACT

There is good evidence that mangrove waterways are important nursery areas for juvenile banana prawns. While there is an overall correlation between the estimated maximum sustainable yield of banana prawns and the area of mangrove habitats, there appears to be enormous variability between estuaries that cannot yet be explained. There is also qualitative evidence for a role for mangrove habitats as nursery / feeding grounds for a number of other commercially important fisheries species.

The value of mangrove habitats as a source of food and as nursery areas is partly attributable to their structural diversity and partly to a detritus–based food chain supported mainly by the mangrove trees. Leaf litter and other plant parts are consumed directly by crabs and other organisms. Other soluble and particulate organic detritus processed by bacteria ultimately passes through to higher trophic levels.

Mangrove habitats thus have significant commercial and ecological values. These will be considered in the context of geographic variations in areas extent and environmental factors affecting their overall productivity.

INTRODUCTION

Mangroves occur along coastlines lying roughly between latitudes 35°N and 38°S. Within Australia they grow over a very wide variety of climates ranging from the extremely arid coast of the Pilbara region of Western Australia, the cool temperature coast of New South Wales, Victoria and South Australia, through to the wet equatorial coasts of north–eastern Queensland and parts of the Northern Territory. Mangroves also grow on a wide range of soils types, including heavy consolidated clays, unconsolidated silts, calcareous and mineral sands, coral rubble, and organic peats, with salinities ranging from almost freshwater through to well above seawater. It is therefore not surprising that mangrove systems are extremely diverse and that their productivity is equally variable, depending on the environmental conditions under which they are growing.

MANGROVES AND FISHERIES

It is often stated that mangroves play an important role in sustaining coastal commercial capture fisheries, including shrimp and pelagic fish species. This view is based on the population densities in mangrove estuaries of both commercial species and of the smaller species that make up the diet of larger fish, and on the known trophic relationships/food chains that exist within mangrove lined estuaries. Further evidence comes from the significant correlation between the estimated maximum sustainable yield of penaeid shrimp and the area of mangrove habitats in several parts of the world (Macnee, 1974; Turner, 1977; Martosubroto and Naamin, 1977; Staples et. al., 1985; Pauly and Ingles, 1986). This relationship is shown diagrammatically in Figure 1.

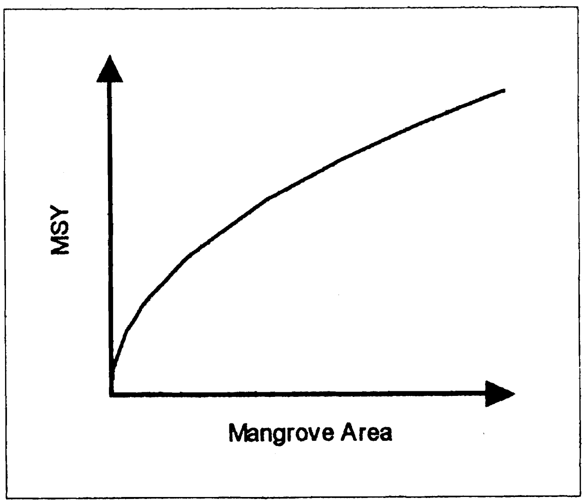

Figure 1: General relationship between the estimated maximum sustainable yield of penaeid shrimp and mangrove area

While this relationship is subject to a large error, and has not been tested experimentally, it does suggest that loss of mangroves may have the greatest negative impact on penaeid fisheries in regions with relatively small areas of mangroves.

It is important to note that there is high variability in population densities of penaeid shrimp and pelagic fish in mangrove estuaries. The reasons for this variability are not know, and in order to assess the impact of removal of mangroves on coastal fisheries it is important that the causes of this variation be investigated in some detail.

The role of mangroves as nursery areas for shrimp and fish is not yet clearly understood. There is good evidence from work in Australia and elsewhere that penaeid shrimp (mainly *Penaeus merguiensis)* use, and probably depend on, mangroves as juveniles. The physical complexity of the stem and root structures in mangrove areas are presumed to provide protection from predators and light, as well as providing a wide range of micro–habitats for feeding.

Mangroves themselves contribute large amounts of organic carbon by way of leaf letter, reproductive parts, root turnover and dissolved organic materials, which provide the initial input into a complex food chain that breaks down this organic detritus. Bacteria play a crucial role in this decomposition, but sesarmid and other crabs also play an important role by consuming some of the litter that falls to the forest floor. Crab zoeae comprise a significant part of the diet of juvenile shrimp and fish at certain times of the year. Other food chains and/or links between mangroves and fish are more difficult to quantify.

It is important to recognise, however, that the value of a particular area of mangrove as fisheries habitat is not always correlated with the size, stature or density of the trees, or with the species composition of the forest.

MANGROVE FORESTRY

Mangroves are used in many parts of South–East Asia, Africa and Central America as a source of timber, fuel and other forest products. In some countries they are cut, replanted and managed as a sustainable timber resource, in much the same way as terrestrial plantation forest. On the whole this has been carried out most successfully along tropical coastlines near the equator, where persistent cloud cover, moderate to high rainfall and high humidity all combine to provide nearly ideal conditions for growth. Under these favourable conditions mangroves can grow at rates approaching those for many terrestrial trees; in Peninsula Malaysia, for example, some species of mangroves grow at the rate of about 1 metre in height annually. Mangroves do not grow so well in arid or seasonally wet/dry monsoonal climates, where high solar radiation and low relative humidity during the dry season leads to temperature and water stress in the mangrove forest canopy, and correspondingly reduced rates of growth.

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CHANGES TO MANGROVE ECOSYSTEM DISTRIBUTION PORT CURTIS 1941 TO 1989

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The comments detailed in this paper are those of the author. They do not necessarily represent the views or opinions of the Department of Environment and Heritage or Queensland Government.

ABSTRACT

The impact of industrial and urban development on mangrove ecosystems in the Gladstone area has been the subject of considerable anecdotal debate. Apart from the Curtis Coast Study which this information is derived from, little quantitative data has been developed to assess the true impacts. Gladstone's development as an industrial city has principally occurred since the 1960's, therefore aerial photography prior to this date would establish a baseline of mangrove ecosystem distribution. Aerial photography from 1941 and 1988/89 was analysed. The data indicated that nearly 650 hectares of mangroves and 950 hectares of coastal salt flat had been lost from the ecosystem. This represented a loss of 17% and 24% respectively. It also indicated that industry and urban development was responsible for greater than 90% of this loss. Catchments with the greatest level of impact were South Trees and Auckland Inlets.

INTRODUCTION

Compared to other Australian ports, Gladstone is a relatively new player in industrial and urban development associated with shipping and process industries. Much of this development has occurred since the 1960's where it has established on sites, in or near the intertidal zone. It is these sites which also provides the primary habitat for mangrove ecosystems.

Prior to the 1960's Gladstone was principally known as a cattle port with relatively small harbour developments located in Auckland Inlet, Auckland Point and Parsons Point. The impact on the intertidal zone and associated mangrove areas at this time was relatively minimal. Any pre–1960's data such as aerial photography, would therefore provide an accurate baseline as to the distribution of mangroves ecosystems and give clues as to their composition.

During the Second World War, Port Curtis was considered an important strategic area on the north Australian coastline. This importance lead to the areas first known aerial photography run in 1941. Interpretation of this photography is used in this paper to establish a baseline of mangrove ecosystem distribution. Subsequent photography taken in the late 1980's is used as a comparison to assess the extent of impact.

BACKGROUND

For the purposes of this paper, Port Curtis includes the inshore marine and coastal areas from Kangaroo Island at the entrance to The Narrows, south to the mouth of the Boyne River. Refer to Diagram 1, which outlines the study area.

Methodology

Three sets of aerial photography were used to establish the extent of mangrove ecosystems. This includes:

- RAAF, Port Curtis 1941 (1:14 550 B&W);
- Sunmap, Gladstone 1989 (1:25 000 colour); and,
- Beach Protection Authority, Urangan–St Lawrence 1988 (1:12 000 colour).

The mangrove ecosystem boundaries interpreted from air photos were transferred directly to existing 1:25,000 orthophoto maps using an 'Aero Sketchmaster'. Locational errors associated with this process are considered to be minimal due to the small height variation within mangrove ecosystems.

The mapped boundaries were limited by the extent of 1941 air photo coverage and base maps comprising:

- Sunmap, 9150–31 Callemondah (Orthophoto 1:25 000)
- Sunmap, 9150–24 Gladstone (Orthophoto 1:25 000)
- Sunmap, 9150–23 Boyne Island (Orthophoto 1:25 000)

From the base maps the data was digitised into an 'ArcInfo' geographical database and analysed on a catchment by catchment basis using 'Arcview'. This analysis involved both a visually and statistically comparison between years. Changes in mangrove ecosystem boundaries were noted. These changes could be attributed to impacts from industrial and urban development and what was assumed to be natural causes.

Mangrove Species

Throughout Australia there has been considerable variation in the interpretation of what is a 'mangrove'. Based on Batianoff (1995), mangrove for the purposes of this paper refers to woody plants which are true obligate and exclusive species of the intertidal area. Although present in the Port Curtis area, this definition therefore excludes mangrove fern *Acrostichum speciosums*. The term 'mangrove ecosystems' is used in a wider context, referring to the tidal wetland comprising; saline herblands, coastal salt flats and mangroves.

Port Curtis supports 13 of the 38 Australian mangrove species. Three of these 13 species are at their southern distribution limit. Table 1 provides a list of species and comments about their distribution.

Table 1: Mangrove species of Port Curtis

Species	Common Name	Comments
Acanthus ilicifolius	holly mangrove	At its southern distribution limit, it has been identified at Gladstone and Boyne Is. on the landward margin of the mangrove community.
Aegialitis annulata	club mangrove	Common on creek banks in sandy or rocky environments it is found in the mid-tidal zone.
Aegiceras corniculatum	river mangrove	A common species along creek banks in the Curtis coast, it is found in the mid to seaward margin of the intertidal zone.
Avicennia marina subsp. *australasica*	Australian grey mangrove	The most widely distributed mangrove in Australia it is found throughout the intertidal zone.
Avicennia marina subsp. *eucalyptifolia*	smooth–bark grey mangrove	At its southern distribution limit this species is similar to Grey Mangrove in appearance. Recorded at Boyne Island and areas north
Bruguiera gymnorhiza	large–leafed orange mangrove	Of limited distribution along the Curtis coast, it prefers well drained soils with some freshwater input. Occurring along most creeks and river systems it is only locally common in Jenny Lind Creek where it is generally found at the most landward fringes of the intertidal zone.
Ceriops tagal	smooth–fruited yellow mangrove	Common throughout the Curtis coast it is found in the very saline upper tidal limits. Originally involving two varieties, this species now include var. *australis* and var. *tagal*..
Excoecaria agallocha	blind–your–eye mangrove	Found throughout the intertidal zone it is most common at the landward margin. In years of severe drought it's leaves will turn red and be discarded.
Lumnitzera racemosa	white–flowered black mangrove	Found on clay soils near the landward fringe generally where there is freshwater seepage. Locally common in Round Hill and Eurimbula Creeks and the northern area of The Narrows.
Osbornia octodonta	myrtle mangrove	Widely distributed along the Curtis coast, it is found on the landward edge of tidal mangrove zone.
Rhizophora stylosa	small–stilted mangrove	Most common species along the Curtis coast where it often forms closed forests in the seaward to mid tidal zone.
Xylocarpus granatum	cannonball mangrove	Some confusion as to the presence of this species in Port Curtis and along the Curtis Coast. Stock *et al.* (1988) suspects the species near Balaclava Is. is a hybrid between *X. granatum* and *X. moluccensis*. Thought to be present along the Calliope River and South Trees Inlet, it is a deciduous species, where annual leaf fall may be a way of removing excess salt.
Xylocarpus moluccensis	cannonball mangrove	Recorded from the Calliope River, The Narrows and Balaclava Is.– Deception Creek area, this species is at its southern distribution limit. Generally found on the landward edge of the mangrove margin. A deciduous species, annual leaf fall may be a way of removing excess salt.

Source: Qld. Herbarium, Olsen et. al. 1980, Hutchings and Saenger 1987, Batianoff and Dillewaard 1988, Stock et al. 1988, Lovelock and Clark 1993, Yezdani 1993, QDEH 1994 and Batianoff 1995.

Mangrove ecosystem classification

The distribution and composition of mangrove ecosystems is determined by a range of factors including; topography and tidal range, temperature, rainfall and evaporation, salinity, substrate type and exposure to wave action (Galloway 1982; Hutchings and Saenger 1987). Mangrove ecosystems can be classified into a range of communities based on their floristic associations and structure. The coastline from Round Hill Head to Tannum Sands was classified by Olsen *et al.* (1980) with six structural formations comprising 29 communities whilst, Stock *et al.* (1988) identified six alliances for the northern Narrows and Balaclava Island area with nine communities.

Classifying mangroves ecosystems according to communities and then mapping those communities can be extremely complex requiring extensive ground truthing. Given the study's primary objective (determining the extent of mangrove change), mangroves ecosystems were broadly classified on the basis of their common patterns of distribution which were relatively easy to distinguish from aerial photographs. These patterns are usually observed as linear bands, or zones that orientate from seaward to land. The species which lend their generic name to these zones occurs either in pure stands or as a generally dominant species.

Avicennia fringe Found on the seaward margin of the more sheltered areas of the Curtis coast. The *Avicennia* fringe comprises *Avicennia* spp. in an open woodland, generally situated directly seaward of the *Rhizophora* zone.

Rhizophora zone The most common zone encountered within the study area. It comprises a closed forest, usually dominated by *Rhizophora stylosa.* It may also contain a range of species including *Avicennia* spp. and *Xylocarpus* spp. as emergents with *Aegialitis annulata* seaward and *Ceriops tagal* appearing towards the landward edge. Although, it is referred to as a Rhizophora zone, any of the above mentioned species with the exception of *Xylocarpus* spp. may appear as the dominant species.

Ceriops zone This zone forms immediately behind the *Rhizophora* zone as a low open shrubland. Generally, it is dominated by *Ceriops tagal* but may have *Aegiceras corniculatum, Osbornia octodonta, Aegialitis annulata* or *Avicennia* spp. present as the dominant species. In some cases a sparse ground cover consists of seedlings of the above species, *Rhizophora stylosa* and a thin cover of salt–tolerant herb and grassland species.

Coastal salt flat A distinctive feature of the Curtis coast, the coastal salt flat is usually devoid of vascular plants and only occasionally inundated by tide. In Port Curtis it is extensive, often equivalent or greater in area than the adjoining mangrove communities. The size and general lack of vascular plants is attributed to limited rainfall causing hypersalinity. Where plants are present it comprises a thin cover of salt–tolerant herb and grassland species or seasonal algal mats.

Ceriops fringe This fringe occupies the high water mark where it may form a narrow margin between the coastal salt flat and terrestrial forests. Varying in structural form it includes *Ceriops tagal, Lumnitzera racemosa* and *Excoecaria agallocha.* Because this fringe may only be one or two plants wide, it can be very difficult to identify and map from aerial photography. For this reason, it is accounted for, and presented within the ceriops zone.

RESULTS

The total area of mangroves in Port Curtis in 1989 was approximately 3 200ha which represents 0.3% of Australia's total mangrove area. Since 1941, the total mangrove ecosystem has been reduced in area by approximately 1 600ha, which equates to a proportional loss of 21% (17% and 24% respectively).

On a regional basis, the Curtis Coast extending from the Fitzroy River mouth to the Town of 1770 supports approximately 24 900ha (QDEH, 1994) which represents about two per cent of Australia's total mangrove area.

Changes to Port Curtis mangrove ecosystems are presented on a zone by zone, and catchment by catchment basis, refer to Table 2.

Table 2: Changes to mangrove ecosystems for catchments of Port Curtis 1941 to 1989

Location / Year	Rhizophora zone (ha)	Avicennia fringe (ha)	Ceriops zone* (ha)	Total mangroves (ha)	Salt flat zone (ha)	Total area (ha)
Boyne River Mouth						
1941	36	0	4	**40**	19	**59**
1989	43	1	0	**44**	12	**56**
Change	+7	+1	–4	**+4**	–7	**–4**
South Trees Inlet and Parsons Point						
1941	1308	13	104	**1425**	1301	**2726**
1989	1068	25	50	**1143**	788	**1931**
Change	–240	+12	–54	**–282**	–513	**–795**
MacFarlane Lagoon						
1941	2		2	**4**	72	**76**
1989			3	**3**		**3**
Change	–2		+1	**–1**	–72	**–73**
Auckland Inlet						
1941	216		49	**265**	248	**513**
1989	42		4	**46**	14	**60**
Change	–174		–45	**–219**	–234	**–453**
Calliope River mouth to south of Boat Creek						
1941	785	6	75	**866**	799	**1665**
1989	717	2	61	**780**	701	**1481**
Change	–68	–4	–14	**–86**	–98	**–184**
Boat Creek north to Kangaroo Is.						
1941	250	21	29	**300**	375	**675**
1989	236	14	7	**257**	402	**659**
Change	–14	–7	–22	**–43**	+27	**–16**
South eastern end of Curtis Island						
1941	676	74	85	**835**	724	**1559**
1989	705	58	61	**824**	711	**1535**
Change	+29	–16	–24	**–11**	–13	**–24**
Facing Island						
1941	87	24	18	**129**	332	**461**
1989	75	26	19	**120**	297	**417**
Change	–12	+2	+1	**–9**	–35	**–44**
Total 1941	**3360**	**138**	**366**	**3864**	**3870**	**7734**
Total 1989	**2886**	**126**	**205**	**3217**	**2925**	**6142**
Total	–474	–12	–161	–647	–945	–1592
% change	–14%	–9%	–44%	–17%	–24%	–21%

***** *Ceriops zone also includes Ceriops fringe, although very little of the fringe was mapped due to its limited size.*

Mangrove Ecosystems

Rhizophora zone

The Rhizophora zone is the largest and most dominant mangrove zone in the Port Curtis area. From 1941 the zone has reduced by approximately 470ha which is 14% of the original 1941 area. All catchments with the exception of the Boyne River and south eastern Curtis Island have suffered a decline.

The decline in the Rhizophora zone is principally due to industrial and urban development which is directly responsible for approximately 90% of the decrease. The decline in the remaining area is unclear, although probably due to natural causes. The narrow linear band running down the west side of Facing Island for example, has reduced by 12ha since 1941. In other locations, such as near Flying Fox Creek, the average 1941 Rhizophora zone width has reduced from 260m, to a width in 1989 of 205m. Interestingly the 1941 photography indicates that a form of dieback was already present at both Flying Fox Creek and Auckland Inlet.

To date, much of the *Avicennia marina* decline has been linked to a form of mangrove dieback caused by a weak fungal pathogen from the *Phytophthora* genus. The fungus is normally a leaf litter decomposer and, as such, it occurs throughout Australian mangrove communities (Hutchings and Saenger 1987). First identified by Pegg and Foresberg (1981) in 1978, it has the capacity to become pathogenic, by attacking the roots of its mangrove host and inducing water stress. The first trees to die are those growing as isolated specimens on the seaward mud flat (Avicennia fringe) followed by the very tall emergents. Approximately 12 months later the *Avicennia marina* within the mangrove canopy begin to showed signs of dieback (Hutchings and Saenger 1987). Whilst Pegg and Foresberg (1981) believed it was not the primary cause of mangrove decline, they speculated that disturbance of mangroves by one or more of the industrial operations in the Gladstone area may provide the stress factor predisposing the plants to fungal invasion.

Wherever outbreaks of *Phytophthora* and high mortalities had been recorded, only one host, *Avicennia marina* had been involved (Hutchings and Saenger 1987). This does not explain the decline observed in *Rhizophora stylosa* and other mangrove species. In fact, there are several example in Port Curtis where the Rhizophora zone (closed forest) has been replaced by an Avicennia fringe (open woodland). In such situations the emergent *Avicennia marina* within the Rhizophora zone has been maintained, whilst the previously dominant *Rhizophora stylosa* has died around it.

Avicennia fringe

In terms of total area, the Avicennia fringe has suffered the least change of any zone within Port Curtis. Since 1941, the zone has reduced by 12ha which represents a nine per cent decline from the 138ha identified. This however, clouds the real picture.

As a species, *Avicennia marina* has suffered a significant decline. Its greater susceptibility to *Phytophthora* (refer to Section 3.1 Rhizophora zone) over other mangrove species has resulted in its rapid demise at selected sites. Following an outbreak near the Calliope River during the late 1970's, the selective mortality of *Avicennia marina* has lead to its replacement by almost pure stands of *Rhizophora stylosa.* However, on the seaward margin where the Avicennia fringe has been lost, it has been left as intertidal mud flats.

Ceriops zone

On a proportional basis, this zone has suffered the greatest change with a 44% loss since 1941. The cause of this loss is linked to at least three activities. In the majority of cases, it is the direct result of disturbance from reclamation associated with industrial and urban development. In a few situations the zone as mapped from the 1941 photography has evolved from a low open shrubland to a closed forest where *Ceriops tagal* has occasionally remained the dominant species. In other situations the zone has declined due to less obvious reasons, possibly natural causes.

The Ceriops zone is particularly susceptible to change because of its location on the inland margin of mangroves. In this location it is prone to high evaporative losses and drying out of the substrate. Often an edge effect is noticeable where mangroves abut salt flats. The evaporative build up of soil salinity results in mangrove dieback and gradual expansion of the salt flat (Hutchings and Saenger 1987).

More recently the mangroves to the north of the Calliope River suffered an intense hail storm during late 1994. This had a particularly devastating affect on all mangrove zones. All mangroves sustained crown damage (defoliation of leaves and twigs) and bole damage (debarking of trunks and branches). Most effected was the Ceriops zone because of its low open structure making each plant very susceptible to the effects of hail stones. Whilst all plants within the path of the hail storm sustained damage, species such as *Avicennia* recovered relatively quickly through epicormic shoots. Other species, such as *Ceriops* and *Rhizophora* sustained losses, because their buds are restricted to the thin terminal branches in mature trees. Several hectares of the mature trees were killed because the terminal branches were removed or damaged. This phenomenon may help explain some of the seemingly natural decline of Rhizophora stylosa and its replacement with an Avicennia fringe within Port Curtis (refer to Section 3.1 Rhizophora zone).

Coastal salt flat zone

In the Gladstone area, coastal salt flats have commonly been regarded as wastelands, and this is reflected in the level of disturbance. Approximately 950ha (24%) of this zone has been lost. Over 90% of this loss can be attributed to reclamation activities associated with industrial and urban development.

The value of coastal salt flats to the mangrove ecosystems is unclear. Usually devoid of vascular plants, it may contain an occasional thin cover of salt tolerant herb and grassland species (QDEH 1994). Occasional wetting of the salt flats during the dry autumn months allows temporary development of filamentous algal mats which contribute to overall productivity (Hutchings and Saenger 1987). Some areas also provide important roosting sites for migratory shorebirds. However, to date little more than anecdotal information is available on the importance and productivity of these areas.

Occasional wetting of the salt flats during the dry autumn months allows temporary development of filamentous algal mats which contribute to overall productivity (Hutchings and Saenger 1987). Some areas also provide important roosting sites for migratory shorebirds. However, to date little more than anecdotal information is available on the importance and productivity of these areas.

CATCHMENTS

Boyne River Mouth

The Boyne River is one of the few areas to show an increase in the Rhizophora zones and Avicennia fringe. This increase is predominantly due to two factors.

The construction of Awoonga Dam has improved mangrove establishment and maintenance by reducing downstream flows and scouring activity. Secondly, the Ceriops zone adjacent to the Tannum Sands sewerage treatment plant has developed as a taller closed community (Rhizophora zone), probably due to the leaching of nutrients and fresh water from the plant.

Overall reduction in the Ceriops and Salt flat zones can be attributed to residential development at Boyne Island and Tannum Sands.

South Trees Inlet and Parsons Point

This catchment supports the largest mangrove ecosystem in Port Curtis. However, together with Auckland Inlet it has sustained the greatest level of mangrove loss.

Approximately 260ha of mangroves and 510ha of salt flat have been lost. This represents 18% and 39% respectively of the 1941 baseline. The principal source of this loss is industrial development associated with the Queensland alumina refinery. This includes the two red mud dams on Boyne Island, the settling ponds at Parsons Point and the diversion of South Trees Inlet and Wappentake Creek.

Interestingly the Avicennia fringe has increased in area from approximately 13ha to 25ha. This has occurred primarily to the east of South Trees Island where the Rhizophora zone has been replaced with an Avicennia fringe. This could be due to the South Tree and Boyne Wharf developments which may have changed the refraction of tidal movements and wave action in the area, placing additional stress on *Rhizophora stylosa* leading to its decline.

MacFarlane Lagoon

MacFarlane Lagoon forms the reclamation between Auckland Point and Barney Point. The area has been extensively modified by the Gladstone Port Authority to allow for the development of a container terminal. A small increase in the Ceriops zone can be attributed to the establishment of mangroves on drainage systems throughout the industrial site.

Auckland Inlet

Of all the major catchments in Port Curtis, Auckland Inlet has sustained the greatest disturbance. Nearly 90% of the intertidal wetlands have been lost. Less than 50ha of mangrove forest remain, whilst virtually all the coastal salt flat has been lost. The cause of this loss can be attributed to urban and industrial development associated with the Gladstone city tip and sporting fields (Gladstone City Council); RG Tanna Coal Terminal and Gladstone Marina (Gladstone Port Authority), and Clinton Ash Pond reclamation (Department of Business Industry and Regional Development, Gladstone Power Station).

The inlet has degraded to the extent that it can be regarded as little more than an open drain for delivering cooling water to the power station or directing stormwater from Gladstone's urban and commercial areas to Port Curtis.

Calliope River mouth to south of Boat Creek

The Calliope River and northern wetlands support the second largest area of mangrove ecosystems in Port Curtis. Although there has been significant impact, in relative terms this impact has been modest given its proximity to Gladstone. Ten per cent of the mangroves and 12% of the coastal salt flats have been lost since 1941. Whilst some of this impact can be attributed to industrial development associated with the Gladstone Power Station, roading and the RG Tanna Coal terminal, much of the decline has been due to a form of dieback possibly caused by a weak fungal pathogen from the *Phytophthora* genus, referred to in Section 4.1 Rhizophora zone.

Indications from the aerial photography are that a form of dieback was already occurring as far back as 1941. The areas between Flying Fox Creek and Calliope River demonstrated a significant loss of mangroves on the seaward margin most of which was *Rhizophora stylosa*. It is suspected that this loss is related to impacts associated with changes in wave and current movements caused by the Clinton Wharf development at the Calliope River mouth.

Proposed reclamation activities by the Gladstone Port Authority will see further loss of mangroves and coastal salt flat in this area.

Boat Creek north to Kangaroo Island

This section of Port Curtis has undergone some interesting changes during the past 50 years. Mangrove communities have decreased by approximately 43ha (14%) whilst the coastal salt flat has increased by approximately 27ha (seven per cent).

The decline in mangrove is partially linked to industrial development associated with the Fisherman Wharf facilities. This lead to the direct loss of approximately seven hectares of Rhizophora zone (2ha), Avicennia fringe (2ha) and Ceriops zone (3ha).

The decline of the remaining 36ha of mangroves is thought to be a combination of natural and introduced causes.

The major decline in the Ceriops zone is assumed to be due to an evaporative build up of soil salinity resulting in mangrove dieback and gradual expansion of the salt flat as described in Section 4.1 Ceriops zone. The decline in the Avicennia fringe is possibly linked to dieback caused by a weak fungal pathogen from the *Phytophthora* genus, (refer to Section 4.1 Rhizophora zone).

The decline of the remaining Rhizophora zone is unclear. Confined to a discrete area on the end of Kangaroo Island, it suggests an individual event has contributed to its demise. In this location part of the Rhizophora zone has been replaced by salt flat, whilst the remaining area has changed to tidal mud flats.

South eastern end of Curtis Island

Of the eight catchments considered in Port Curtis this is the only relatively large catchment which has shown minimal changes overall. Since 1941 the mangrove and salt flat areas have decreased by one and two per cent respectively. Much of the reduction in the Ceriops zone can be attributed to a corresponding increase in the Rhizophora zone. Whilst a reduction in the Avicennia fringe appears to be consistent with the rest of Port Curtis.

Part of the decline in the coastal salt flat can be attributed to a corresponding increase in the Rhizophora zone, however, this does not account for total reduction. It is possible that it forms part of an error that is introduced through interpretation, mapping and digitising the data.

Facing Island

The major changes to mangrove ecosystems around Facing Island relate to reductions in the Rhizophora and Salt flat zone.

The Rhizophora zone has reduced in a narrow linear band running down the west side of Facing Island. Approximately 12ha or 14% has been lost. There appears to be no obvious cause for this loss. The reduction in salt flat is however a much clearer picture. The loss can be attributed to earthworks on the island possibly during the second world war when an aircraft landing strip was established.

DISCUSSION

Mangrove ecosystems in Port Curtis over the past 50 years have suffered. Since 1941 approximately 1600ha have been lost, representing a 21% reduction. Much of this occurred as a result of industrial and urban development prior to an appreciation of the systems biological value. Organisations such as Queensland Alumina Ltd have played a major role in this decline, whilst the Gladstone City Council, Gladstone Port Authority and State Government through interests in the Gladstone Power Station and Department of Business, Industry and Regional Development have also made significant contributions.

Although there is now an appreciation of mangrove values, removal of mangroves and reclamation of salt flats is still happening in the Gladstone area and is proposed to continue. Such continued action presents a number of questions.

1. How much of the of the mangrove ecosystem are managers and the community prepared to lose in the pursuit of economic development? Should a minimum figure be set, and will this then be sufficient to maintain a viable productive mangrove ecosystem?

2. What is the ecological value of a coastal salt flat?

3. Are mangrove ecosystems under valued?

To some extent the first of the above questions has been answered. The Gladstone Port Authority through its current and proposed reclamation program has indicated that it is proposing to adopt a no–net–loss mangrove principle ie. re–establish an equivalent area of mangrove to that which will be lost. Whilst this is commendable, it does not account for the loss of salt flats, nor does it account for the short coming in the no–net–loss principle eg. habitat trading and productivity compensation.

The no–nett–loss principle was suggested by the Queensland Government in the early 1990's, although never adopted. The principle has been applied in overseas countries and other states of Australia. Whilst it may have merit in theory, its specific application can have problems. The principle works best where there are degraded sites suitable for rehabilitation. In locations like Gladstone with few degraded sites available, then the dilemma is where to establish mangroves. The solution to date has involved habitat trading such as exchanging salt flat through re–profiling to accommodate the establishment of mangroves. This could be inappropriate, given that salt flats or other habitats may have important values, critical to the overall ecosystem. In addition the no–net–loss principle does not compensate for the productivity losses of a site.

One of the zones which has suffered significant impacts in the Port Curtis area are coastal salt flats. Widely regarded as wastelands, they have been readily reclaimed for urban and industrial development even though the value of the system is poorly understood. Such actions is in conflict with the 'Precautionary Principle' which is one of the guiding principles of the National Strategy for Ecologically Sustainable Development.

This principle requires that, unless impacts associated with a proposed activity or use are known with reasonable assurance, governments should proceed cautiously while ensuring that substantial and irreversible impacts are not imposed. There is an urgent need for research in this area.

Recognition of the importance of mangroves and their partial protection under legislation appear insufficient to maintain mangrove communities in areas of major urban and industrial development. Is it time to put a monetary value on mangrove ecosystems, where the direct beneficiaries from mangrove removal pay an environmental levy. This levy could then be used to fund mangroves research,. re–establishment, re–habilitation, protection of other mangrove ecosystems or compensation.

Acknowledgements

Several people have contributed to the preparation of this paper. Ian Bell, Rebecca Hendry, Owen Betts and Les Hawkes (Consultancy Bureau), assisted with air photo interpretation, ground truthing, mapping and digitising. Grahame Byron and George Batianoff reviewed the paper and made useful suggestions on how it may be improved. Thank you all.

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Diagram 1

Port Curtis Catchments

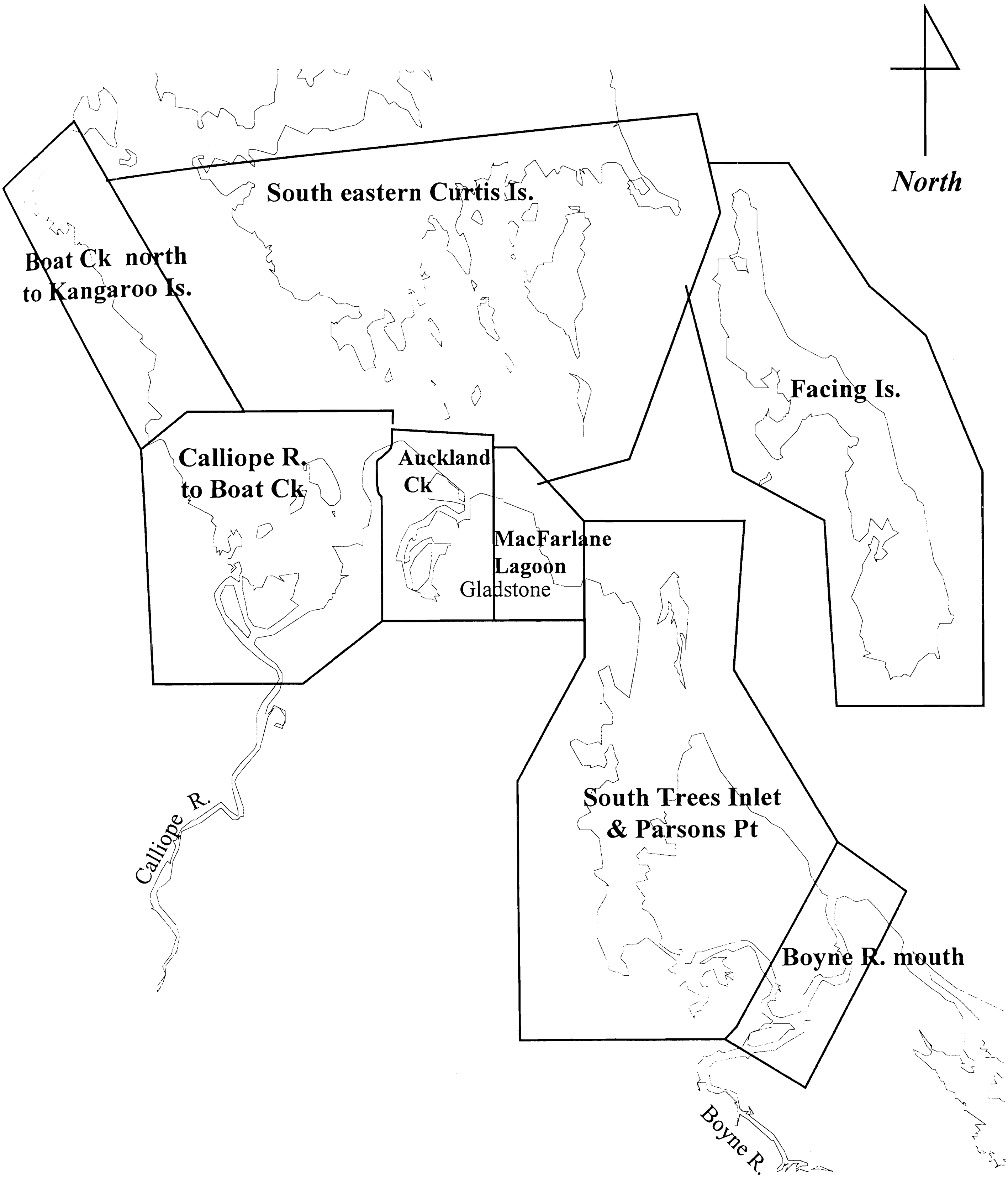
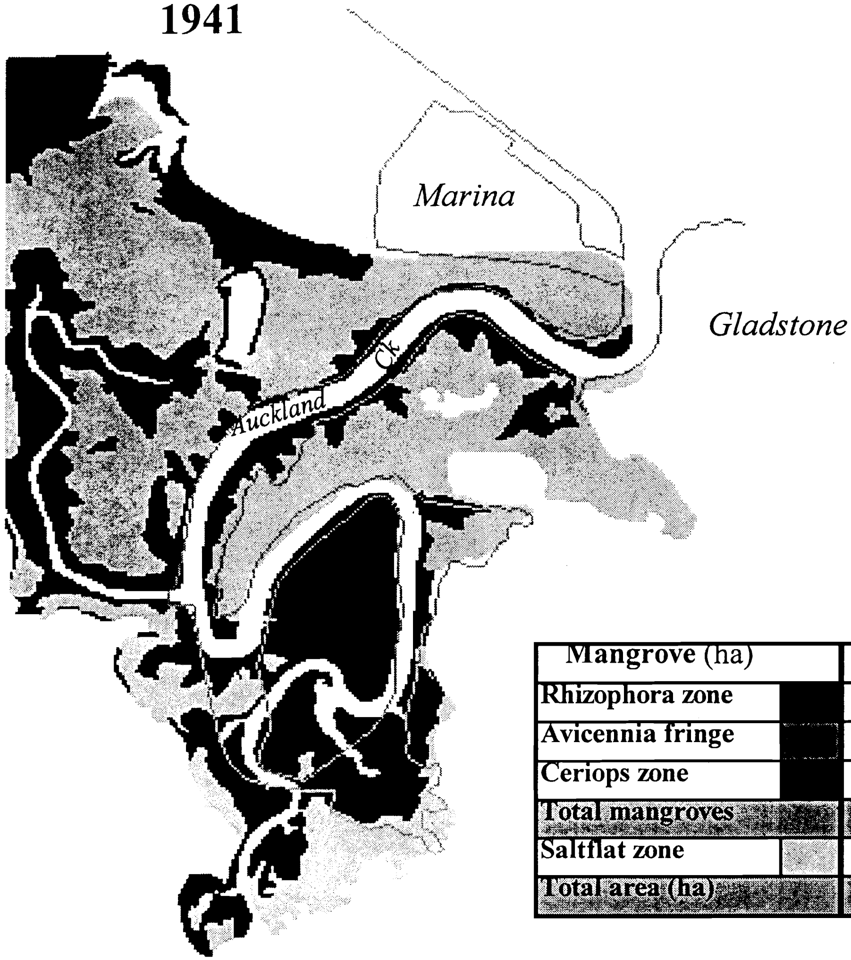


Diagram 2

Mangrove Ecosystems Auckland Inlet

1941



Mangrove (ha)		1941	1989	Change
Rhizophora zone		216	42	-174
Avicennia fringe		0	0	0
Ceriops zone		49	4	-45
Total mangroves		265	46	-219
Saltflat zone		248	14	-234
Total area (ha)		513	60	-453

1989

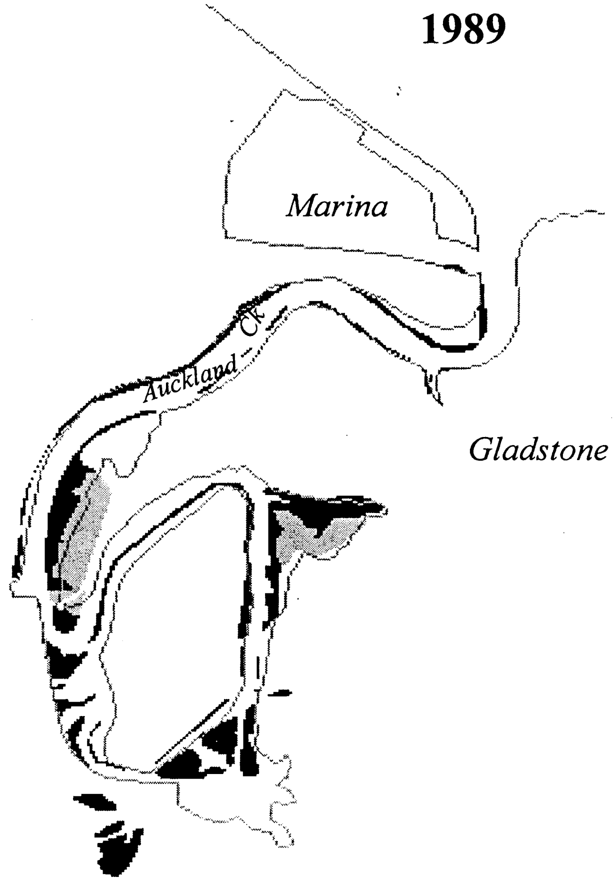
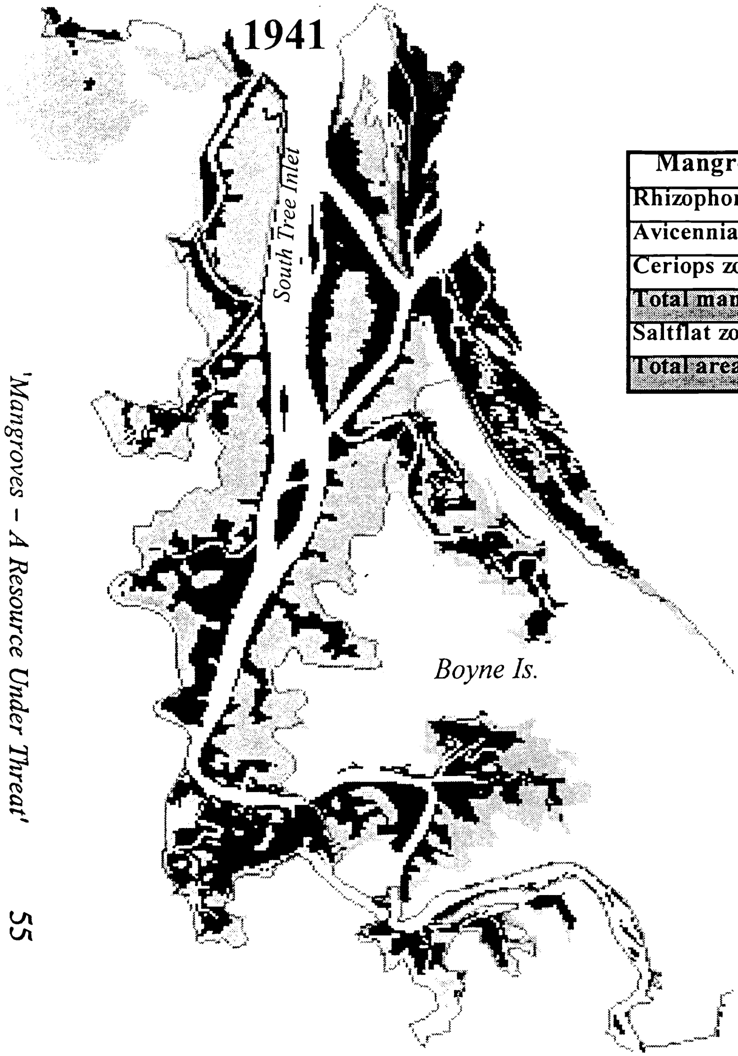


Diagram 3

Mangrove Ecosystems
South Trees Inlet & Parsons Point



Mangrove (ha)	1941	1989	Change
Rhizophora zone	1308	1068	-240
Avicennia fringe	13	25	12
Ceriops zone	104	50	-54
Total mangroves	**1425**	**1143**	**-282**
Saltflat zone	1301	788	-513
Total area (ha)	**2726**	**1931**	**-795**

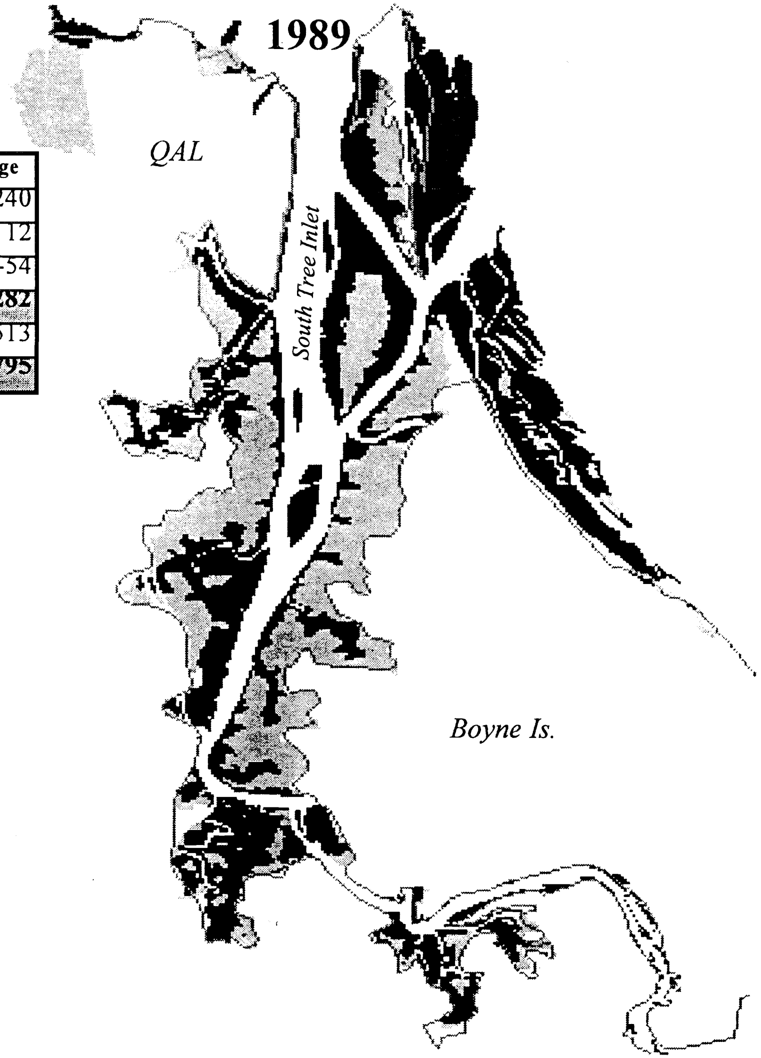
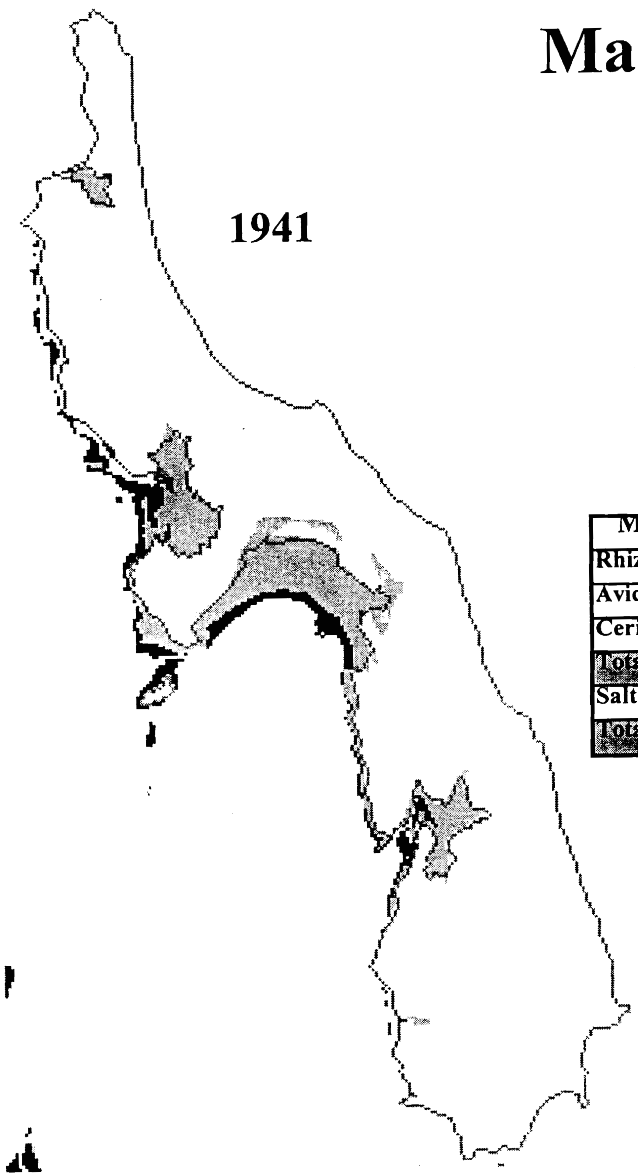


Diagram 4

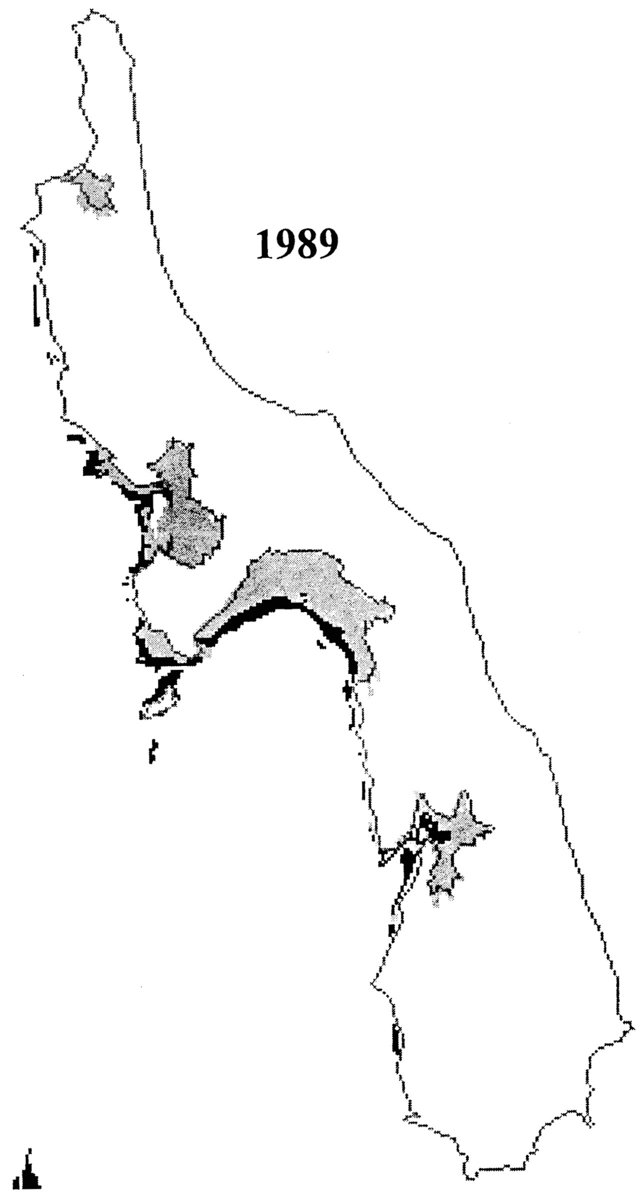
Mangrove Ecosystems Facing Island

1941



Mangrove (ha)		1941	1989	Change
Rhizophora zone		87	75	-12
Avicennia fringe		24	26	2
Ceriops zone		18	19	1
Total mangroves		129	120	-9
Saltflat zone		332	297	-35
Total area (ha)		461	417	-44

1989



SESSION THREE

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PRESSURES

PRESSURES - INDUSTRY DEVELOPMENT

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ABSTRACT

The paper initially looks at pressures on the mangrove resources from industry. A range of industries are considered, starting with minimal impact industries such as eco–tourism, through garbage disposal and development of Canal Estates, and finishing with Port and Industry Development.

The second part of the Paper looks at Gladstone as a case study. The case study documents the changes in mangrove areas and looks at community losses and benefits resulting.

BACKGROUND

The community only becomes concerned about conservation of an asset when there has been sufficient loss of that asset to cause concern. Thus, loss of mangroves became a concern mainly following large scale Canal Estate and other waterfront development in the Gold Coast area.

Meanwhile, back in Gladstone in the early 1960's, a town of 6,000–7,000 people surrounded by mangroves, residents were able to catch all the fish and crabs they wanted (at least when considered in hindsight) and even the use of crab hooks was not frowned upon. A greater problem to the community was sandflies (biting midges). This problem was reduced by chopping down the mangroves along Auckland Inlet upstream of Welby Creek. Using an area in the upstream section of Welby Creek for a rubbish tip (Memorial Park) served two purposes, garbage disposal and midge control. With this community attitude to mangroves in those days, it was logical to alienate some mudflat/mangrove areas for waste disposal (red mud and boiler station ash) when the new wave of industry started to come to Gladstone. It would be interesting to see what would be done today to provide a waste storage area for such a plant. Would it be on some grazing land and involve a lot of energy (a greenhouse no–no) to provide containment walls?

Later that same decade, when the Powerstation was planned, the adjacent claypan area with mangroves on the fringes and in an internal creek draining the area, was allocated to ash disposal as a means of minimising electricity costs to consumers. However, this planning also provided for future industrial land and Port industry land adjacent to deep water. While the area is still being used for ash disposal, some areas have already been used for a Coal Terminal and Marina.

PRESSURES - INDUSTRY DEVELOPMENT

To get to the purpose of this paper – pressure on the mangroves resources from industry, we will look at the types of industries thus:

1. Eco–tourism
2. Fishing
3. Aquaculture/mariculture
4. Marine and smallcraft development
5. Garbage and other waste disposal
6. Development of canal estates
7. Industry development
8. Port development

These have been ranked in order of what I perceive as public concern, starting with the most benign:

1. Eco–Tourism

Eco–tourism is promoted as a 'good' ie. sustainable use for our natural areas. Generally, this is the case. However, even this can lead to people pressure and need for facilities. Risk to mangroves can occur from the need to clear mangroves to provide access facilities eg. jetties, boat ramps, etc. However, it is unlikely that such a facility would be located where it destroyed part of a small stand of mangroves, ie. an access requiring destruction of mangroves is only likely to be built if the target waterway was completely surrounded by mangroves. Hence, the percentage loss would be small.

Other 'people pressure' could have a minor effect, eg. tramping around roots, wash and oily exhaust emissions from vessels, etc. However, the benefits of awareness of the mangrove area would more than compensate for any losses from this cause.

2. Fishing

Generally, people fishing have an awareness of the role that mangroves play in the fish breeding cycle. Hence, the only losses of mangroves likely are similar to those listed above in eco–tourism, eg. for access facilities.

3. Aquaculture/Mariculture

Aquaculture/Mariculture has been responsible for the loss of significant amounts of mangrove terrain in countries to our north. Our local experience is that the ponds are located back from the mangroves either on the claypan or on natural terrain behind. Ease of excavation and understanding of the acid sulfate soil situation are factors in this. However, small losses of mangroves may occur in obtaining access to waterways for water supply etc.

Generally, the concern with aquaculture is the discharge of excessive amounts of nutrients when the ponds are drained. While these nutrients may not significantly affect the mangroves, they can affect the marine ecosystem. It is expected that 'farming' of the products of the sea will continue t grow. Most section of wild stocks are close to the limit of exploitation, hence aquaculture/mariculture will be the only way to meet significant growth in demand for the product.

4. Marina and Smallcraft Facility Development

These facilities must be located on the land/water interface. Scale can be from small to significant.

Again, with increasing awareness and DPI scrutiny, proponents are looking to minimise losses of mangroves and/or provide compensation planting.

This type of development was highlighted in the RAC Coastal Zone enquiry where a combination of population growth, desire of Australians to live by the sea and increasing affluence lead to a demand for such facilities.

These factors lead to a demand for boating facilities, ranging from a boat ramp and parking area for launching the proverbial 'tinny' up to a marina for large yachts and powerboats.

The 'open slather' approach of the past to destruction of mangroves for these facilities is no longer accepted by the community. Hence, proponents must prepare a proposal which minimises destruction of mangroves and considers compensation actions. This usually involves extra financial cost compared to the previous approach.

The community would be expected to have input to any significant proposal through an IAS proposal under Commonwealth, State or Local Government legislation. Council planning processes would also be involved. I cannot conceive of a marina style development with any significant loss of mangroves without a requirement for an IAS under DHLG legislation.

Additionally, there is the requirement to obtain a permit from the DPI for destruction of mangroves and this is not given lightly.

5. Garbage And Other Waste Disposal

Wetland areas have been a favourite location for refuse tips and other waste disposal. Probably every coastal council in Queensland has or had a tip in a mangroves or wetland area.

There are a number of reasons for this including:

- the land was free (vacant crown land)
- enclosure costs were minimised (provision of bund walls)
- land was often perceived as unsightly, mosquito and midge breeding area
- did not involve alienating productive land eg. used for farming and grazing
- usually provided the community with a park on completion

Generally, this was regarded as being in the interest of the community eg. keeping rates down. While it is regarded as fair to make industry pay for doing things properly on the basis of 'they' can afford to, there is a different attitude to putting up the rates of 'ordinary people'.

There may be legitimacy in some of these projects. I can see why a Council would want to reclaim a creek in a developed urban area which was causing visual, mosquito and midge problems.

There is also the health and amenity aspects. 30 years ago, the 'Hospital Hill' area was a sandfly problem area. Many residents of the area suffered from infected sandfly bites. They were also virtually held prisoner in their houses morning and evening by sandflies outside. What is the trade–off between maintaining fisheries' productivity and residents suffering from sandfly attacks?

Industry has also used wetland areas for waste disposal, mainly on the basis of availability of site and least cost to provide enclosure.

Both of these uses are given greater scrutiny these days. The scrutiny may be from Council's planning process or an IAS process. With greater tendency for private enterprise to carry out garbage collection and refuse tip operation, the selection of a tip site is becoming more remote from the decision of Councillors, hence giving more chance of it being decided on factors other than just what Councillors thought the ratepayers could pay.

6. *Development of Canal Estates or Waterfront Land*

Development of canal estates caused the loss of many mangroves areas, particularly at the southern end of Moreton Bay and on the Gold Coast Strip[1]. Mangroves inlets provided the opportunity for a cut and fill operation which provided premium priced water frontage house sites. These sites were in demand for the reasons listed previously in 3.4, ie. desire to live near the water and increasing affluence to pay the premium to do so.

Community concern manifested itself as the realisation dawned that the fish breeding habitat was being depleted by such development. A moratorium on new canal estate development was called until problems were sorted out. Not only loss of mangroves but other factors such as greatly increased tidal prism were concerns.

Today, development of canal estates, or waterfront land involving destruction of wetlands is virtually a 'no–no'.

7. *Industry Development*

Industry would not be expected to select a mangroves/wetland area as a site for its main plant because of difficult foundation conditions, etc. However, in some situation, it may be necessary to provide access through mangroves for services, such as pipelines or drains.

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[1]Calculated as 3% for the period 1974–88 from tables in 'The distribution and modification of mangroves and saltmarsh–claypans in Southern Queensland. Hyland, S.J. and Butler, C.T. (1988) DPI Fisheries Research Branch Information Series'

In a situation such as this, it is assumed that the industry is of benefit to the community. Hence, action that can be taken in respect of affected mangrove areas is minimisation and restoration.

8. Port Development

This is at the end of the list because Port Development is perceived by many as the greatest threat to mangroves. This perception is not correct for Gladstone, as greater losses have occurred as a result of Local Government and industry activities[2].

I think the vast majority of people agree on the need for overseas trade to maintain and enhance our standard of living. If we look at examples of sea trade blockades, eg. South Africa during the apartheid years, there is always a demand to end the blockade. Hence, we can take it as read that the community wants Ports.

Just as mineral have to be mined where they are located, Ports are located at a site which offers a combination of need for the facility, sheltered deep water and landside space.

Given the need to provide a facility which provided for the effective and economic transfer of cargo across the land/sea interface, if nature has grown mangroves at the site which meets the conditions listed in the previous paragraph, then loss of some mangroves is nearly inevitable as the Port develops.

In view of the geographic constraints on the location of Port sites, can constructing a Port in a location which results in the loss of mangroves be justified?

There is scope for land transport to be used to transfer Port operations to a less sensitive area. This approach was explored in the Torres Strait and Barrier Reef Shipping Study (for oil spill reasons). The study showed that the financial cost of the land transfer options was not acceptable to the community. The Study did not cover other costs such as greenhouse effect from additional energy use by land transport compared to sea transport.

Hence, it can be seen that the community needs Ports and with growing population and standards of living, needs those Ports to develop.

We will, therefore, have to accept that there may be some losses of mangroves to Port development, with minimisation and perhaps compensation for the losses as the only remedy.

LEGISLATIVE ASPECTS

The legislation protecting mangroves is the *'Fisheries Act 1994'*. Under the provision of this Act, it is necessary to obtain a permit from DPI fro the removal or destruction of mangroves.

[2]Changes to mangroves ecosystem distribution Port Curtis 1941–1989. Donald B Arnold (This conference).

As destruction of mangroves is usually a component of a project rather than an end in itself, approval processes are usually triggered for the project at Commonwealth, State or Local Government level.

This may required an IAS under the following Acts:-

- Commonwealth - *'Environment Protection (Impact of Proposals) Act'*
- State - *'State Development and Public Works Organisation Act'*
- Local Government - *'Local Government (Planning and Environment) Act'*

Community input to these IAS's is normal.

There is major updating of legislation underway, particularly in Queensland, hence it will be necessary to check the current legislation applicable at the time of application.

Appendix 1 of the Curtis Coast Study Resource Report summarises 'Main Government Agencies and Area of Responsibility' and 'Government Initiatives' current to 1994.

New Queensland Legislation such as the Planning Environment and Development Assessment Bill, with its 'Integrated Development Assessment System' and the *'Coastal Protection Act'* have a planning and 'whole of Government' approach, which should give better outcomes than the 'piecemeal' approach used in many instances previously.

As noted previously (page 60, item 4), approvals for destruction of mangroves are not given lightly by DPI. However, officers assessing the permit applications do give consideration to the overall project, including interests of other Government Departments and the community.

GLADSTONE - A CASE STUDY

Gladstone is an example where reclamation of land for Port Development, Industry and Waste Disposal has caused some loss of mangroves.

Gladstone (or Port Curtis) has been gifted by nature with relatively deep sheltered water, suitable land for Port and Industry Development and a Hinterland rich in minerals and to a lesser extent, agricultural land.

From a town of 6,000–7,000 people in the early 1960's with a meatworks operating 5 months a year, a butter factory and a small coal exporting facility, it has grown to a city of 25,000 people with an alumina plant, smelter, major power station, cement plant and two chemical plants. Trade through the Port is now 36.8 million tonnes a year. Exports are valued at more than 2.2 billion dollars. This is about equal to Australia's balance of trade deficit, ie. we need another Gladstone and Hinterland to balance to balance Australia's books!

Pressures - Industry Development

The Curtis Coast Study Resource Report[3] provides documentation on loss of mangroves. The Study covers an area from Round Hill to the mouth of Raglan Creek. Generally, this section of coastline is fringed with mangroves.

The Study (p.55) showed that te loss of mangroves over the study area for the period 1941–1992 was 2.5%. Even looking a the smaller area of the active Port area, the loss was 16%. The loss of mangroves given was for all reasons, including some due to natural causes near Friend Point and at Facing Island, not just Port and Industrial Development.

If fishing productivity was related to the area of mangroves, the above figures indicate that for a catch of 40 fish in the meatworks' days, you would catch 39 now. Even looking at the inner Harbour, the catch would drop from 7 to 6 fish. However, documentation also shows that while variations occurred in product and year, the commercial catch increased over 100% over a 4 year period.[4] (Note: in 3–4 years time fisherman can catch the missing fish at Awoonga Dam, following the GPA/GAWB Fish Stocking Program being implemented for that waterway.)

What do we get in exchange for the loss of this percentage of mangroves to Port and Industry Development?

- Jobs in Gladstone, Weipa, Hinterland resulting from $3.0 billion in trade. Probably 80,000 direct jobs[5]. The multiplier effect would increase this by a factor of 4 to give flow on jobs. There could be a discount on these on the basis that a higher cost Port could be constructed elsewhere.

- The Government revenue from taxes would be at least one third of the $3.0 billion plus that from indirect jobs. (Based on income tax, excise, sales and other taxes coming out of spending of one week's pay.)

- For people living in Gladstone there is a good lifestyle on the coast with a pleasant climate (compared with capital city, inland or tropical locations) and all amenities.

- Facilities funded by GPA and Industry - Parks, Greenbelt, Marina, Lake Callemondah, Turtle Way etc.

- Fishing facilities, ie. commercial fishing facilities in Auckland Inlet and Marina. Recreational boating facilities which benefit fishermen.

- 10 major artificial reefs in the Harbour (otherwise known as Wharves and Bridges).

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[3] Curtis Coast Study Resource Report
Gladstone Port Authority & Q'ld Dept of Environment & Heritage 1994.

[4] Appendix XXI Curtis Coast Study Resource Report

[5] Calculated on $30,000 p.a. average wages.

Pressures - Industry Development

Given the above, should the Government and community have decided to preserve the mangroves at all cost and let Gladstone develop into a fishing recreational area similar to places like Keppel Sands or Turkey Beach?

With the increased awareness of the need to maintain our present mangrove stocks, the loss of mangroves in future is expected to be minimal. The Gladstone Port Authority's planning for future wharves in the next 30-50 years will result in the loss of 40 ha of mangroves and the Port Authority has committed itself to compensation for this loss. In addition to the compensation, the Authority is embarking on a barramundi restocking program of the local waterways especially Awoonga Dam, as a joint project with the Gladstone Area Water Board.

SUMMARY

One thing I remember from my primary schooling was being taught that Australia had a population of 7 million people. Now 40-45 years on, I understand it has now reached 18 million ie. an increase of over 150% in that time.

Does this mean that in 40 years' time, Australia will have a population of over 40 million people, all having a high standard of living and most wanting to live and have their recreation (including fishing) on or near the coast?

If this is the case, there will be increased pressure on the mangroves resources, despite greater community awareness of the value of mangroves and the greater responsibility by Industry and Government.

I see compensatory measures such as greater use of mariculture/aquaculture, and restocking of both saltwater and freshwater habitats being carried out to balance the increased population pressures.

While this symposium is on mangroves, it is obvious to me that they are but one component in the broader commercial/recreational fishing scene. There is scope for the community to look at how to handle both commercial and recreational fishing needs and desires when these are stressed by increasing population in the future.

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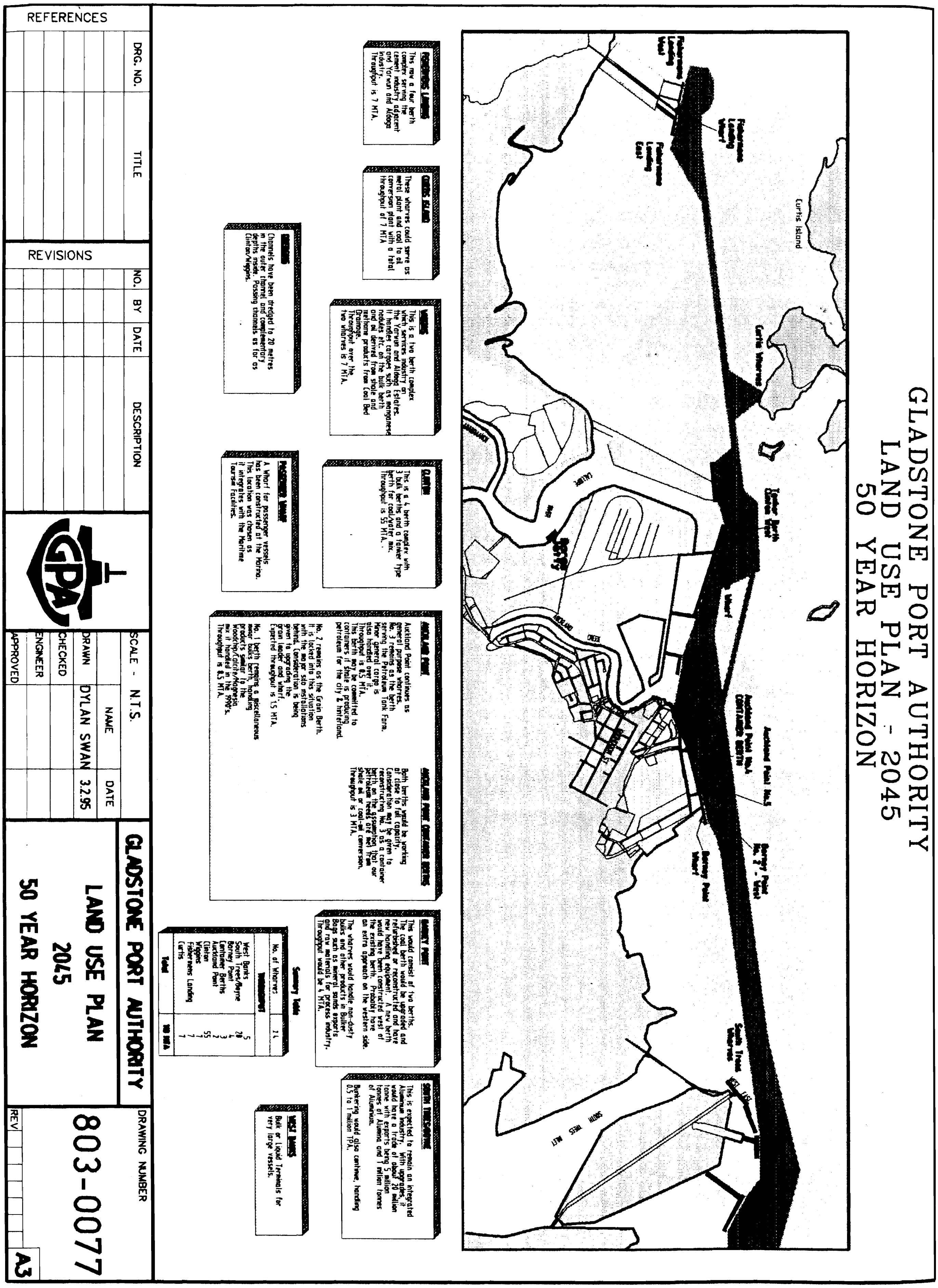
GLADSTONE PORT AUTHORITY
LAND USE PLAN - 2045
50 YEAR HORIZON
Curtis Island
Curtis Wharves
South Trees Wharves
REFERENCES
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TITLE
REVISIONS
NO.
BY
DATE
DESCRIPTION
SCALE - N.T.S.
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APPROVED
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LAND USE PLAN
2045
50 YEAR HORIZON
DRAWING NUMBER
803-0077
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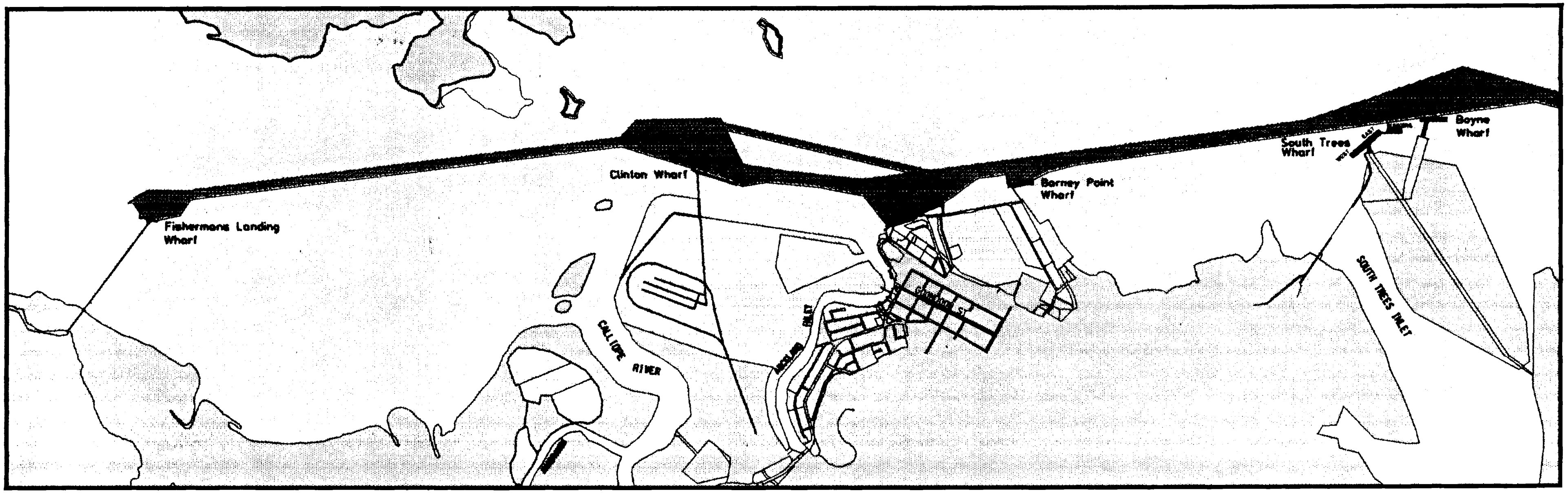
GLADSTONE PORT AUTHORITY
LAND USE PLAN - 1995



GPA

CARGO DATA

Wharf	Cargo	Total 1993/94	Utilisation	Comment
Fishermans Landing	Cement clinker, Fly ash, Caustic soda, Ammonia, Cement	556.205 T	16.7%	
Clinton 1 & 2	Coal	17.879.050 T	63.11%	
Auckland Point No. 1	Magnesia, Calcite, Woodchip	180.180 T	16.30%	
Auckland Point No. 2	Grains	142.184 T	18.30%	Unlikely to handle other cargoes not requiring grain loader.
Auckland Point No. 3	Petroleum, L.P.G., Sulphuric acid, Caustic soda, General cargo, Passenger vessels, Containerised cargo	397.870 T	20.56%	
Barney Point	Coal	2.087.385 T	19.10%	
South Trees West	Bauxite, Caustic soda, Fuel oil, Coal bunkers	7.725.917 T	62.91%	Caustic & fuel oil can go through either berth.
South Trees East	Alumina, Caustic soda, Fuel oil, Fuel bunkers	3.314.340 T	46.58%	
South Trees Bunkers	Bunker fuel	TOTAL 1993/43 (not recorded)	Not applicable [illegible]	
Boyne Wharf	Aluminium, Petroleum coke, General cargo	272.358 T	18.85%	Wharf can accommodate plant extension.

Summary Table

No. of Wharves	11
COAL	19.964.040 T
ALUM IND.	11.312.623 T
OTHER	1.278.784 T
TOTAL THROUGHPUT	32.555.447 T

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WATER QUALITY: IS THE EFFLUENT FROM AUSTRALIAN MARICULTURE OPERATIONS A PROBLEM IN MANGROVE COMMUNITIES?

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ABSTRACT

Mangroves are a community under pressure from many sources. Most pressure comes from clearing, in–filling and erosive events. Increasingly there are questions about the effects of long term changes in the quality of the tidal waters that flow through the communities. Estuarine and coastal waters that flow through mangrove communities receive run–off from industrial, domestic and agricultural processes. As well the waters may receive high volumes of pollutants from short term accidental discharges.

In considering the effects of water quality on the mangrove communities we are looking at either short term polluting events or long term alterations in the chemical constituents and contaminants that are found in the water that moves through the communities. These components may be taken up and stored in the sediment or the biomass in the communities or remain in the water column. The fates of these extra inputs are not clearly understood.

Clearly defining what is meant by the term water quality as it applies to these concerns about mangrove communities is a difficult process. While studies on the effects of pollution events eg. oil spills are found in the literature, there has been little published research on the long term effects of changes in water quality on mangrove communities. There are particular examples where research is required.

The difficulties are that the base–line studies to define the chemical and biological constituents of the water have not been carried out. Instantaneous measurements of water, biomass or sediment composition are not enough. What is needed are long term surveys covering as wide a range of chemical and biological parameters as possible.

WATER QUALITY

With the wild catch of seafood at or above a sustainable yield, the world demand for fish or other seafood products will increasingly be satisfied from mariculture production units (Scientific American 1995). The World Bank has suggested that early in the next century, up to 40% of the world demand for fish products will be supplied by aquaculture. While difficult to predict, current developments in Australia are such that by early in the next century it would be expected that between 10,000 and 20,000 hectares of ponds or their equivalent would be in production in tropical Australia. While cage culture of fish is expanding the mariculture production of marine shrimp will be a significant part of total Australian production. The future for shrimp culture is very bright (Weidner and Rosenberry, 1992).

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In Australian conditions the economics of pond based shrimp mariculture demand high production rates per hectare. Often referred to as intensive or semi-intensive operations, such units are planned on yields of at least 5000 to 6000 kg per hectare per crop with two crops per year. A dominant feature of management concerns in mariculture operations in Australia is the maintenance of pond water quality conditions that will allow the maximum growth rate of the organisms being cultured (Boyd, 1986). High water exchange rates and a constant supply of clean good quality sea water are essential management tools. A major concern is the amount of wastes produced (Smith, 1993; Wang, 1990; Williamson, 1989). Per hectare of ponds the total waste produced per crop is difficult to estimate. The dissolved, colloidal and suspended wastes discharged from the ponds are high in Nitrogen, Phosphate and suspended solids (Boyd and Musig, 1992 Pruder, 1992). Robertson and Phillips (1995) give values for intensive shrimp pond effluent compared with pristine mangrove waterways (Table 1).

Table 1: Some Water Quality Variables in Shrimp Pond Effluent (from Robertson and Phillips, 1995)

Water Quality Variable	**Intensive Shrimp Pond Effluent**	**Pristine Mangrove Waterways**
NH_3 (μM)	10.0 - 35.0	0 - 37
NO_3 (μM)	1.97 - 73.15	0.10 - 1.42
PO_4 (μM)	0.53 - 4.21	0 - 5.26
TSS (mgl^{-1})	119 - 225	67 - 3312
Chla (μgl^{-1})	20 - 250	0.2 - 5.07
Bacterial Cells ml^{-1}	8.8 - 25.7 x 10^6	0.85 - 4.7 x 10^6

It is the impact of the disposal of effluent near or in mangrove areas that has to be considered. If an average water exchange of 10% per day is used then a 1 hectare pond (average depth 1.2m) will discharge approximately 168 Ml over the 20 week crop cycle.

With the rapid change in biomass in the pond and feeding rates being altered to cope with these changes, average values of effluent materials are not of great value. Mangrove communities, either natural or constructed appear to have a great potential as bio-filtration units for the processing of these discharges from mariculture operations as well as waste-water treatment (Tam and Wong, 1995).

The Australian mariculture industry would regard itself as a strong supporter of any efforts to manage and conserve the mangrove communities of tropical Australia. With a few exceptions, Australian mariculture operations are generally not constructed on or in mangrove communities. Mariculture ponds are generally constructed above high tide levels to ensure rapid draining at any stage of the tide and to avoid any problems with sulfate rich marine sediments. Most of the interference to mangrove communities in Australia from mariculture operations would come from the construction of inlet and outlet structures and access tracks.

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With such construction subject to permitting requirements direct interference with mangrove communities is minimal. This contrasts with many mariculture operations in the Asian region where large scale destruction continues to occur.

Mangrove communities as we have heard, are a major feature of low energy inshore environments in estuarine and coastal areas. A major focus in research in mangrove communities relates to the monitoring of damage and recovery from clearing and in-filling processes which destroy the community or from hydrodynamic changes that cause major erosion of communities. The effects of changes in water quality have not received the same attention from researchers as damage from development or studies of community dynamics. Research has been aimed at explaining these major changes in community structure and the extent of change that has occurred. With few exceptions (and I think Gladstone is one of them) the problem in such studies is that baseline data is slight or non-existent.

A second research focus is studies, of which the work of Australian Institute of Marine Studies is a major example, that attempt to quantify and explain the conditions within what could be termed a 'stable' system. A significant part of this research output has looked at the fluxes of materials into and out of stable mangrove communities that are not under development or pollutant stresses. Of particular interest to those interested in water quality are the studies that explain the effects of reduction in water velocities in the community on the deposition and adsorption processes occurring and those studies that deal with the bio geochemistry of the sediments (Wolanski,1995). Particularly the idea that some elements are relatively mobile between the sediment and water mass and others are relatively immobile.

Although the marine environment is almost the dumping ground of choice for effluents (the run a pipe out to sea and it will be diluted approach) the research into the impacts of waste waters on mangroves are limited. Yet in waste water or effluent studies there has been a lot of research based on the idea that the processes that are involved in the trapping of nutrients in natural communities apply just as much to the pollutants entrained in the water mass (Chamberlain 1988; Dixon and Florian,1993; Folke and Kautsky,1992; Iwama,1991).

There is major interest in using natural or constructed wetlands for waste water treatment. Effectively, waste water is distributed into wetland communities. Pollutants are adsorbed into the sediments, taken up into biomass or stored in the sediments. This increases the turn-over time of the pollutants and the materials are held long enough for microbiological breakdown or remineralisation to occur. Mangrove communities in this view represent a potential 'bio- or nutrient filter' acting to trap and degrade 'pollutants' in the water masses that flow into and out of the communities.

It is over ten years since Clough et al. (1983) looking at previous work of Nedwell, evaluated the potential use of mangrove communities in sewage treatment. A literature search on work published since then reveals that very little research has been carried out on the questions that they started with:

"what is the effect of sewage and waste-water on mangroves and .... how effectively can mangrove systems trap the various components of these effluents which would otherwise enter offshore systems?"

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There are really very few papers addressing this. Robertson and Phillips (1995) do address the question of what effluents contain and the potential use of mangroves in trapping these pollutants. In Australia there is currently a deal of work in process on the distribution and fate of pollutants in the marine environment. Eg Ocean Rescue 2000 and the State Of Marine Environment Report documents and the current Senate Inquiry into Marine Pollution. It is a comment on the development of technologies that much of the information is published on the Internet and readily accessible.

Declining water quality and sedimentation have been identified as key issues in the marine environment, particularly in ecosystems such as estuaries, salt marshes, mangroves, seagrasses, rocky shores and sandy beaches in developed parts of Australia. It is surprising that there is still little published research on the long term effects of these low level but permanent changes in water quality on the dynamics of mangrove communities. It seems to me that one of the most important questions which could be asked about the interaction of mangroves and water quality and extend the ideas of Clough et al is:

"What are the long term implications, for the food chains that originate in the mangroves, of changes in water quality?"

Before we go any further it is best to review what we mean by water quality. Generally we would define the term water quality almost from a human health point of view and this is the approach adopted here. This does not consider 'toxic' events that would destroy mangroves but long term low level changes in the water quality bathing the communities. Estuarine and coastal waters that flow through mangrove communities receive run–off from industrial, domestic and agricultural processes. mangrove communities are receiving:

- run–off of agricultural fertiliser, pesticides, soil and industrial run–off (Mackey et al.,1992)
- domestic sewage and storm water run–off (Tam and Wong, 1993; Wong et al.,1995)
- episodic inputs from disposals of wastes and accidental discharges eg. oil and other products (Burns et al.,1993; Lewis,1983; Scherrer and Mille,1990)

As well the waters may receive high volumes of pollutants from short term accidental discharges. Such changes can be broadly described as long term degradation of the water quality. In considering the effects of these changes in water quality on the mangrove communities we are looking at either short term polluting events or long term alterations in the chemical constituents and contaminants that are found in the water that moves through the communities.

For an example of the water quality parameters that may impact on mangrove communities the table is a listing of the parameters that was defined the STEWARD system (Support Technology for Environmental, Water, and Agricultural Resource Decisions), by The Pennsylvania State University (Centre for AI Applications in Water Quality).

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From a water quality point of view there is not so much a debate about how to measure as rather what to measure. Currently there are several excellent works covering the methods of water quality assessment. There have been for some time extensive Water Quality Assessment Databases with tested methods. The question is whether over a long term where there is a change in these inputs there are major effects on water and sediment quality, marine bio-diversity and commercial and recreational users of the resource.

From a mariculture management point of view the studies that are needed to assess the impact of pollutants, land use or water use on mangrove communities are both general scientific questions (Table 3) and more specific questions (Table 4).

Table 2: Some Parameters for the Analysis of Water Quality in Mangrove Communities (Based on the STEWARD System)

Acidity	Cyanide	Ozone
Alkalinity	Dissolved Oxygen	pH
BOD	Fluoride	Phosphate
Boron	Hardness	Salinity
Bromide	Heavy Metals	Silica
Carbon,	Herbicides	Suspended Solids
- organic	Insecticides	Sulfate
- total	Iodine	Sulfide
Carbon Dioxide	Nitrogen (all forms)	Taste
COD	Odor	Temperature
Chlorine, residual	Oil and Grease	Turbidity
Chlorophyll	Organic Compounds	
Colour		
Conductivity		

The table doesn't include those microbiological components that are more clearly of interest to those people working on sewage treatment and control.

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Table 3: Assessing the impact of pollutants on mangroves

1. Baseline studies to provide information:
   - on the presence and levels of pollutants
   - comparisons between impacted and non–impacted areas

2. Sampling programs of plant material to provide a regular monitoring program. Advantages of using plants are:
   - Usually present before and after any polluting event
   - Represent long term exposure to problem unlike animals
   - Tissue collection and analyses may be standardised and there are fewer ethical clearance problems

3. Toxicity and bio–assays to link the pollutants to observed effects

4. Studies of bio–concentration and bio–accumulation to assess the effects along the food chain

Table 4: Particular questions that are relevant to the interaction of mangroves and mariculture effluents

- What is the fate of pathogenic micro organisms entrained in effluents and deposited in mangrove systems, particularly, do they enter the food chains?

- With continual input from pollutants can the sedimentary Phosphorus and/or Nitrogen pool be saturated? If this occurs what is the sedimentary concentration of Phosphorus and/or Nitrogen at which the sediment release becomes equal to uptake?

- What is the interaction between algal blooms in estuaries and mangroves? Already in many estuarine and inshore areas world wide we are seeing nuisance blooms of toxic algae.

- Can aquaculture effluents be processed through the mangrove communities without causing significant damage?

- Are heavy metals trapped in the sediment, entrained in the food chain?

- What are the effects of oils spills in mangroves?

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The central question in discussions on the effects of mariculture effluents in mangroves is whether there will be any environmental changes and the rates of environmental change. Rates of environmental changes are as important to decision makers as are the magnitudes of those changes over the long term. Much confusion and controversy surrounds the estimates of the rates of slow-onset, low-grade, long-term changes that are possibly seen as noise in the ecological process. Almost by definition the long term changes will only become evident when their reversal will be difficult and expensive. Unfortunately the low level of effluent produced from mariculture operations may be in this class.

The difficulties are that sufficient base-line studies to define the chemical and biological constituents of the water have been carried out in mangrove communities. Instantaneous measurements of water, biomass or sediment composition are not enough. What is needed are long term surveys covering as wide a range of chemical and biological parameters as possible.

It is important to emphasise therefore that while discharges from mariculture operations in Australia do not currently pose a major threat to mangroves, as in many other countries this may change. The problem for the Australian industry is to justify the exploitation of the mangrove communities where many people see these overseas experiences as being indicative of potential problems in Australia. The mariculture industry looks to research and development outcomes that will support the exploitation but maintain conservation of the natural resource.

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SESSION FOUR

*

MANAGEMENT

MANGROVES - A RESOURCE UNDER THREAT?
CONSERVATION ISSUES

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There are two aspects to the conservation of mangroves, namely legislation and awareness.

I will begin with the Awareness Aspect.

I feel a sense of joy when walking in a mangrove forest. This wasn't always so. Twelve years ago, after living twenty years in Sydney, all I knew of the mangroves fringing the Hawkesbury River was that they had these spiky, breathing roots that made walking difficult; that they were nearly always in muddy rather smelly situations, and that sometimes you could be met there by an army of biting insects.

When I left Sydney, scientific magazines were beginning to point out that mangroves had their uses.

Since 1983 I have lived less than five minutes away from eight species of mangroves and I have spent the lat five years finding, researching and filming 20 species in all. Friends call me 'Mangrove Molly' and the local Shire Clerk once referred to me as the 'lady with mangroves at the bottom of her garden'.

I have written articles and given slide shows and talk to schools and adult groups. For a few minutes I would like you to share with me a – Celebration of Mangroves – as I have seen them.

At this point Mrs Crawford presented slides depicting:

- Flowers
- Fruit – vivipary, cryptovivipary, non–vivipary
- Leaves – the salt problem
- Roots – oxygen intake
  – anchoring
- People use – protection & and shelter
  – seafood
  – scientific studies
- People abuse – clearing for habitation, playing fields, roads
  – dumps and leaching from dumps
  – ponded pastures on marine plains and tidal wetlands

To continue, awareness leads to evaluation. Three main reasons for conserving, rather than clearing and destroying mangroves, emerge from this awareness.

1. The protection of the coastline. Cyclones are largely a tropical phenomenon. So are mangroves by and large. These two phenomena can coexist, not like cyclones and human dwellings. Also erosion of coastlines is a dynamic two-way happening. The run-off from torrential tropical rains can erode; as well as invasion from the sea. Mangroves buffer the land from both directions.

2. In Australia, in particular, the mangrove habitat is seen to be an important part of a major food web supporting the fishing industry. In other countries mangroves have other uses; but here, just by leaving mangroves alone to do their own thing, we are allowing a sustainable industry (provided it is not over-fished), worth millions, to continue.

3. At a time when so many species of wildlife are under threat, mangrove communities provide protection and a food source to wide range of other life forms.

I will conclude with a few slides. I need not comment on them except to remark at the outset that the present legislation that is supposed to protect mangroves, can too easily be circumvented by local authorities and developers. I am hopeful, however, that the level of awareness in the general public, has so increased through the showing of wildlife documentaries, education in the schools, the construction of mangrove board-walks and active rehabilitation programs, that the public will become the watch-dogs and demand more stringent conservation.

COASTAL IMPACTS ON THE MANGROVE FRINGE
WHAT CAN GBRMPA DO?

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ABSTRACT

Mangroves exist within and on the boundaries of the Great Barrier Reef Marine Park. Boundary issues influence how much the Great Barrier Reef Marine Park Authority can protect mangroves. This paper describes the processes for management decisions within the Great Barrier Reef Marine Park. It explores complex jurisdictional issues which hamper integrated management of coastal resources, including mangroves. Issues of World Heritage, the precautionary Principle, integrated planning and management and Queensland planning regimes are discussed.

Areas close to the Great Barrier Reef Marine Park World Heritage Area, have experienced and continue to experience growth. Urban growth at 4% per annum in a number of provincial centres is predicted, with visitor numbers up to 11.4% predicted in the Cairns Port Douglas area. Up to 40 large scale coastal and island developments remain pending within the World Heritage Area

Options from broad strategic planning to site specific management are explored using case studies.Questions are raised regarding whether existing legislative regimes available to the Authority are adequate, using case studies it is argued that in coastal areas the Authority is often the last to hear of damage and is often left with difficult and complex legal avenues as recourse to prevent potential damage to mangrove eco-systems within the area.

INTRODUCTION

Thankyou for the opportunity to present to you a perspective on the role that the Great Barrier Reef Marine Park Authority has in the protection of Mangroves along the coast of Far North Queensland.

Firstly, I am speaking in lieu of Dr Wendy Craik the previous Executive Officer of the Authority. Most of you would know that Wendy has taken up a senior position in the National Farmers Federation, a position, I suggest, of much relevance to the health of mangroves. Wendy knows more than most, I suspect, the effects of land uses, particularly agriculture on the coastal and marine environments within and adjacent to the Great Barrier Reef Marine Park so I'm sure she has our interests in mind.

My paper today will attempt to provide you with an overview of the scale and legal complexities of managing the coastal areas which may be inside or close to the Marine Park boundary. The Great Barrier Reef Marine Park has been established for twenty years, the regulatory provisions provided in 1975 have provided a basis for management to date. It is important to note that there are legislative problems when considering how the Marine Park Authority can influence or indeed protect mangroves. I shall be illustrating these complexities by reference to case studies.

BACKGROUND

The Great Barrier Reef Marine Park contains the largest system of coral reefs and associated life forms anywhere in the world. The Marine Park provides a most spectacular marine environment, which is of global significance and renown. The Reef is of great economic importance to Australia since it is one of the nations premier tourist destinations, and supports a major fishing industry.

The Great Barrier Reef Region covers approximately 350,000 km^2 on Australia's continental shelf. It extends along almost 2000 km of the Queensland coastline from just north of Bundaberg (approximately 24°S) to the tip of Cape York (approximately 10°S). The Great Barrier Reef contains approximately 2900 individual reefs, including 760 fringing reefs; some 300 reef islands or coral cays; and about 600 continental islands, often with fringing reefs.

There are about 350 species of hard reef-building corals, and more than 1500 species of fish in the Great Barrier reef region, and in excess of 240 species of birds which inhabit or visit the reef and adjoining islands. The Marine Park and adjoining coastal area represents a highly variable physical environment having complex biological features. The diversity of form and size of individual reef and islands, and the biota of the reef, makes the Great Barrier Reef an area of enormous scientific importance. This unique coral reef ecosystem is of considerable interest ecologically, and the region is aesthetically attractive.

The Great Barrier Reef Marine Park was declared and became law in 1975, and is the world's largest marine protected area. It is a multiple use marine park which provides for reasonable use but specifically excludes mining and oil drilling.

The Great Barrier Reef has not been used intensively used for human subsistence, although it has been subjected to areas of intense tourism and other activities. The limited usage to date, and the absence of significant economic dependence, apart from commercial fishing and tourism, has assisted in the management of the Reef, in preservation of the physical environment, and the maintenance of bio diversity within the Reef region.

The unique environment, size and diversity of the Great Barrier Reef have been recognised in the inscription on the UNESCO World Heritage list in 1981. The declared World Heritage Area encompasses the Great Barrier Reef Marine Park (93%), continental islands within the Marine Park boundary (5%), and the adjoining Queensland tidal waters outside the Marine Park, (2%).

INSTITUTIONAL FRAMEWORK

The Great Barrier Reef Marine Park Authority has the legislative obligation to ensure the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the development and care of the Great Barrier Reef Marine Park.

The Great Barrier Reef Marine Park Act enables the development of Zoning Plans which provide for as of right activities, prohibited activities and activities that can be undertaken with consent and for regulations to be made to enable the provisions of the Act to be carried out. There is a range of legal and administrative provisions from the Great Barrier Reef Marine Park Act through to, regulations, zoning plans, management plans and permits. In 1994 the 25 year Strategic Plan was launched and provides a long term strategic direction for the management of the Marine Park.

The Authority as a statutory Commonwealth body must have consideration of other Commonwealth laws. Figure 2 illustrates the major regulatory interactions with other laws.

The day to day management of the Marine Park is undertaken by the Queensland Government in accordance with an agreement between the Commonwealth and Queensland struck when the Marine Park was declared. In practice this means that Queensland Marine Parks have similar, complimentary zoning and regulatory provisions to the Commonwealth. There are provisions for complimentary decision making at all levels, including the permitting process. Two agencies have the responsibility of administering major project proposals in or adjacent to the Great Barrier Reef Marine Park, the Authority itself (GBRMPA) and the Queensland Department of Environment and Heritage (QDEH). Both Agencies work closely together to avoid unnecessary duplication and to simplify demands on users and potential users.

The Authority is taking lead agency role in providing the Commonwealth portfolio interests to ensure that the World Heritage Values of the area are appropriately considered in the assessment of development proposals.

The Authority will act as a referral agency on proposals outside the Marine Park and where the proposal is close to or within the World Heritage Property.

It may help to provide a background to the issue of the geographical differences between the Marine Park and the World Heritage Property.

In the nomination document for the Great Barrier Reef World Heritage Property, the area as described is the same area as that in Schedule 1 of the *GBRMP Act* , therefore the western boundary of the area runs along the coastline at low water. The Great Barrier Reef Region is defined in the *GBRMP Act* as the area in schedule 1 minus non-commonwealth owned islands and internal waters of Queensland. Thus the WHA and the GBR Region are not the same thing. In addition, the GBRMP is proclaimed over part but not all of the Region.

Coastal impacts on the mangrove fringe - What can GBRMPA do?

In terms of specifically addressing the protection of World Heritage Values within the Marine Park you may be aware that Section 12 (1) of the *World Heritage Properties Conservation Act 1983* exempts the Authority from provisions in sections 9.10, and 11 of the Act because actions taken under the provisions of the zoning plans in the Marine Park, in accordance with the *Great Barrier Reef Marine Park Act 1975* were seen to be not inconsistent with the *WHPC Act.*

The provisions of Regulations 26 and A(4) of the *GBRMP Regulations* ensure that the Authority considers impacts of proposals in accordance with regulatory assessment criteria the Authority or it's delegates must have regard to. In this assessment process there are provisions for designation under the *Environment Protection (Impact of Proposals) Act 1974.* (EP(I) Act).

The object of the EPIC Act is to ensure, to the greatest extent practicable, that matters affecting the environment to a significant extent are fully examined and are taken into account in relation to Commonwealth actions and decisions. If foreign investment is sought for a project then designation of a proponent is possible.

The Authority's main concerns involve, inter alia, the following points:

- Impact on World Heritage Values including:

    a. explicit reference to World Heritage values at or near the site (ie natural values referred to in the nomination document at a minimum)

    b. details of direct or indirect potential impact on those values from the construction and operational phases, including consideration of cumulative impacts. (details should include the likelihood of the impact as well as its expected nature, magnitude, duration and geographic spread); and

    c. evaluation of strategies to reduce or prevent adverse impacts to World Heritage values.

- Impacts on the National Estate
- Water Quality
- Examination of Prudent and feasible alternatives with particular reference to cumulative impacts.
- possible foreign ownership and FIB related issues.

The Authority takes the broad view that consideration of impacts outside the Great Barrier Reef Marine Park should meet or exceed the standards for impact assessment processes within the Marine Park. For example, the Authority has developed Marina construction and operational guidelines which describe the factors for consideration in the design and operation of marinas which have, historically at least, potential to affect mangrove communities.

In addition the Authority must have regard to the *Australian Heritage Commission Act* in particular section 30(2) regarding the duties of Ministers and authorities to consider adverse effects of parts of the National Estate, particularly as it relates to the consideration of prudent and feasible alternatives and where the delegate is satisfied that no prudent and feasible alternatives exist that all steps have been taken to mitigate against adverse effects.

The Commonwealth can initiate action under the *WHPC Act* if it is satisfied that a part of a World Heritage property is likely to be damaged or destroyed. This action was taken in the Oyster Point proposal. It is also possible for the Authority to promulgate regulations under Section 66(2)(e) of the *GBRMP Act* by regulating or prohibiting acts (whether in the Marine Park or elsewhere) that may pollute water in a manner harmful to animals and plants in the Marine Park.

MAJOR USES AND IMPACTS

Impacts on the Park are increasing due to escalating development pressures from both marine and land based industries. While tourism is the fastest growing activity in the region, urban expansion, industrialism and expansion in the agriculture and fishing industries also potentially pose significant threats.

Areas close to the Great Barrier Reef Marine Park World Heritage Area, have experienced and continue to experience growth. Urban growth at 4% per annum in a number of provincial centres is predicted, for example, visitor numbers are predicted to increase by 11.4% in the Cairns Port Douglas area over the next few years.

Currently the Authority receives approximately 40 major project applications per year, each project is unique in some way and requires specific attention to the individual application. With a 21% increase in applications and with no further resourcing there are inherent delays in assessing applications, it is clear, therefore, that there is a need to develop policies which have general application rather than developing one-off policies for each permit application. Addressing individual applications has identified the need to review the technical provisions for developments in the Marine Park which are interdependent with requirements for changing administrative procedures.

Coastal development can produce significant changes in adjacent marine areas due to habitat destruction in mangroves, estuaries and tidal marshes, and from pollution. Such impacts on the biological diversity of coastal and marine eco-systems may threaten the survival of fringing reefs and seagrass beds

Environmental Impact Assessment

The Marine Park Authority has procedures specified in statute which ensure that appropriate consideration is given to environmental impacts. Before the Authority can grant permission for an activity in accordance with provisions in respective zoning plans, it must first assess the impact of the activity on the Marine Park. Regulations in the

Marine Park Act provide specific assessment criteria that are considered for each proposal requiring a permit.

For projects that have potentially significant environmental effects, it may be decided that further investigation is warranted through the EP & I Act. This is most likely to lead to the preparation of an environmental report and to public review. Smaller projects that markedly affect the use of an area of the Marine Park by others, may be required to publicly advertise the project.

The complexity of the impact assessment depends on the significance of the potential impacts on the physical, biological and social environment.

The Impact assessment process does not, as a general rule, result in the prohibition of a project which is reasonable use of the particular Marine Park Zone, even though it might appear that there may be potential for significant environmental impacts. The assessment process tends to force environmentally sound design onto projects to ensure acceptance. Applications may be refused where the impacts are deemed to be unacceptable. All GBRMPA decisions can be appealed against by affected persons.

CURRENT DIRECTIONS

There needs to be a clearer understanding of the purpose of environmental assessment in the coastal zone. Up until recently there has been a lack of uniformity both in approach and standards across agencies. There have been no clear guidelines that apply generally.

The critical environmental condition of Queenslands coastal zone has been recognised in the Resource Assessment Commission's Coastal Zone Inquiry. There is a growing awareness that ecologically sustainable use within the coastal zone requires the integration of activities of all stakeholders and the recognition of the ecological relationships between the marine and terrestrial environments.

While the regulatory provisions for management has been in place inside the Great Barrier Reef Marine Park the same cannot be said for other coastal developments which have been implemented in the region since the Park was declared in 1975. Many of the coastal development proposals lack full integration with other legislative approval systems. The twenty five year Great Barrier Reef World Heritage Area Strategic Plan has identified the need for integrated coastal management and realises that the Great Barrier Reef Marine Park is inextricably linked with activities of agencies, groups and individuals in and close to the property.

Recent State and Commonwealth Government initiatives are building on the principle of integrated management and approval systems. The Queensland Planning Environment and Development Bill aims to formalise integrated planning and development between the State and Local governments through an integrated development approval system (IDAS). The Commonwealth has a Local Government Approvals Review Program and an Integrated Local Area Planning Program.

The coastal protection strategy and legislation being introduced by the Queensland Government does attempt to place the possible cumulative impacts of coastal development into a better context. The combined effects of these strategies is laying the groundwork towards integrated approaches to development which by its nature must be of benefit to the natural systems of value including mangroves.

Development pressures within and adjacent to the Marine Park provide an imperative for careful management. The State of the Environment Reporting Framework for Australia in 1994 stated that development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends is ecologically sustainable development. The question remains, however, if we do not get on top of integrated development approval systems mangroves will continue to be lost and difficult legal arguments will arise leading to uncertainty and costs. Will such regimes between jurisdictions ever come about? If Oyster Point is a topical and typical example then it is clear we still have some way to go. The Marine Park at the end of the catchment, as it were, will suffer from poor land and coastal practices. Mangroves are the buffers, lets protect them as best we can.

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RECOMMENDATIONS FROM THE SYMPOSIUM

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'MANGROVES - A RESOURCE UNDER THREAT AN ISSUE FOR THE CENTRAL QUEENSLAND COAST.'

RECOMMENDATIONS FROM THE SYMPOSIUM

At the conference held in Gladstone on 27 October 1995, and sponsored by the Australasian Marine Science Consortium (AMSC), more than 70 delegates from a range of relevant industries, government instrumentalities, local governments, environmental groups, universities and interested citizens discussed the theme *'Mangroves, a resource under threat? An issue for the Central Queensland coast.'*

The following recommendations were formulated and endorsed by the delegates for the attention of relevant government authorities and other agencies:

This conference re-affirmed that a policy of no loss of mangroves whatsoever should be adopted in the local region; and supported the principle of no net loss of biodiversity and abundance where activities have the potential to impact on mangroves and associated wetlands.

The conference further supported a general requirement for the rehabilitation of land degraded through anthropogenic factors, but not at the expense of other ecosystems. It urged that since replanting mangrove species in alternative areas to compensate for loss of mangroves through industrial development, does not necessarily result in the re-establishment of a mangrove ecosystem, careful design and monitoring of such efforts must be undertaken to ensure their success.

Policy and Planning

This conference urges that there be:

- better use of existing knowledge with regard to mangroves and associated species to inform policy development
- better coordination of all levels of government in the development of policies
- adoption of both reactive and adaptive management strategies for mangrove and wetland systems
- an acknowledgment of the need for a full range of management options based on the identification of key uncertainties, critical management objectives, and including feedback links to allow further refinements to be included in the models developed for mangrove system management
- recognition that integrated coastal zone management, including total catchment management and the linkages between extensive salt pans and mangroves, is essential

- acceptance that strategic plans for wetland management should be inviolable and that these strategic plans should interlock at all levels of government
- a system for regular state of the (marine) environment reporting developed
- policies developed to focus on long term environmental management and broad issues as well as immediate and local issues
- long term planning that focuses on optimal population size for a region because of any associated urban and industrial development needs which may alienate mangroves and associated wetlands
- regional planning to reduce the need to use waterfront land for industry

Management Strategies

This conference urges that:

- more sanctuaries be declared
- waterfront land be used by industry only when there is a clearly demonstrated and agreed absolute need
- cooperative management practices be established to ensure that care for our coastal systems is implemented across jurisdictional boundaries
- recognition be given to the fact that because of environmental variability and complexity, specific regional studies are necessary, since extrapolation between regions may not be valid
- there be an increased level of monitoring mangrove systems to allow early detection of any changes
- public participation be incorporated into any monitoring and policing program
- greater authority be given to QDEH and QDPI Fisheries with regard to policing and prosecution
- industry be made responsible for the rehabilitation of any wetlands and mangrove systems damaged by their activities

Research Issues

This conference affirmed that there is an urgent need for research towards:

- developing indicators / indices of the state of the marine environment, particularly in relation to the health of mangrove systems

- better understanding of the natural variability of mangroves with respect to productivity as it relates to events such as long–term climatic cycles

- determining the interactions between salt pans, salt marshes and mangroves lucidating pathways of energy flux through mangrove systems

- development of national inventories of mangrove systems

- determining the real and possible impacts of interfering with water catchments through dams, reservoirs, bundwalls, ponded pastures and the like on coastal systems

- validating explanations of the value of mangrove systems as nursery habitats

- determining the tolerance of mangroves and associated species to levels of pollution

- understanding the effectiveness of mangroves and associated wetlands as biological filters

- ensuring that industry accepts responsibility for sponsoring research into alternative ways of preserving species associated with damaged areas of wetlands

Education Issues

This conference recommends that:

- all levels of society from school children through to government ministers need to be brought to a greater awareness and understanding of the value of mangroves and the ways in which mangroves operate within the environment

- there should be better communication of scientific knowledge to interest groups, managers and various levels of government

- local councils, state and federal government agencies should make every effort to keep the public well informed of proposed developments that may threaten mangroves and associated wetlands

Legislative Issues

This conference considers that:

- current legislation with respect to alienation of mangroves is inadequate

- current penalties for breeches of the law are inadequate

This conference recommends that:

- substantial environmental bonds ($$) are needed prior to any development which might threaten mangroves, the funds so lodged being available (in whole or in part) to facilitate re–establishment

Finally, the conference expressed major concerns about threats to the marine environment arising from ballast water discharges in our ports, both regionally and nationally, and urged strong support for the Ballast Water Committee.

ATTENDEES AT THE 1995 MANGROVE SYMPOSIUM

NAME	*ORGANISATION*
ARMSTRONG, Sid	Yeppoon Wilderness Society
ARNOLD, Don	Department of Environment and Heritage
ASHWATH, Nanjappa	Central Queensland University
BENNETTS, George	Gladstone
BERGHUIS, Andrew	Department of Primary Industries
BOWLEY, Noel	Gladstone Port Authority
BOWMAN, Roly	Queensland Commercial Fishermen's Organisation
BUTLER, Alan	Adelaide University
BYRON, Graham	Department of Environment and Heritage
CAMPBELL, Clayton	Gladstone State High School
CIESIOLKA, Heather	Capricorn Conservation Foundation
CLOUGH, Barry	Australian Institute of Marine Science
COATES, Mike	Central Queensland University
COGILL, Col	Shire Councillor V/P GRMAC
COOK, Clive	Great Barrier Reef Marine Authority
COOK, Laurie	Central Queensland University
CRAWFORD, Molly	Wildlife Preservation Society
DAVIS, Roger	Queensland Department of Housing Local Government & Planning
DE GROOT, Heiko	Department of Environment and Heritage
DE PINTO, Serge	Mackay Region Marine Resource Advisory Committee
DIXON, Pat	University of New South Wales
DUNCUM, Catherine	Central Queensland University
DUNGLISON, Craig	Rockhampton City Council
ELMER, Mark	Queensland Fisheries Management Authority
ETCHELL, Rex	Queensland Commercial Fishermen's Organisation
EXTON, Rick	Department of Primary Industries
FAWKES, Richard	Queensland Alumina Ltd
FINGLAS, Peter	Department of Primary Industries
FINLAY, Des	Queensland Commercial Fishermen's Organisation
FLETCHER, John	Capricorn Coast Landcare Group
GARDINER, Amanda	Queensland Alumina Ltd
GOLDING, Ray	James Cook University of North Queensland

Attendees at the 1995 Mangrove Symposium

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GREENWOOD, Joan	University of Queensland
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HOPLEY, David	James Cook University of North Queensland
HYLAND, Stuart	Department of Primary Industries
JOHNSON, Jacqui	Gurang Land Council Aboriginal Corporation
KAY, Alice	Department of Environment and Heritage
KENNY, Anne	Gladstone State High School
KUNZE, John	NRG Gladstone Power Station
LEYDEN, Brendan	BHP Australia Coal Pty Ltd
MACNAUGHTON, David	Queensland Cement Ltd
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RAYNER, Donna	Central Queensland University
RICHTER, Jos	Department of Environment and Heritage
RIDER, Ernie	Department of Primary Industries
ROBERTS, David	Department of Primary Industries
ROBINSON, Ray	Department of Primary Industries
SAENGER, Peter	Southern Cross University
SHEPHERD, Virginia	Central Queensland University
SIMMONS, Jeff	Yeppoon Wilderness Society
SINKKO, Maaret	Livingstone Shire Council

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NAME	*ORGANISATION*
SUSANS, Tom	Central Queensland University
SUZUKI, Kunio	Yokohama National University
TUCK, Graham	BHP Australia Coal Pty Ltd
WALKER, Mike	Central Queensland University
WARNER, Lesley	Central Queensland University
WHITEHEAD, Noel	Sunfish Mackay Branch
WILD, Anita	Department of Primary Industries
WINTER, Drew	Department of Primary Industries