FRINGING REEF WORKSHOP

Science, Industry and Management

Proceedings of a Workshop held at Arcadia Resort, Magnetic Island, Australia, October 23-25, 1986.

Edited by C.L. Baldwin

Great Barrier Reef Marine Park Authority

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FRINGING REEF WORKSHOP

EXECUTIVE SUMMARY

The Great Barrier Reef Marine Park Authority's Fringing Reef Workshop was held on Magnetic Island during October 1986.

More than 60 people, including scientists, consultants, tourist operators, and managers gathered to discuss the ecology, issues, management and interpretation of fringing reefs on the Great Barrier Reef.

The final day of the workshop was an excursion to fringing reefs at Orpheus Island. This report outlines the proceedings and findings of the workshop.

Fringing reefs are coral and algal reefs adjacent to the mainland or continental islands. Approximately one-quarter of all the reefs on the Great Barrier Reef are fringing or incipient fringing reefs. Of these approximately 663 are located within the Marine Park and a large proportion of these are situated between 20°-22° South (corresponding to an area from Bowen to St.Lawrence on the mainland).

The catalyst for the workshop was a combination of two factors.

1. The paucity of information available on fringing reefs, especially those outside of the usual study areas - of the Australian Institute of Marine Science and James Cook University, for use in the zoning and management process.

2. Some of the major management issues faced by GBRMPA in recent years relate to specific fringing reefs, in particular Cape Tribulation, Shelburne Bay, Whitsunday Islands, and Magnetic Island. Being adjacent to land, fringing reefs are vulnerable to the effects of land use. Pollution, siltation, tourism and general pressure due to their relative accessibility are just some of the factors that need close study.

The objectives of the workshop were:

1. to bring together scientists, tourist operators, and park managers to ensure continuing cooperation and sharing of information on fringing reefs;

2. to stimulate interest in all aspects of fringing reefs; and

3. to emphasise the value of fringing reefs for tourism.

Although there was not an enthusiastic response from tourist operators in terms of numbers, those attending the Workshop were willing to share their ideas and recommendations. Thirty-three reports and papers were presented, concerning a range of scientific and management-oriented topics, aimed at the different interest groups at the Workshop.

Papers were considered by the Workshop under the following headings:

- Fringing Reef Setting. Topics that provided a basis for theme development were the geomorphological structure and development of fringing reefs, the zonation of coral communities and their larval connections, and the role of algae.

- Description of Fringing Reef Communities. A number of specific fringing reef communities were described, particularly Lizard and Magnetic Island fringing reefs, where sites have been monitored for a number of years. In addition, recent work on more controversial areas - Cape Tribulation and Shelburne Bay - was also presented.

- Human Use of Fringing Reefs. Topical papers on the effects of reef walking and shell collecting, as well as latest developments in giant clam mariculture and tourism trends were presented.

- Tourist Operators Discussion of Reef Use. Three representatives of the tourist industry talked about the various uses of fringing reefs, and gave their views on the requirements of the industry in relation to fringing reefs.

- Issues. The main issues dealt with, included: impacts of siltation, pollution and engineered structures and factors to be taken into consideration in designing and constructing marine structures.

- Management. Discussion covered a range of -topics from issues for day-to-day management and zoning, to permit requirements and monitoring.

- Education/Interpretation. Highlights of education/interpretation material to be produced by GBRMPA in the next year were revealed and low impact mooring design proposals were put forward.

The third day of the Workshop was spent visiting some fringing reefs of Orpheus Island, in the Palm Island group. Participants were impressed by the diversity of coral and algal growth on the fringing reef at the northeast end of Orpheus, as well as the variety of fauna observed. A highlight of the field day was a visit to the giant clam mariculture project at Orpheus Island Research Station to observe clam spawning. Snorkelling the Pioneer Bay reef flat and inspecting racks where young clams grow out proved to be of great interest.

RECOMMENDATIONS

1. Tourist operators requested that GBRMPA arrange courses/workshops for tourism operations regarding fringing reef biology and interpretation closer to their businesses in the Whitsundays or at actual islands or fringing reefs. It was suggested that engaging scientifically trained people or training their own tourist staff in coral reef ecology could be beneficial to tourist operations.

2. A symbiotic relationship should be encouraged between resorts/tourist operations and nearby, research stations. In this way, researchers could offer interpretation of research in progress and resort operators could facilitate monitoring of reefs that are impacted by their operation.

3. Research on fringing reefs should focus on providing a better understanding of the response of fringing reefs to disturbance such as siltation, to determine the level of stress that can be tolerated by fringing reefs.

4. Research should focus on developing agreement on indicator species for baseline surveys. This should be accompanied by more extensive monitoring to present a view of temporal variation on specific sites giving an indication of the health of the reef. Integration of remote sensing and ground truth techniques should be developed for use in monitoring.

5. There were differences of opinion as to whether additional workshops were required. Those against more workshops felt a need for more information before holding further meetings. Those recommending workshops felt they should be more relevant to the tourist industry, more appropriately timed and located.

6. Research should aim at developing a better understanding of usage patterns together with the nature of tourist experiences and their expectations. Tourist operators should consider visitors' expectations by preparing them for their visit to fringing reefs.

7. The potential for fringing reef use can be facilitated by encouraging developers to assess alternatives to rigid structures in order to maximise opportunities and maintain flexibility.

8. There is a need for better strategic control of tourism development. It was suggested that zoning does not allocate uses according to the "best possible use" or optimal potential of fringing reefs.

An overall realisation of the need for sustainable use of the Great Barrier Reef and its resources appeared to pervade the Workshop and assisted participants with diverse backgrounds in meeting the objectives of the Workshop.

ACKNOWLEDGEMENTS

The Authority gratefully acknowledges the valuable contribution made by all workshop participants. As a workshop held on Fringing Reefs, the workshop and its findings represent an important reference point in our understanding and management of the Great Barrier Reef Marine Park.

The Authority would particularly like to recognise the assistance of the speakers and their contributions to this publication. The skilled guidance of the chairman, Dr Don Kinsey ensured workshop objectives were met. The assistance of the Working Group leaders, Dr Clive Wilkinson, Peter Hunnam, Dr Wendy Craik, and David Steen for maintaining direction during discussion and of the rapporteurs, Dr Leon Zann, Ian Dutton, Dr Kevin Parnell, and Dr Zena Dinesen, in synthesising discussion, are greatly appreciated.

Christine Dalliston, Felicity Gray, Bruce Miller-Smith and Ian Preece provided logistical support for the workshop. Assistance with editing of the manuscript was provided by Karen Weaver and graphics for the publication were prepared by Brenda Lynch. Actual publication was arranged by Gillian Matthew. Special mention should also be made of the assistance of Sandra Anderson and Beryl Dennis who carefully typed much of the report,

Further information on any aspect of this report, or of the workshop generally, may be obtained from:

The Assistant Executive Officer
Research and Monitoring Section
Great Barrier Reef Marine Park Authority
P.O. Box 1379
TOWNSVILLE QLD 4810

REGISTRATION FORM

Registration fees are payable on arrival and include cost of morning and afternoon tea as well as lunch on each day.

PLEASE INDICATE DAYS ON WHICH YOU ARE ATTENDING

No. OF PEOPLE

DAY 1 ______ X $15 = ______
DAY 2 ______ X $15 = ______
DAY 3 ______ X $60 = ______

Spouses are welcome on excursion. Advance booking required. If insufficient numbers indicate interest in excursion to Palm Island Group; excursion will be changed to Magnetic Island at lower cost. Please indicate preference and whether you would join the Magnetic Island excursion if Palm Island Croup excursion is not offered.

Palm Island Group ($60 each) ______
Magnetic Island ($15 each) ______

Please return this form as soon as possible to:

C.B.R.M.P.A.
P.O. Box 1379
Townsville, Qld. 4810

If any queries, call Claudia Baldwin, *81 8811*

Name/s: ....

....

Address:

....

ACCOMMODATION AVAILABLE
AT ARCADIA HOLIDAY RESORT
(Tel. 077 78 5177)

A rate of $44 per night per room whether occupied by 1 or 2. Please organise hotel booking yourself but state you are with the Workshop.

Extra costs you can expect at Arcadia:

Dinner, 23 October, BBQ Grill — $7.50
Breakfast — $5.00 — $8.00

EDUCATION/INTERPRETATION

"Reef Ed and Reef Activities Manual" — Mr. R. Neale and Mr. C. Tilley, G.B.R.M.P.A.

"Snorkelling Trail Proposal and Design" QNPWS, Townsville Region

WORKING GROUPS

— divide into groups with cross-section of interest areas represented in each group
— ask each group to answer the same set of questions

1. What are the needs of tourist operators re fringing reefs?
2. What are needs for research and management?
3. Recommendations of the workshop?

AFTERNOON TEA

— Groups form taking tea with them
— Presentations of working groups (10 min. each)
— Summary of workshop/Preview of excursion Day 3 — Chairman of Workshop

Day 3: EXCURSION

Option One: — visit to Orpheus Is.: tour of Research Station; picnic lunch at Research Station; view of Giant Clam spawning snorkel tour led by Dr. T. Done; return by 5 p.m.

Option two (if not sufficient numbers for Option One): — visit to Geoffrey Bay snorkel trail; Florence Bay for BBQ lunch and snorkel/glass bottom boat tour of Bay; Finish by 3 p.m.

Great Barrier Reef Marine Park Authority

FRINGING REEF WORKSHOP

SCIENCE, INDUSTRY AND MANAGEMENT

OBJECTIVES

1. To gain an appreciation of the value of fringing reefs.
2. To review existing information on the status and functioning of fringing reefs.
3. To review management problems of fringing reefs.
4. To seek strategies to assist in management and reasonable use of fringing reefs to enhance their value.
5. To determine needs for research regarding fringing reefs.

WHO SHOULD ATTEND?.

1. Tourist operators! Are you aware that fringing reefs frequently are just as rich bioliogically as the outer reefs?. Are you aware of the potential of the fringing reefs that you are on or near ? Do you try to maximise visitor interest in the fringing reefs nears you? Do you realise the benefit of fringing reefs to your business?

2. **Researchers!** Are you aware of the issues and management constraints in managingfringingreefs? 'How can your information be used to maximise value of fringing reefs?

3. **Planners,** Managers! What are the issues that must be addressed in proper management of fringing reefs?

How can you facilitate conservation of fringing reefs while encouraging their proper use?

- 6 -

FRINGING REEF WORKSHOP: PROGRAMME

Day 1: ECOLOGY AND HUMAN USAGE

8.30 a.m. — Registration

9.00 a.m. -'Chairman of Workshop: Dr. Don Kinsey, Executive Officer, G.B.R.M.P.A

Welcome: Mr. G. Kelleher, Chairman, C.B.R.M.P.A.

SETTING (20 min. each)

What are fringing reefs? What are their characteristics?

"Structure and Growth of North Queensland Fringing Reefs" — Prof. D. Hopley and Mr. B. Partain, J.C.U.

"Coral Communities on Fringing Reefs — Stressed or Favoured" — Drs. J.E.N. Veron and T. Done, A.I.M.S.

"Coral Populations Fringing Island: larval Connections" — Dr. J. Stoddart, A.I.M.S.

MORNING TEA

"Coral or Algal Reefs?" — Dr. tan Price, J.C.U.

DESCRIPTION OF FRINGING REEF COMMUNITIES (15 min each)

Lizard Island Ref, Pandora Reef — Dr. T. Done

Magnetic Island Reefs — Dr. J. Collins, J.C.U.

Whitsunday/Southern Section Fringing Reefs — Mr. R. Van Woesik, J.C.U.

Shelburne Bay — Dr. P. Saenger

Cape Tribulation fringing reefs — Dr. W. Craik (G.B.M.P.A.), Dr. T. Ayling (Sea Research), Dr. V. Harriott and Mr. D. Fisk (Reef Research and Information Services), Mr. B. Partain, Mr. D. Hoyle (J.C.U.)

1.00 p.m. — LUNCH

HUMAN USE OF FRINGING REEFS (20 min. each)

"Opportunities for, and Constraints to Human Use of Fringing Reefs: An Overview" — Mr. I. Dutton and Ms. C. Baldwin, G.B.R.M.P.A.

"Overview of Fishing Activity on Fringing Reefs: Recreational and Commercial" — Mr. J. Tilbury, Qld. Dept. of Primary Industry,

"Review of Tourist Developments on Continental Islands in the GBR 'Region" — Ms. S. Driml, G.B.R.M.P.A.

"Economic Benefits of Fringing Reefs" — Mr. Ross Woods, Horwath and Horwath Services Pty.

"Giant Clam Mariculture" — Dr. J. Lucas, J.C.U.

AFTERNOON TEA

"Shell Collecting on the GBR: First Impressions" — Ms. B. Barnett

"Reef Walking" — Dr. Michael Liddle, Griffith University

"A View of Fringing Reefs" — Mr. David Colfelt

TOURIST OPERATORS TALK ABOUT USE (1 hour)

Panel Discussion: Cardwell area, Lizard Is., Hinchinbrook is., Whitsunday Islands, Kurrimine, Magnetic Island, Palm Island Group.

Note: Speakers from these areas will discuss methods they use to encouragevisitors to visit/learn about fringing reefs and any problems/dilemmas they may have regarding fringing reefs.

— Summary of the Day/ Preview of Day 2 — Chairman

7.00 p.m. — Informal BBQ Grill at Arcadia (cost not included in registration fee) . .

Day 2: ISSUES AND MANAGEMENT OF FRINGING REEFS

8.30 — Registration (for those not attending Day 1)

ISSUES (20 min. each)

9.00 a.m. — Start

"Effects of Run-off, Siltation, and Sewage" — Dr. D. Kinsey

"Waste Water Discharge Problems" — Mr. K. Parnell, University of Auckland

"Pollution and Sponges on GBR and Caribbean Nearshore Reefs" — Dr. C. Wilkinson, A.I.M.S.

Some Potential Problems Associated with Boat Harbours and Marine Structures on Coral Reefs —Dr. M. R. Gourlay, University of Queensland

Stingers and other Hazards on Fringing Reefs — Mr. David Exton, Australian Surf Lifesaving Association'

MORNING TEA

MANAGEMENT (20 min. each)

"Zoning Fringing Reefs in the Great Barrier Reef Marine Park" — Mr. R. A. Kenchington, G.B.R.M.P.A.

"Key Issues for Day to Day Management of Fringing Reef Areas in the Central Section of the Great Barrier 'Reef Marine Park" — Dr. Z. Dinesen, Q.N.P.W.S.

"Management Issues from Assessment of State Proposals for Marine Parks" — Mr. P. A. Roe, Cameron McNamara

"Monitoring of Fringing Reefs" — Dr. W. Craik

Discussion on Anchor damage/Mooring design — Mr. P. Hunnam, Q.N.P.W.S.

12.30 LUNCH

P.T.O.

FRINGING REEF WORKSHOP: PROGRAMME

ECOLOGY AND HUMAN USAGE: Day 1, October '2'3'

8.30 - Registration

9.00 Chairman of Workshop: Dr D. Kinsey, Executive Officer, Great Barrier Reef Marine Park Authority (GBRMPA)

Opening Address: Mr G. Kelleher, Chairman, Great Barrier Reef Marine Park Authority

SETTING (20 min. each)

What are fringing reefs? What are their characteristics?

9.10 - "The Structure and Development of Fringing Reefs off the Great Barrier Reef Province" - Prof. D. Hopley and Mr B. Partain, James Cook University of North Queensland (JCU) (presented by B. Partain)

9.30 - "Zonation and Disturbance in Coral Cpmmunities on Fririging Reefs" - Dr. T. Done, Australian Institute of Marine Science (AIMS)

9.50 -- "Coral Populations Fringing Islands: Larval Connections" - Dr. J. Stoddart, AIMS

10.10 - MORNING TEA

10.30 - "Coral or Algal Reefs?" - Dr Ian Price, JCU

DESCRIPTION OF FRINGING REEF COMMUNITIES (15 mins each)

10.50 - 1. Lizard Island Reef, Pandora Reef - Dr T. Done
2. Fringing Reefs of Magnetic Island - Dr J. Collins, JCU
3. "Towards the Development of a Spacio-Temporal Atlas of the High Island Fringing Reefs for the Southern Section of the Great Barrier Reef Marine Park" - Mr R. Van Woesik, J.C.U.
4. "A Reconnaissance Account of the Rodney 'Island Fringing Reefs 'and Associated Marine Communities, Shelburne Bay" - Dr P. Saenger, Northern Rivers C.A.E. (presented by Dr D. Gartside, Northern Rivers C.A.E.)

11.50 - "Cape Tribulation Fringing Reefs and Monitoring, Program" - W. Craik, GBRMPA
"Is Silt Run-off Affecting Coral Communities on the Cape Tribulation Fringing Reefs?"
T. Ayling and A. Ayling, Sea Research (presented by T. Ayling).
"Recruitment an8 Mortality of Juvenile Corals on the Fringing Reefs North and South of Cape Tribulation, over One Year" - D. Fisk & V. Harriott (presented by D. Fisk)
"Structure & Growth of the Cape Tribulation Fringing Reefs" - Preliminary Conclusions" - B. Partain.

1.00 - LUNCH

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HUMAN USE OF FRINGING REEFS (20 min. each)'

2.15 - "Tourist Developments of the GBR Region" - Ms S. Driml, GBRMPA

2.35 - "Economic Benefits of Fringing Reefs" - Mr Ross Woods, Horwath and Horwath Services Pty.

2.35 - "Overview of Fishing Activity on Fringing Reefs: Recreational and Commercial"- Mr J. Tilbury, Qld. Dept. of Primary Industries

2.55 - "The Fringing Reef Paradox: Opportunities and Constraints" - Mr I. Dutton and Ms C. Baldwin, GBRMPA

3.35 - AFTERNOON TEA

3.50 - "Giant Clam Mariculture" - Dr J. Lucas, JCU

4.10 - "Shell Collecting on the GBR: First Impressions" - Ms B. Barnett, JCU

4.50 - "Reef Walking" - Dr Michael Liddle, Griffith University (presented by Dr T. Hundloe)

4.50 - "Fringing Reefs: The Tourist's View" - Mr David Colfelt

TOURIST OPERATORS TALK ABOUT USE (30 min.)

5.00 - Discussion: Cardwell area, Lizard Is, Hinchinbrook Is., Whitsunday Islands, Kurrimine, Magnetic Island, Palm Island Group

Note : Speakers from these areas discuss methods they use to encourage visitors to visit/learn about fringing reefs and any problems/dilemmas they may have regarding fringing reefs.

5.30 - Summary of the Day/ Preview of Day 2 - Chairman

7.00 - Informal BBQ Grill at Arcadia

ISSUES AND MANAGEMENT OF FRINGING REEFS: Day 2, October24

8.30 - Registration (for those not attending Day 1)

ISSUES (20 min. each)

9.00 - "Stingers Relative to the Tourist Industry" Mr McMaster, Australian Surf Lifesaving Association

9.20 - "Effects of Run-off, Siltation, and Sewage"- Dr D. Kinsey

9.40 - "Maintaining Water Quality on Fringing Reefs, with Emphasis on Tourist Development"- Dr K. Parnell, University of Auckland

10.00 - "Pollution and Sponges on GBR and Caribbean,Nearshore Reefs" - Dr C. Wilkinspn, AIMS

10.20- "Some Potential Problems Associated with Boat Harbours and Marine Structures on Coral Reefs"- Dr M. Gourlay, University of Queensland.

10.40 - MORNING TEA

MANAGEMENT (20 min. each)

10.55 - "Key Issues for Day-to-Day Management of Fringing Reef Areas in the Central Section of the Great Barrier Reef Marine Park" - Dr Z. Dinesen, Queensland National Parks and Wildlife Service.

11.15 - "Permit Requirements for Offshore Developments" - Mr Simon Woodley, GBRMPA

11.35 - "Management Issues from Assessment of State Proposals for Marine Parks". -Mr P. A. Roe, Cameron McNamara

11.55 - "Zoning Fringing Reefs in the Great Barrier Reef Marine Park" - Mr R. Kenchington, GBRMPA

12115 - "Monitoring of Fringing Reefs" - Dr W. Craik

12.30 p.m. - LUNCH

EDUCATION/INTERPRETATION

1.45 - "Management of Anchorages in the Great Barrier Reef Marine' Park" - Mr Hunnam, Q.NPWS, Cairns

2.05 - "Providing a Better Reef Experience" - Mr R. Neale and Mr C. Tilley, GBRMPA

WORKING GROUPS

2.25 - groups formed with cross-section of interest areas represented in each group, with each group to answer the same set of questions

1. What are the needs of tourist operators re fringing reefs?

2. what are needs for research and management?

3. Recommendations'of the workshop?

2.45 - AFTERNOON TEA

3.25 - Presentations of working groups (5 min. each)

4.00 - Summary of workshop, Preview of 'Excursion (Day 3) - Chairman of Workshop, Dr D. Kinsey

4.15 - Close

OPENING ADDRESS
FRINGING REEF WORKSHOP

Graeme Kelleher
Chairman
Great Barrier Reef Marine Park Authority

It is my pleasure to welcome you to this Workshop and briefly to tell you why there is a Workshop on Fringing Reefs.

As you know the last Section of the Great Barrier Reef Marine Park to be zoned is the Southern Section. The second last 'was the Central Section'adjacent to Townsville. When we were zoning the Central Section it was apparent that quite a bit was known about the fringing reefs there largely because of the existence in the north of the research institution's, the Australian Institute of Marine Science and James Cook University. But the same cannot be said about some of the reefs around the, Whitsunday area or the Cumberland Reefs further south. Very little is known about those reefs and the consciousness of the Authority was drawn to this situation when we began the process of preparing zoning plans in those areas.

Furthermore some of the 'major issues with which the Authority has had to deal over the years have focussed on fringing reefs and this continues' to be the. case. All of you would have heard of the controversy surrounding the Shelburne Bay and Cape Tribulation fringing reefs, but the fringing reefs surrounding the Whitsunday Islands have also been a focus for some controversy for different users over the last zoning process. What not everyone might know is that in the old days at the end of the Second World War this Island - Magnetic Island - was surrounded by beautiful fringing reefs. Don Kinsey has photographs of Nelly Bay taken after the Second World War where the quality of the fringing reef was as good as you are likely to find on the Great Barrier Reef today.'

What caused the change? The answer to that sort of question will tell us all sorts of things about other fringing reefs on the Great Barrier Reef, as well as other reefs - not just fringing reefs. It's a fact that all too often commercial and recreational users of fringing reefs can degrade the qualities that brought people to use those fringing reefs in the first place. Some people have said that the challenge is to use 'the environment without using it up and that sort of thought can be expressed in many ways.

The principal goal of the Authority is to 'provide for the protection, wise use, appreciation and'enjoyment of the Great Barrier Reef in perpetuity. Fringing reefs are an important part of this Region and a very important part of.the total reef system, because generally speaking they are more accessible than 'other reefs and therefore are subject to greater use. We believe that activities that depend on the reef or parts of it require that the use of renewable resources should be held at'levels that can be sustained forever. All of our management' activities' are directed towards that end, although it would be a mistake to pretend that we know what level of activities of any kind can be sustained forever. We are in the learning situation: and this work'shop is part of that process.'

Tourism perhaps more than any other activity could be regarded as the activity that is most compatible with conservation. People come to reefal areas for tourism purposes in order to see the natural qualities of the area. Therefore tourism perhaps more than any other activity should be working hand in glove with management and the scientists to make sure that this precious resource is not degraded with time.

What do we hope the people who attend this workshop will get from it? Well we certainly hope and expect that at the end of the workshop you have new ideas and new information to take back and to apply in what you do. We hope that people who use the reef for tourism purposes will learn more about the characteristics o'f fringing reefs that make them especially interesting and exciting places to visit and to conserve. We know that if you are convinced of that then you are likely to take action to conserve them.

There are fewer representatives of the tourism industry here than we hoped and I guess that this illustrates the difficulties the Authority has met from the very start. There was a conference in Townsville last week run by the Townsville Development Bureau called "Tourism-taking up the Challenge" and a strange phenomenon that the Authority has noticed since it has been created is the fact that generally speaking the tourism industry does not recognise, by either putting in submissions in relation to zoning or by other actions, the dependence of that industry on the natural qualities of the Great Barrier Reef. If they do recognise this, they don't demonstrate it by their actions. This workshop was set up specifically to help the tourism industry develop programs that will in the long run meet their interests. We hope that in this workshop some of the issues that are related to tourism development are thought about and alternatives are considered to what might be seen to be damaging options. We rely on tourist operations to help spread the word about the Marine Park concept, that is - wise use in perpetuity. There will be offered during this workshop some positive solutions or suggestions in the form of educational manuals, snorkelling trail ideas and in design options that could be supported by the tourism industry.

We hope that the scientists that are here at this workshop get ideas about how to structure their science so that the results of the science will be usable by managers and by the tourism industry itself.

We hope that this workshop will tell us, the managers, what are the views of other interest groups, scientists, and the tourism industry; what are the trends; what are the local priorities; and what are the attitudes to zoning. In other words we hope that there is going to be a major exchange of information in this workshop.

It has been said that there are three great lies that have been spread by the human race since the creation of men and women. The first is that I shall still love you as much in the morning. The second is that my cheque is in the mail. And the third great lie that's been perpetrated through the ages is that I'm from the Government and I am here to help you. Now there are exceptions to every rule and we hope that this workshop shows that there are government agencies that are trying to help people to protect, use wisely, appreciate, and enjoy the Great Barrier Reef forever. Welcome to the Workshop.

THE STRUCTURE AND DEVELOPMENT OF FRINGING REEFS OFF THE GREAT BARRIER REEF PROVINCE

DAVID HOPLEY
Head
Sir George Fisher Centre for Tropical Marine Studies
JAMES COOK UNIVERSITY

BRUCE PARTAIN
U.S. Rotary Exchange Postgraduate Student
Department of Geography
JAMES COOK UNIVERSITY

Introduction

Within the Great Barrier Reef Marine Park area there are some 618 high continental islands and a mainland coastline of several thousand kilometres. Fringing reefs are common on many of the islands and are found on the mainland, particularly to the north of Cairns. Some 545 fully developed fringing reefs have been identified with a further 213 incipient fringing, reefs within the Park area. However, the.fringing reefs extend further south than the southern limits of the Marine Park and are found on the Queensland coast within Moreton Bay and extending south to the Solitary' Islands off the New South Wales coast. Further offshore the southernmost reefs in the world are found as fringes around Lord Howe Island at 31°35' south. Within'the Park the fringing reefs have a total area of about 350 km^2; small compared to the total reefal area of the oute'r reefs which are approximately 20,000 km^2.

In spite of the relatively small area, the fringing reefs are however important for a number of reasons.

1) All but three of the Great Barrier Reef resorts are located on high continental islands and fringing reefs are therefore the most easily accessible and the most commonly seen by the majority of visitors to the Great Barrier Reef.

2) The fringing reefs are closest to the mainland and therefore are most susceptible to anthropogenic influences resulting from land use changes and industrial development.

3) Although fringing reefs are limited to the inner shelf zone now, they were probably the most common reef form throughout the period of development of the Great Barrier Reef of the Quaternary period during the last 2,000,000 years. During this time low sea level phase dominated and at best, reef development occurred as fringes around older reef limestone foundations formed during the short inter-glacial periods of high sea level. At the lowest sea level stage, as for example 18,000 years ago, fringing reefs on the steep shoulder of the Continential Shelf were the only reef form occurring in Queensland. Fringing reefs therefore have an important historical part in the total development of the Great Barrier Reef. (Hopley, 1982, Ch. 6, 12)

A Structural Classification of Fringing Reefs

Over the last 13 years since the 1973 Royal Society Expedition an enormous amount of data has become available on the structure of reefs of the Great Barrier Reef through shallow drilling programmes, particularly those carried out by the Bureau of Mineral Resources (Dr. P.J. Davies), and James Cook University (A/Professor D. Hopley). Fringing reefs make up a small proportion of the data set (table 1). However, structural information, from radio-carbon dated cores is available for eight separate fringing reefs: Hayman Island (Hopley et al., 1978); Pioneer Bay, Orpheus Island (Hopley et al., 1983); Iris Point, Orpheus

Island (Hopley & Barnes, 1985); Fantome Island (Johnson and Risk, in press); Rattlesnake Island (Hopley et al., 1983); and three reefs of the Cape Tribulation area (Partain, this conference). In addition further information is available for several of the resort islands where jet probes or drilling has been carried out for jetty construction, etc.

The sea level scenario in which reef growth has taken place has been one of a rapid rise (circa. 7 mm per year) up to approximately 6,500 years ago when modern sea level was first achieved. Subsequently because of the inner shelf situation of the fringing reefs'a location in which some hydroisostatic uplift.can potentially take place, there has been a relatively higher sea level of up to +1.5 m involved in the development of the fringing reefs. This higher level was reached approximately 5,200 years ago and sea level has slowly subsided in a relative sense to its present position. Because of the relatively shallow nature of the, inner shelf within which most of the fringing reefs are situated, drowning of even the lowest portions of the sea floor around the high islands (circa. -20 m) took place only some 8,000 years ago. For mainland fringing reefs where the water depths are even less submergence probably took place little more than 7,000 years ago. However, as, noted, previously by Davies et al. (1985) there may have been a significant delay in the recolonisation of the reef foundations of the outer, reefs during the Holocene transgression which has meant that foundation dates for, the Holocene reef even for the outer reefs, are little more than 8,000 years B.P. Thus the fringing reefs of some of the outer continental islands may have been initiated at approximately the same time as their outer reef counterparts.

* The following is a suggested classification (fig. 1):

1) Simple reefs formed from the foundation on the lowest portion of the rocky foreshore during the Transgression These reefs were developed while the sea level was still rising. Most of their development has gone into upward growth over the rocky slopes of the island, following the Transgression. After the still-stand period and when the reef had reached sea level a small amount of outward growth may have been possible over the reef's own forereef talus slope. On the whole such reefs are growing from relatively deep water and reef flat development is therefore limited due to the great vertical extent of these reefs. Their structure is thus one of a basal framework unit immediatley over rock and then a small biogenic detrital frontal unit with thin reef flat veneer. Examples include the narrow fringing reefs on the windward side of the Palm and Whitsunday Islands, and probably the more narrow reefs on steep rocky shores of the Cape Tribulation area.

* 2) Reefs developed over more gently sloping substrate, particularly where older foundations of Pleistocene reefs may be present In these instances the reef foundation is initiated offshore from the present coastline, although would probably have started as a fringing reef as sea level would have been lower at the time. The rising sea level however, isolated this initial reef which continued to grow upwards during the transgressive phase as an offshore barrier. Possibly because of poor circulation and terrigenous input growth behind this barrier was very slow. After the still-stand and after

the reef had reached sea level, the outer reef became attached to 'the island by lagoonal infilling, this infill coming from both the land as a terrigenous unit and from the outer reef as a biogenic carbonate unit. Following the still-stand, some small outward growth may also have taken place. The structure is therefore one of a. framework unit offshore from the present shoreline and an interdigitated terrigenous and biogenic detrital fill behind the framework. A thin, reef flat framework veneer may be present over the entire reef and a small, reef front biogenic talus may also 'be present. The best example of this type of reef is provided by Hayman Island, developed over. an older Pleistocene reef. (fig. 2)

* 3) <u>Reefs developed over pre-existing positive sedimentary structures</u>

Reefs have long been regarded as requiring hard substrate for initiation. However, there is increasing evidence from North Queensland reefs that the presence of even a muddy sedimentary' structure with positive relief may greatly enhance or speed up reef flat development. Such sedimentary structures may be in the form of terrigenous mud/sand banks or barriers, lee side sand spits attached to islands, boulder beaches, deltaic bar gravels, and low angle Pleistocene alluvial fans. During the transgressive phase, even though' a bank may have existed previously no reef development is possible because of the inhospitable nature of the substrate. However, once the rocky shores of the adjacent island or' mainland are inundated reef colonisation takes place rapidly on these shores at shallow depth. Progradation 'of the reef is then rapid over the pre-existing structure with hard substrate now being provided over the sedimentary base by the forereef talus from the prograding reef front. The structure of such reefs is thus one of a basal terrigenous sedimentary unit, an' inner framework with a prograding carbonate detrital unit extending over the terrigenous base, and an upper, thin, generally less than 4 m, reef flat framework veneer. Examples show the range of the existing sedimentary structures, and include:

a) Pioneer Bay (fig. 3) and Fantome Island where terrigenous sand/ mud wedges provide the sedimentary foundation and were probably brought inshore by wave action during the Transgression.

b) Rattlesnake Island (and probably numerous other small islands with large, lee side fringing reefs) where the foundation is provided by lee side sand spits similar to the more recent spits developed over the top of the reefs themselves (fig. 4).

c) Great Palm (fig. 5) and Magnetic Island (fig. 6) reefs where the carbonate reef appears to be extremely thin, and developed over low angle Pleistocene alluvial fans.

d) Iris Point, Orpheus Island where the rocky shore of the island is bordered by a well sorted Pleistocene boulder beach which extends beneath the Holocene reef flat and appears to have provided the foundation of the reef flat (fig. 7).

e) The cuspate reefs of 'the Cape Tribulation area where the foundations are provided by deltaic fan gravels. Modern streams often debouching over reef flats show similar deltaic gravel fans. Changing'location of a creek mouth with migration has led to a very widespread gravel fan formation along this coast, and hence the continuity of fringing reef development. Apparent spur and groove systems on these reefs may reflect the gravel bar structures'rather than the normal high energy control which produces windward spur and groove formations (see Partain, this conference).

Comparative Growth Rates of Fringing Reefs

In a review of Holocene reef growth in the Great Barrier Reef province, Davies and Hopley (1983) indicated that fringing reefs grew at rates comparable to middle and outer shelf reefs, though usually at the' lower end of the growth scale, i.e. for framework construction in the range of l-4 mm per year. This may be in part a reflection of the greater proportion of massive as opposed to branching, framework. As with outer reefs the fringing reefs showed a bimodal detrital accretion rate, a lower range of l-5 mm per year representing accumulation under, normal weather conditions, but with higher rates up to 15 mm per year indicative of infrequent high energy cyclonic events. Data from all the drilling results of both the BMR and JCU programmes has also been plotted as growth rate against depth of water at the time of growth (fig. 8). Data used here includes results subsequent to the earlier 1983 paper. Fringing reefs show genera'lly, very low growth rates in shallow water, particularly when compared to the mid-shelf reefs which have both a protected situation and clear water. The lower rate for fringing reefs is probably a reflection of the turbid water conditions and periodic decline in salinities. However, at depths between 4 and 7 m, fringing reef growth seems to be at least equal to the rate of growth of both . mid-and outer-shelf reefs. Below this depth there appears to be a rapid decline in accretion rate. This is interpreted as the result of the high turbidity of inshore waters and rapid decline in light levels at these depths. Equivalent decline in growth rates for outer reefs takes place below approximately 15 m.

Surface Features of the Fringing Reefs

Fringing reefs, particularly the larger lee side reefs show a remarkably diverse range of morphological features. Windward fringing reefs have a zonation which is similar to that of mid-shelf reefs with a well defined energy gradient evident across the reef. Features such as algal pavement, shingle ramparts, and wide turf algal zones typify many reefs in these situations. The largest fringing reefs are frequently found on the lee side of smaller islands with minimal run-off (see Hopley, 1971). These have a remarkably similar range of features to the low wooded islands which are found on the inner shelf to the north of Cairns (see Philosophical Transactions, Royal Society London, 1978; Report of 1973 Royal Society Expedition for detail). This similarity is not surprising. Fringing reefs and low wooded islands have a similar inshore location, rising from similar water depths with similar exposure to sediment laden fresh water plumes. They also have a very similar sea level history because of their inner shelf location with a small amount of hydroisostatic emprgence of approximately l-l.5 m, approximately 5,000 years ago. The cays of the low wooded islands are reciprocated by the sandy spits extending across the lee sides of fringing reefs, both have a series of terraces with graded soil profile development across them with similar age sequences, back to approximately 6,000 years. The platform rocks of the low wooded island have their equivalent in the beach rock terraces, both extending over emerged micro-atoll fields. Basset edges formed by the cementation of shingle ramparts are also found in both environments. Mangroves with associated peats up to 1 m in thickness can also be found on both low wooded islands and lee side fringing reefs. Shingle ramparts are common and the moated pools which they enclose contain large micro-atoll pools. Variations in the rampart systems due to cyclonic interference has been reported from both low wooded islands (e.g. Moorhouse, 1936) and high island fringing reefs (e.g. Hopley & Isdale, 1977).

Questions and Problems relating to Great Barrier Reef Fringing Reefs

This Workshop is deservedly giving fringing reefs the prominence which they have formerly lacked. A review of the geomorphological research already carried out on these reefs suggest that there are a number of prominent questions which need to be addressed in the near future.. These include:"

(a) With the exception of the foundations of Hayman Island reef and also Cockermouth Island reef formed from dune calcarenite there are no reports of Pleistocene last inter-glacial reefs from either the mainland or high islands. Pleistocene foundations of the modern reefs are almost without exception non-carbonate. This is in spite of the fact that the last inter-glacial high still-stand a few metres above present sea level is well documented for mainland locations. The question arises as to whether or not it was possible for near shore reefs to'develop during the last inter-glacial and if not, why not? Alternatively it is possible that severe erosion has taken place which has removed all visible vestiges of these earlier reefs. This is not the case however, elsewhere in the world, and it is most probable that there was a very poor development of such reefs 125,000 years ago. This question requires further research.

(b) Fringing reefs clearly can be highly productive in terms of laying down a carbonate framework, even in areas apparently non-conducive to reef growth. Why should this be so? Is it possible that there are specialised communities which will survive in the more fluctuating environment of the near shore zone as compared to the outer reef? Further ecological work on near shore communities is obviously required.

(c) For the mid- and outer-shelf reefs the major geographic variation in growth rate and framework construction appears to be longitudinal across the shelf rather than latitudinal. However near shore waters have much greater latitudinal environmental variations than do the mid- and outer-shelf waters, and to date. information on fringing reefs is limited to the Central Section of the Great Barr'ier Reef. Further work is needed on both reefs at the southern end of the Great Barrier Reef Marine Park and extending as far north as Torres Strait. This may indicate some significant south to north gradients for these near shore reefs.

(d) The southern limits of significant fringing reef development off the Queensland coast provide a fascinating research question. At about the latitude of Mackay in the Cumberland group of islands, there is a very sharp line of demarcation between wide, well developed fringing reefs to the north and poorly developed (at best, incipient) fringing reefs to 'the south. The reasons for this are being investigated and may include effects of the greater energy related to high tidal,range, the effects of open ocean swells and Tasman Sea waters entering into the Great Barrier Reef region via The Capricorn Channel, or alternatively the effects of the flow from the Fitzroy River, Australia's second largest river system. An understanding of the distribution of reefs in this area is seen as particularly significant as the region has the greatest concentration of tourist development of any part of the Great Barrier Reef.

(e) Further work is requir'ed on the viability of near shore fringing reefs. 'Because they are so close to the mainland they will be the first to feel the' effects of any pollution or man-made perturbation and therefore, in many respects may be seen as the initial monitors for the whole of the Great Barrier Reef province. Degradation of some fringing reefs (e.g. in the Bowen area) has been documented for over 50 years. However, many of the comments made are based on qualitative, subjective information and it would seem appropriate at this time that a more scientific approach be adopted towards the monitoring and detailing of the immediate past history of the fringing reefs.

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Table 1

DATA BANK FOR NORTH QUEENSLAND FRINGING REEFS

Reef	No. Holes	Max. Depth (m)	No. C^{14} Dates (incl. reef flat)	Oldest Holocene C^{14} Date	Oldest C^{14} Date within 1 m of Reef Flat Level
Iris Pt., Orpheus Is.	7	8	12	7320 $\pm$ 125	6260 $\pm$ 120
Pioneer Bay, Orpheus Is.	3	17.25	10	6610 $\pm$ 250	5970 $\pm$ 100
Fantome Island	3	10	17	5520 $\pm$ 100	5520 $\pm$ 100
Rattlesnake Island	1	10	5	7010 $\pm$ 180	5530 $\pm$ 130
Hayman Island	6	47	15	9320 $\pm$ 730* (8300 $\pm$ 500)	4090 $\pm$ 150
Cape Tribulation Reefs					
. Rykers Reef	4	6.95	8	n.a.	n.a.
. S. Myall Reef	3	8.3	4	n.a.	n.a.
. Emmagen Reef	2	5.8	3	n.a.	n.a.

* Questionable Date

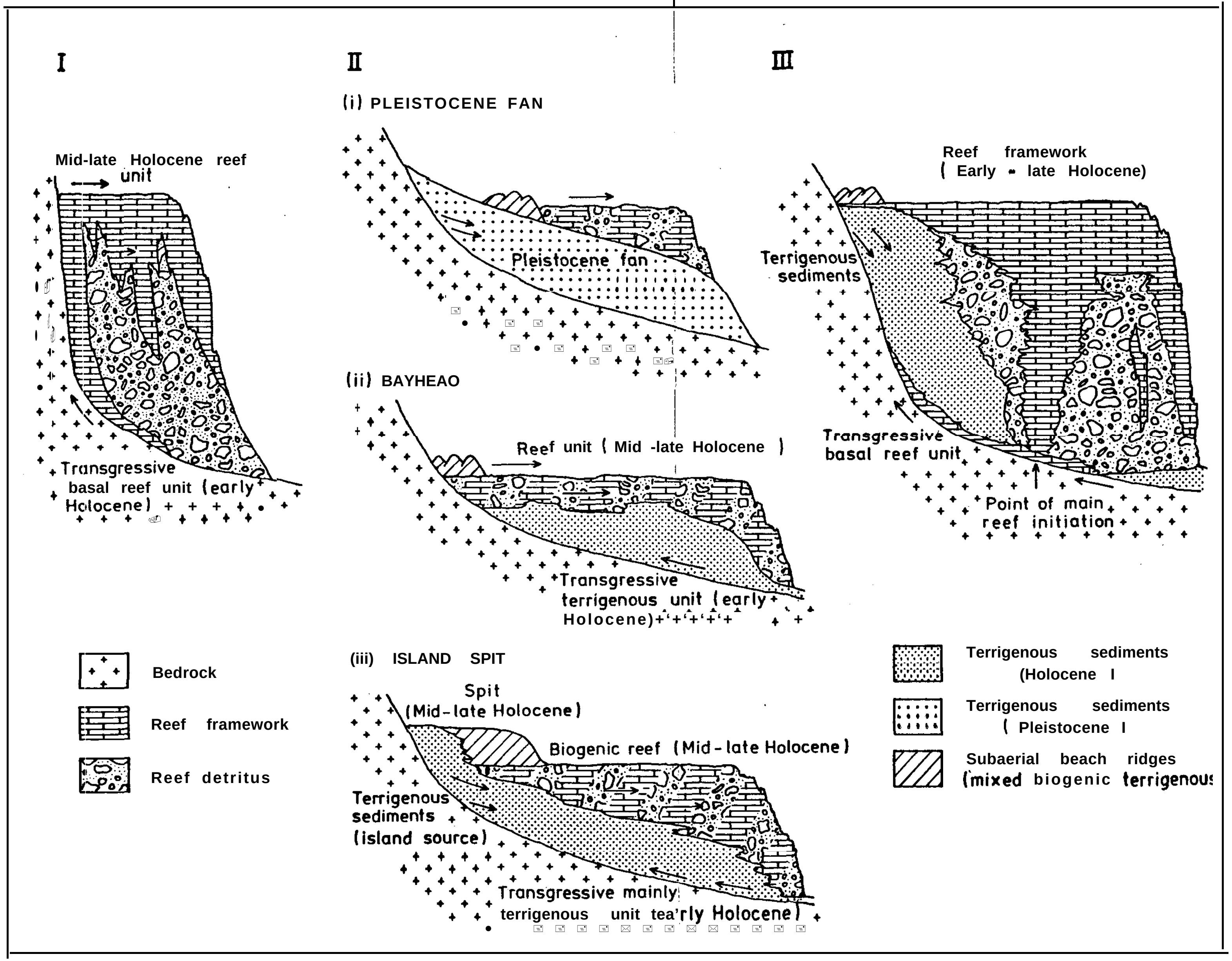

Figure 1: A Structural Classification of Fringing Reefs

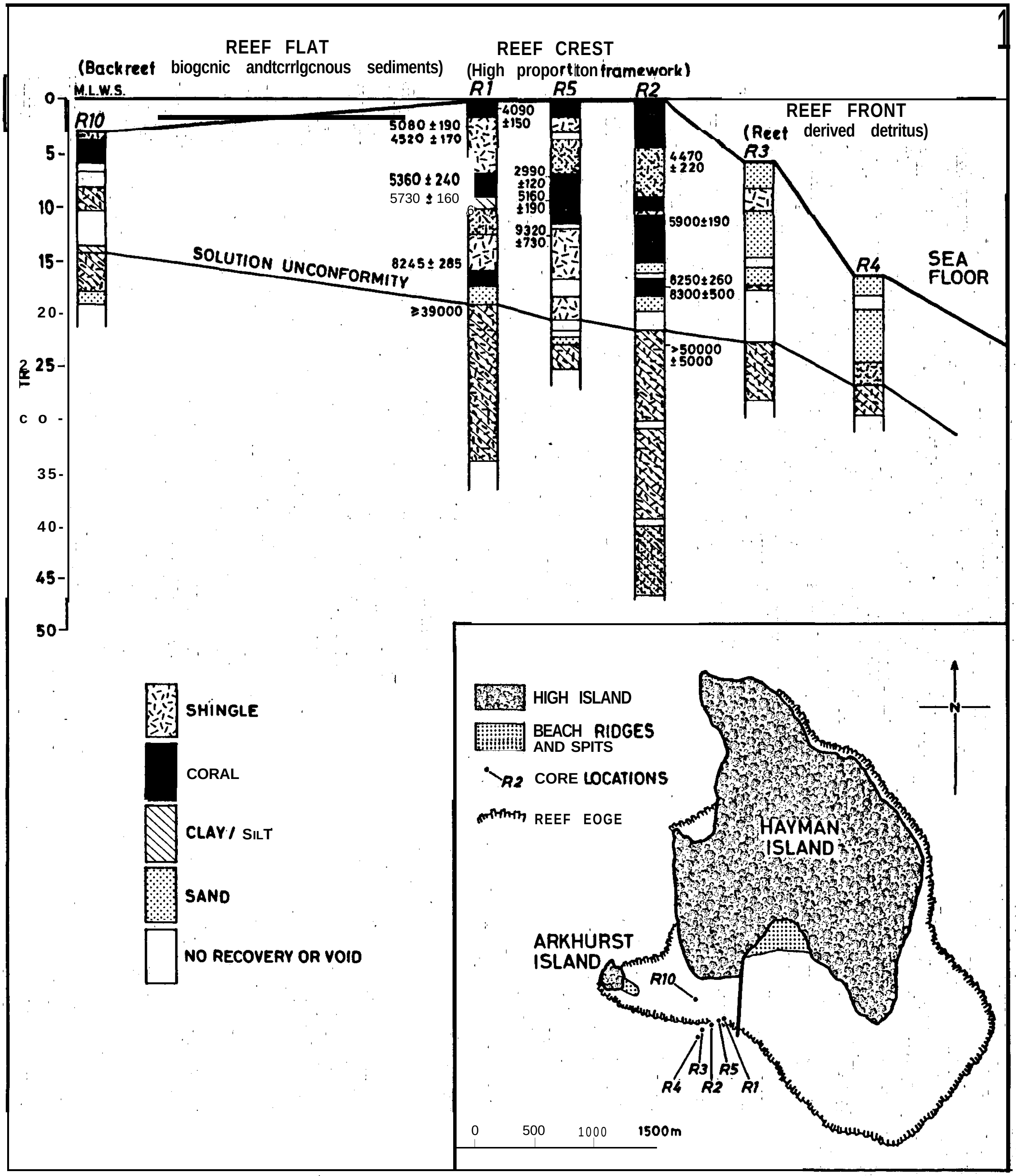

Figure 2: Hayman Island Fringing Reef

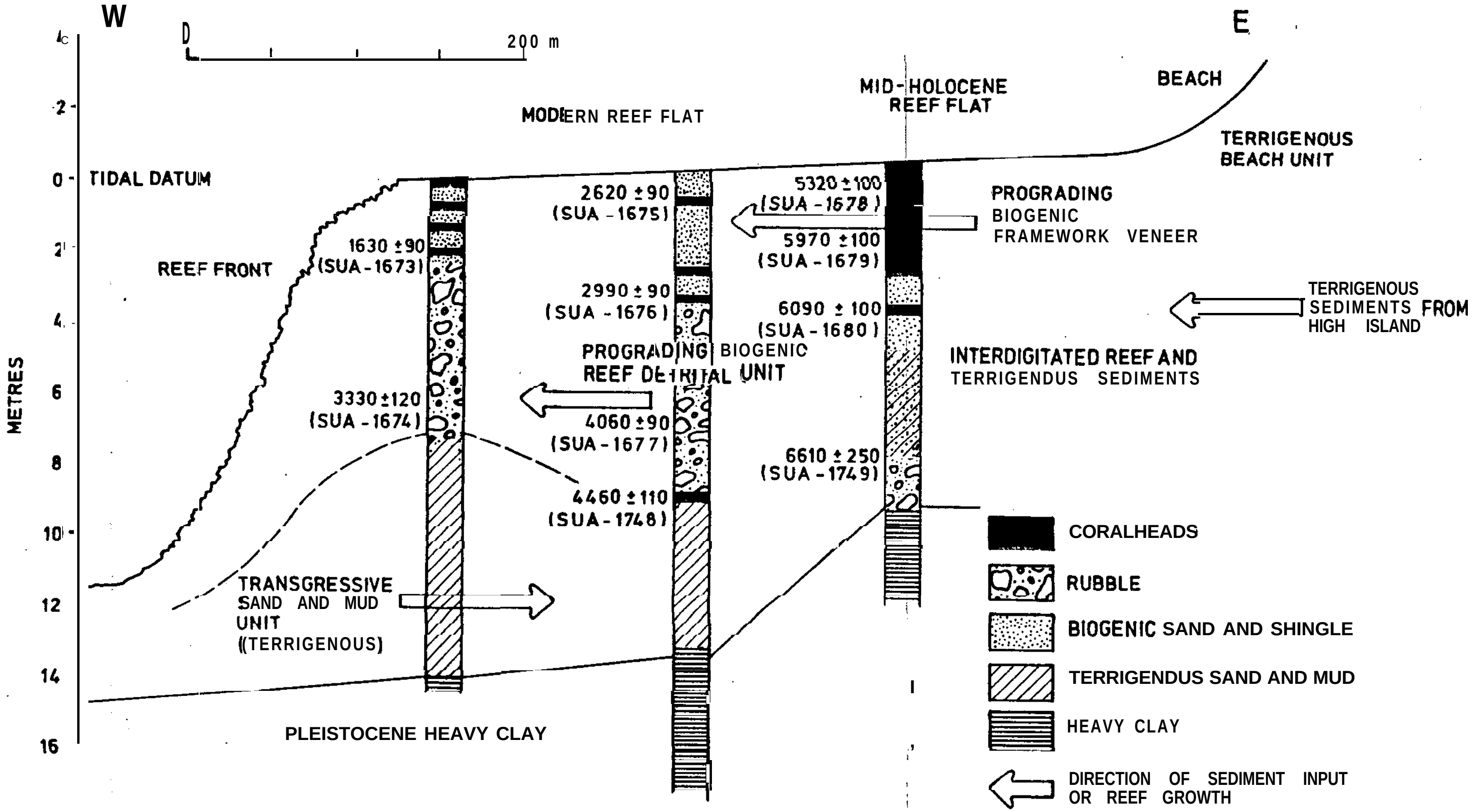

Figure 3: Pioneer Bay Orpheus Island Fringing R&f, Section and Dated Drillholes

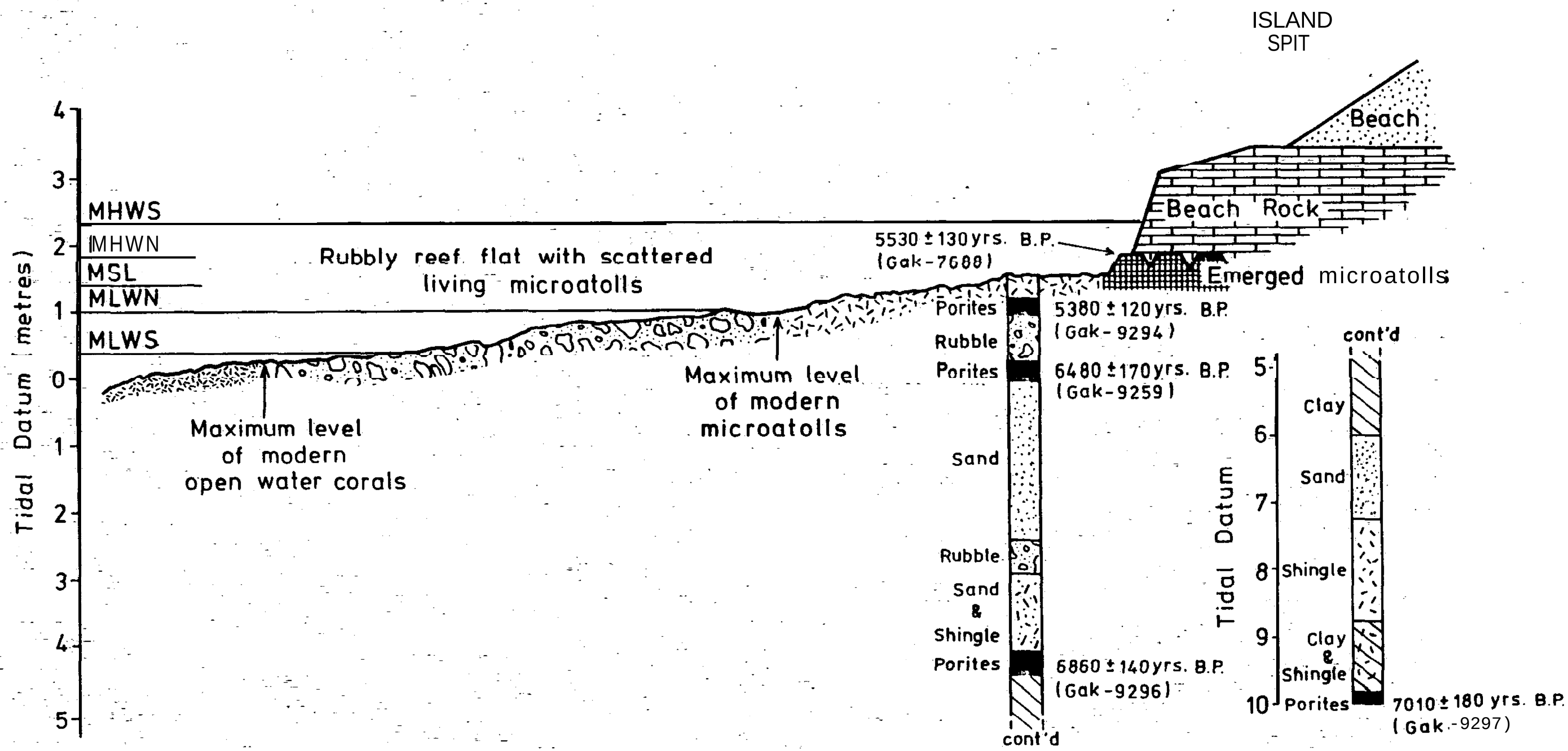

Figure 4: Results of drilling Rattlesnake Island Fringing Reef

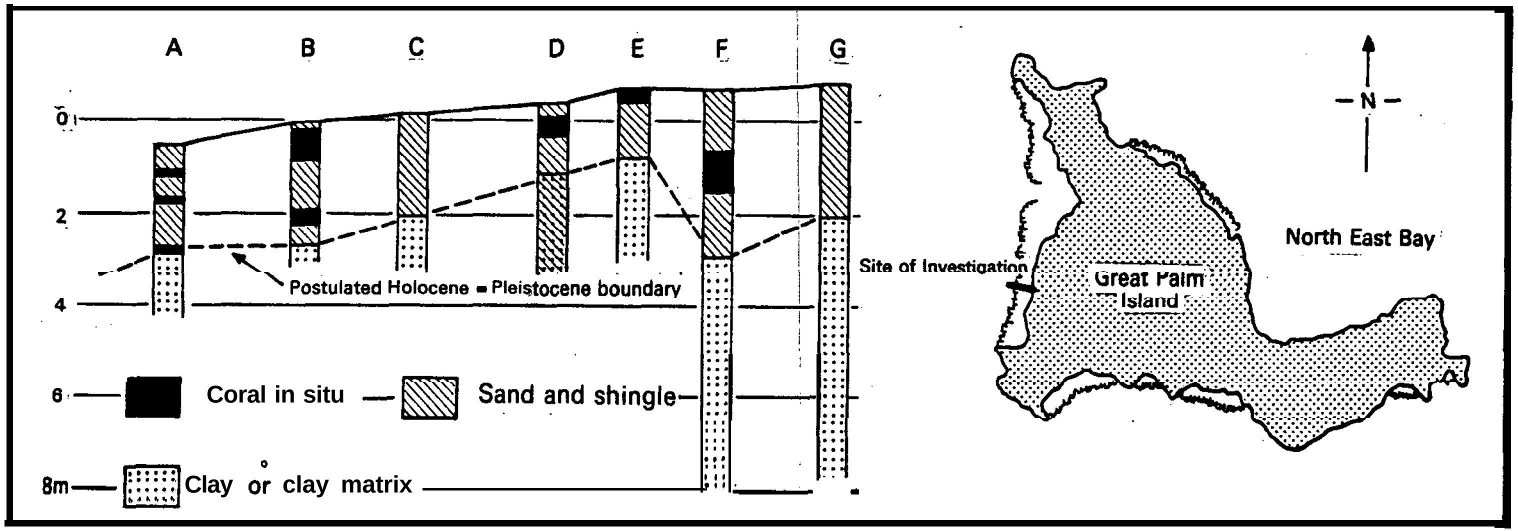

Figure 5: Structure of Fringing Reef by Aboriginal Settlement Great Palm Island based on engineering jet probes.

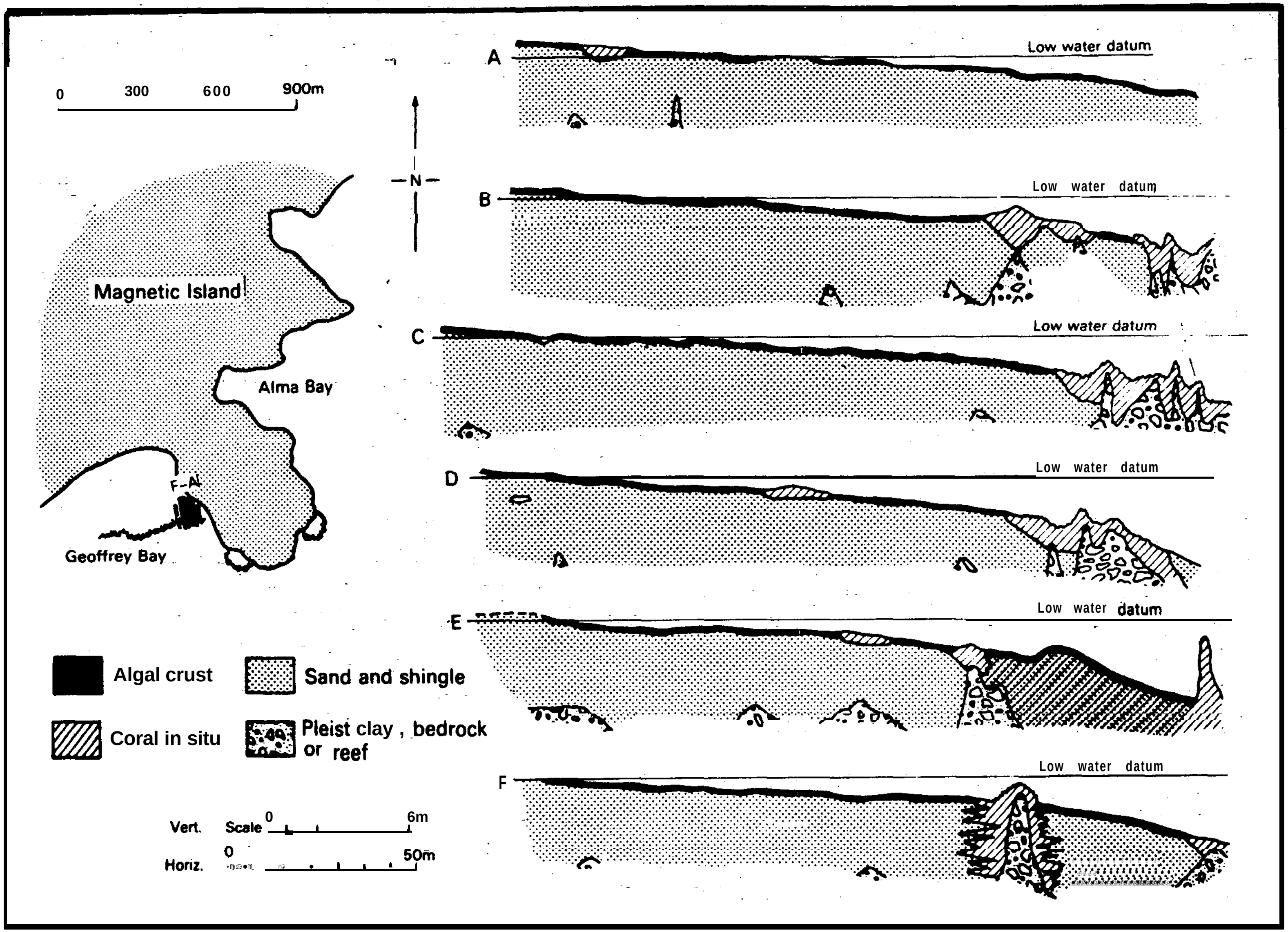

Figure 6: Geoffrey Bay Magnetic Bay Fringing Reef Structure from jet probes

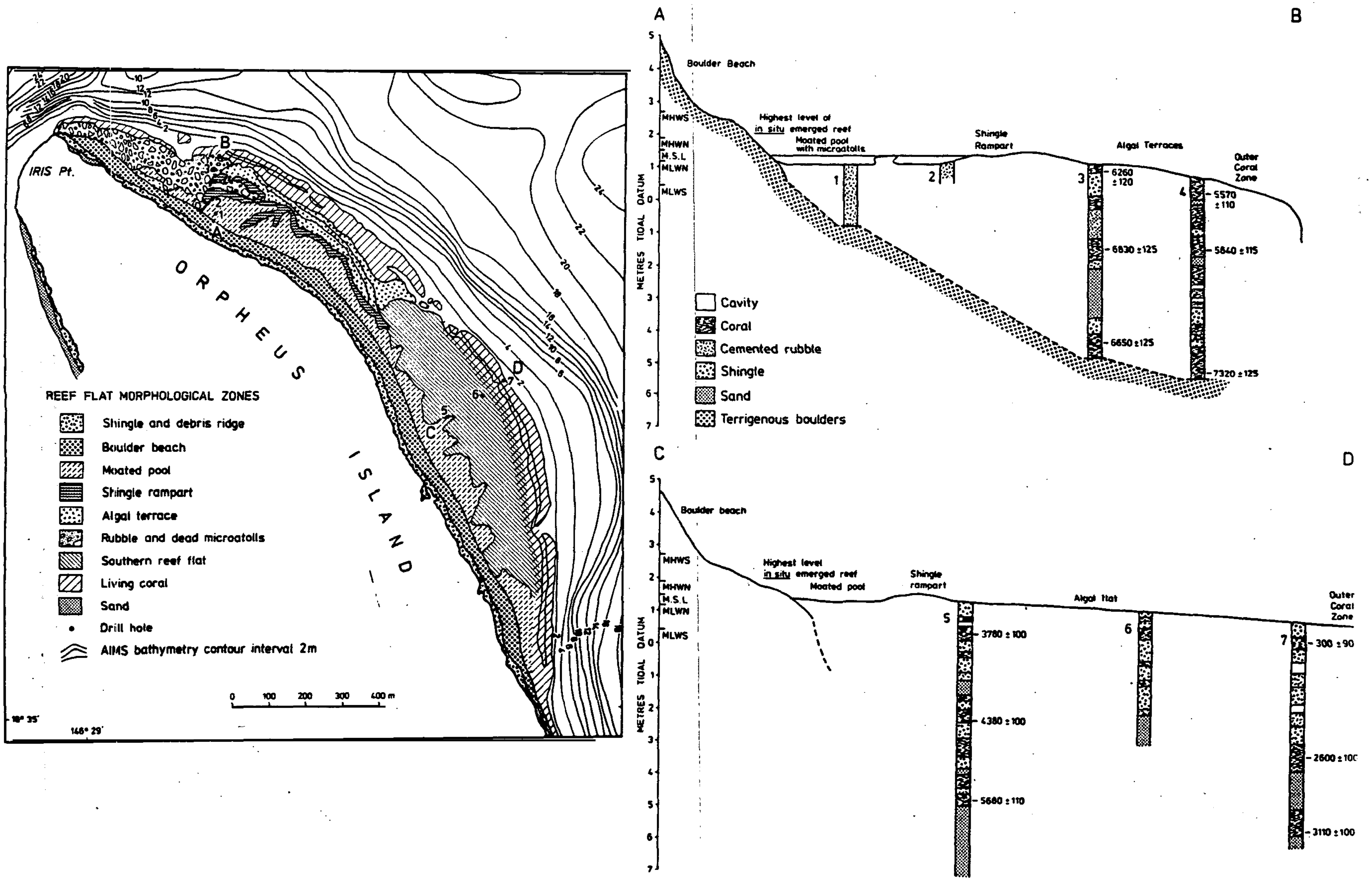

Figure 7: Iris Point Orpheus Island Fringing Reef Structure

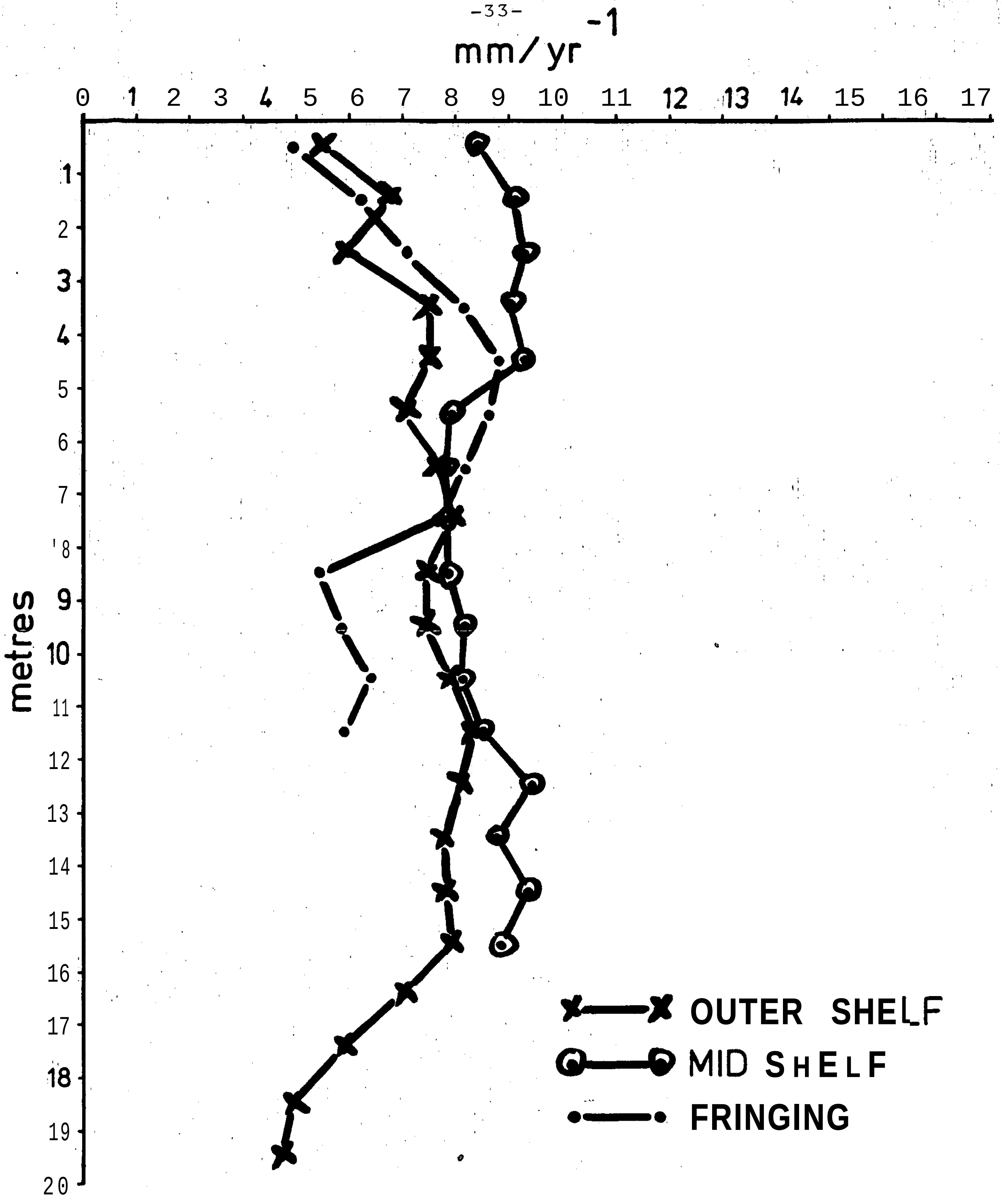

Figure a: Growth Rate versus depth of water for Fringing mid-shelf and outer-shelf reefs, Great Barrier Reef.

ZONATION AND DISTURBANCE IN' CORAL COMMUNITIES ON FRINGING REEFS

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This meeting asks the question "what's different or special about fringing reefs ?" I hope to show you two things:

First, that being adjacent to an island or the mainland provides environments which result in the development of some biological communities which are distinctive yet superficially similar to those found on open water reefs. Here, I refer to the zonation patterns of hard and soft corals and algae as compared with those on open water reefs.

Second, I suggest that because natural frequencies of catastrophic physical and biological disturbance in sheltered sections of the shore are very low, coral structures with unusually long return times can develop. I refer in particular to the large size and old age reached by individual corals.

Zonation Patterns: There are hundreds of species of corals, soft corals algae and many other organisms which attach to and form part of the coral reef structure. These are divisible into 'communities' which are defined by different forms of plants and animals which live together in the same zone of the reef. Zonation schemes are used to summarize the distribution of communities on reefs but I know of no scheme for fringing reefs on the Great Barrier Reef.

A zonation scheme for open water reefs off Townsville is presented in Table 1. This scheme relates the distribution of communities to the degree of exposure to waves. Wave exposure varies with depth and aspect on any single reef, as well as across the continental shelf. It is a very low resolution scheme which serves to illustrate only very broad similarities ; each community type contains a great deal of variability at the level of genus and species and there is considerable overlap in the composition of the communities (Done 1982).(The organisms listed in parenthesis in Table 1 are present in communities dominated by corals and in some places, they are more abundant than corals, sometimes as a result of recent disturbance - see below).

These communities track wave exposure on reefs as shown in Fig.1. Note both the absence of communities 1 and 2 from nearshore reefs (reflecting their lack of oceanic swells) and the upward shift in the depth range of communities in backreefs (reflecting the shelter provided by the reef platform). These general trends have been described on coral reefs throughout the world (e.g. Barnes et al. 1972; Rosen 1975, Geister 1977, Done 1983 - review). Observations by the author on fringing reefs at Murray Islands (outer shelf), Lizard Is (mid-outer shelf), Palm Islands, Whitsunday Islands((nearshore), Starke River, Cape Tribulation (mainland) suggest that, the same general trends apply to fringing. reefs as open water reefs.

The composition of the biological communities vary down reef slopes, across reef flats'and along the coast, tracking wave energy environments broadly in accordance with Table 1. For a given fringing reef system, the absolute wave energy levels and the extent of the exposure gradient (hence the local zonation 'patterns) depend 'on the location of the reef on the continental shelf, the depth of the sea floor, and the complexity of the coast line. Islands with the greatest gradients in exposure plus the most complex coastlines and hence the greatest variety of habitats., have the greatest variety of community types. Conversely, open mainland coast or small and simple islands without sheltered embayments and a limited exposure gradient have a greatly reduced diversity of community types.

Return times for disturbed coral communities:

While low resolution zonation schemes such as Table, 1 and Fig.1 describe gross trends in the distribution of communities, it is also important to consider potential and actual changes in biological communities, as they respond to local ecological factors and to externally imposed disturbances which occur from 'time to time .Disturbance by storms, increased siltation, pollution or mass predation of corals may cause widespread and sudden shifts from coral dominance to algal dominance (severe disturbance) or to a lesser dominance by corals (intermediate disturbance).

The coral communities of sheltered bays and coasts are of considerable interest because such locations are favoured by man as well as by corals. While corals can attain great size, very old age (to several centuries) and/or very high densities in many reef habitats, sheltered bays are frequently characterised by coral populations with all three of these characteristics simultaneously (Potts et al. 1985) . The development of such populations is an indication of the ability of individual corals to persist in conditions which, until recently, were presumed to be stressful for corals, namely, high sediment loads, poor illumination, high variability in salinity.

There are management implications in this observation' 'which are as yet unresolved. Should it be assumed that the coral species involved are tolerant to conditions which are deleterious to other corals, and by implication, capable of tolerating increased stresses imposed on the reefs by human usage or adjacent land practices? Or should we conclude that the conditions have not been stressful, that the present dense populations of large colonies have developed simply by the present colonies occupying space and pre-empting its occupation by other colonies or by more opportunistic species ? A rider to the second interpretation is that physical and biological disturbance of a type that kills corals episodically and opens up space for new settlement must have been rare. This carries the implication that additional stresses and disturbances associated with human usage and adjacent land use practices might not readily be absorbed, and that widespread coral mortality may result.

The time for restoration of the previous adult-dominated coral populations is often measured in decades to centuries, depending on the extent of mortality, the coral species involved, and the population structure prior to the disturbance. Coral communities of fast-growing species such as Montipora and **Acropora** can displace dominance by the seasonal brown algae Sargassum **'in** the space of a decade (Done and Navin, in prep.) whereas slow-growing corals such as Porites , where they are locally dominated by colonies which are centuries old, may have much longer replacement times, depending on the severity of the disturbance (Done in prep.). The issues for conservation and mahagement of these very old communities are comparable to those relating to rainforest trees as in both cases, the old individuals contribute significantly to the physical structure of the habitat, and individual replacement times far exceed human life spans.

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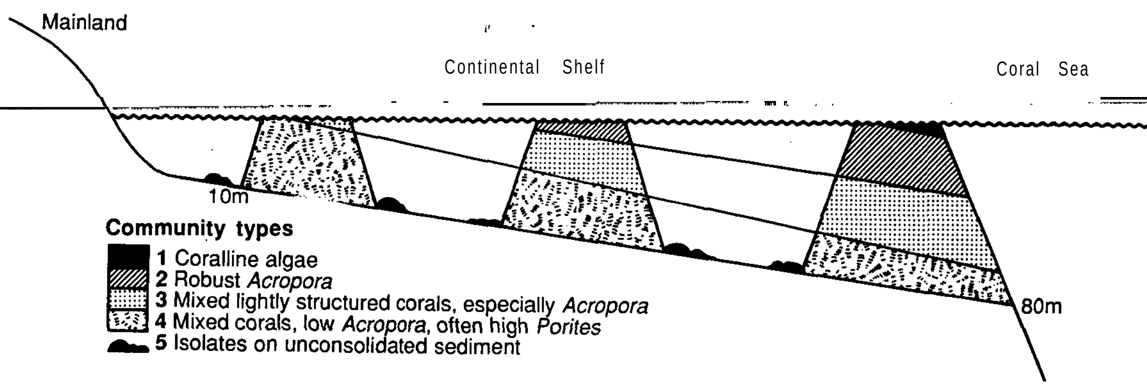
Table 1

Comparison of Fringing Reef and Open Water Reef Communities (Corals and Algae)

Broad Community Types of Open Water Reefs		Fringing Reefs
1. coralline *algae* dominant (+ algal turfs)	Exposed	1. not seen on gbr fringing reefs except with corals
2. robust Acropora dominant (+ algal turfs and various macro algae)		2. mid-shelf fringing reefs, surf zones
3. mixed corals, high diversity, often dominated by more lightly structured forms, especially Acropora . massive corals present (+ various macro algae, alcyonarians (soft corals))		3. **a)mid-shelf** fringing **reefs,slopes** b)nearshore fringing reefs frequently:- i) cohabitation with Sargassum ii) replacement by Sargassum
4. mixed **corals,** high diversity, low acropora, often high Porites (+ soft **corals)**		4. a)mid-shelf fringing reef-leeward bays b)nearshore fringing reefs i) high densities,, -large sizes ii) mud adapted 'morphology and life histories
-5. coral isolates and solitary **corals** on uncolidated sediment (usually sand)	Sheltered	**5.** a)mid-shelf - lagoon floors, sand -terraces **b)nearshore** fringing **reef s -** muddy sea floor

Figure 1.

Figure 1.



CORAL POPULATIONS FRINGING ISLANDS: LARVAL CONNECTIONS'

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ABSTRACT

Connectivity in natural systems is a central issue in predicting not only how 'far a perturbation at one point will spread through a system, but also the role the rest of'the system will play in that point's recovery. Population genetics studies are well placed to estimate the level and pattern of connectedness for 'a system's component species. This paper compares estimates of;' 'connectedness between populations of Pocillopora damicornis on fringing reefs around an island, Rottnest Island off southwestern Australia, with estimates for populations on patch reefs within an embayment of similar' size, Kaneohe Bay on the northeastern coast of Oahu, Hawaii.

Pocillopora damicornis utilises two modes of larval dispersal; one operates over short distances and involves a,, brooded, asexually-produced, planula;, the second acts over longer distances and involves a sexual propagule. When examined genetically, larval connections between definable populations were weaker between fringing reefs around an island than they were between patch reefs in an embayment of similar dimensions. Differing hydrodynamic regimes are inferred to explain this pattern.

Estimates of genetic similarity between populations at each area were calculated on a basis designed to reflect either the spread of clones by asexual reproduction, the dispersal of sexually produced propagules, or a combination of both. The major' difference between, the pattern of genetic structure of the' populations around Rottnest Island and the pattern of those within Kaneohe Bay resulted from the extended distribution of clones within the latter set. The most likely explanation for the paucity of shared clones among the Rottnest Island reefs is that once larvae are swept offshore from these small embayments they are almost never returned to the, island. However, in Kaneohe Bay the water has a substantial period of residence allowing a greater proportion-of the recently produced planulae to settle. This settlement most probably occurs on a reef adjacent to the site of planulae production. Recruitment from sexual reproduction plays a minor role at Rottnest Island but has virtually no influence in Kaneohe Bay.

This comparison suggests strongly that in Pocillopora damicornis, and presumably those species of coral with similar modes of reproduction, patch reefs within large embayments are strongly. connected in a stepping-stone fashion as a result o'f obtaining the bulk of their recruits, from asexually produced planulae orginating from neighbouring reefs. Populations in isolated embayments fringing islands receive the majority of their recruitment from larvae with significant dispersal capability, presumably resulting from sexual reproduction, which originate from sites outside the system. They 'are connected weakly in a pattern following an 'island' model.

The implications of this result are:

1) patch reefs like those of Kaneohe Bay will recover from major perturbations faster than those located in embayments fringing islands,

2) perturbations at a single reef within a large embayment may produce noticeable effects on adjacent reefs, while similar disruption in an isolated fringing reef should have no 'distant' effects,

3) the greater genetic isolation of fringing reefs in situations like those around Rottnest Island is likely to produce unique populations, while one patch reef will be much like another.

Taken together, results 1 and 3 point to the special consideration which must be given to the conservation of fringing reefs if we wish to retain the rich variety of reefs which occur in such areas.

CORAL OR ALGAL REEFS?

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ABSTRACT

Photosynthetic plants occupy a central position in all living communities, and reefs are no exception. In terrestrial communities plants are usually the largest and most obvious organisms, and their importance cannot be ignored. In reef communities on the other hand, certain animals, such as corals, are larger and more conspicuous than most of the plants, whose vital importance may therefore be underestimated. Although many of the species present are small, and even microscopic, plants dominate reefs in terms of overall surface cover and biomass, and are responsible for the high productivity of reef communities.

The major group of photosynthetic plants in reefs is the algae, although seagrasses and mangroves may also be present. A wide variety of algal species occur as normal inhabitants of reefs; from a structural and functional point of view they can be categorized in the following way:

1. Phytoplankton - free floating, and mostly unicellular and microscopic plants (eg., Trichodesmium, 'sea sawdust'). The contribution of phytoplankton in reef communities is generally considered to be insignificant.

2. Benthic (attached) algae - ranging from microscopic, unicellular plants to seaweeds several metres long. These benthic algae are the most abundant and important plants in reefs, and include:

   A Seaweeds (the more familiar and mostly macroscopic algae)

      (i) Fleshy (non-calcareous) seaweeds, including large and, erect types (such as Sargassum spp.) and the minute, creeping turf algae.

      (ii) Calcareous seaweeds, including the larger, mostly erect and jointed forms (such as Halimeda, spp.) and the encrusting coralline algae.

   B. Perforating algae - microscopic species which actively bore into calcareous reef materials, such as reef rock, calcareous algae, and the skeletons of hermatypic corals. They produce vast numbers of minute channels which greatly weaken the surface of shallow-water substrates.

   C. Symbiotic algae, comprising a range of algal species living in association with a variety of reef animals. The best known are the zooxanthellae, which are intimately associated with all reef building corals, and represent about one-third of the living tissue in a coral colony.

The larger seaweeds are the most conspicuous algae on reefs, and are particularly abundant on fringing reefs. Many of the other macroalgae are overlooked by the reef visitor, and even by some reef scientists!

The various types of algae perform several vital functions in reef growth and maintenance, such as:

- primary production, the basic energy. input into the system via photosynthesis (all algae, particularly turf algae); .
- cementing (especially crustose coralline algae);
- sediment formation (especially species of Halimeda);
- bioerosion (the perforating algae); and,
- nitrogen fixation ('some turf and perforating algae, and Trichodesmium).

Research into the activities of algae, in terms of the rates of these processes in reefs, has only been undertaken in the past few decades, and only a sketchy picture is so far available. It has, however, been shown that algal-dominated communities on reefs can achieve higher rates of primary production than coral-dominated communities, and equal, rates of calcification. In relation to the reef foundation, Maxwell has published the following approximate average composition of reef rock and surface sediments in the Great Barrier Reef:

corals	28%
coralline algae	30%
Halimeda spp.	30%
foraminiferans	10%
other organisms	2%

Because of the dominance of algae in both the living community and the reef foundation, the term 'algal reef' would be more appropriate than 'coral reef'. However, both terms lay undue emphasis on only one particular group of organisms in an extremely diverse and complex community. In view of the presence and importance of a wide variety of plants and animals in reefs, it has been suggested by Womersley and Bailey that the most suitable term would be 'biotic reef' (or living reef).

With regard to fringing reefs in the Great Barrier Reef Region, an important biological characteristic is the generally high cover and biomass of large. (particularly brown) seaweeds, especially on the reef flat, where coral cover may be very low. Dramatic changes . in the composition and biomass of the seaweed vegetation take place through the year. Many of the species are effectively annual, with rapid growth rates and relatively short life spans. Some of the production is consumed by grazers, while much of it breaks away following reproduction; dense bands of drift algae may form on the beaches behind fringing reefs at this time. Considerable inter-annual variation in the peak biomass of some of the seasonally abundant species has been observed.

In terms of algal species composition, fringing reefs are broadly intermediate between shelf reefs and mainland rocky shores. Large brown algae, for example, are abundant on rocky shores in the region, but are almost absent from most shelf reefs.

Probably the best studied fringing reef in Australia, from the biological aspect at least, is Geoffrey Bay on 'Magnetic Island. The distribution and abundance of the algal and coral species has been well documented by James Cook University students and staff, and the strong seasonal changes in the algal vegetation recorded. In addition to these descriptive studies, seasonal changes in the biomass and productivity of the algae, and the rate of production of algal detritus, have more recently been monitored,, (Morrissey and Pichon, pers. comm.). The fate of this organic detritus is yet to be determined,, but most of it probably remains within the reef system itself. Some of the algal production appears to be exported from the fringing reef, as 'large plants of <u>Sargassum</u> have been recorded drifting among mid-shelf reefs from which the genus is absent.

It seems probable that the seasonal development of dense beds of large algae strongly influences populations of other reef organisms, both plant and animal. Those organisms closely associated with the individual algal thalli might be most affected, but the algae may also compete with corals for resources such as space, light, and nutrients. This is an area where further research is needed. There is also little infbrmation on the level of grazing on the algal vegetation, and the grazers involved. The ultimate fate,and significance of algal detritus in the reef system also remains unclear.

The patchiness, strong seasonal changes, and inter-annual variations in the seaweed vegetation are important considerations in any monitoring programs on fringing reefs. In addition, algae can respond dramatically to environmental changes, and there may well be species which would serve as useful indicators of marked shifts in the reef environment due, for example, to coastal development.

In addition to its scientific importance, the diverse flora of reefs holds considerable interest for the environmentally aware reef visitor, because of the variety of colour, size, and form, as well as the range of ecological function. Australian publications which cater for this general interest are now readily available.

FRINGING REEFS OF MAGNETIC ISLAND

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The fringing reefs of Magnetic Island are all sited on the south-west sides of headlands (Figure 1). The extensive growth of reef platforms in Geoffrey and Nelly Bays has allowed the southern ends of these reefs to become exposed to the north-easterly swells and wave action. The large Cockle Bay reef has grown in protection from wave action. Thus the fringing reefs of Magnetic Island are exposed to conditions that range from very protected to moderately exposed. This range of conditions no doubt contributes to the high species diversity (over 100 species, see appendix) found around the Island.

The approximate sizes of the reefs can be found in Table 1. These sizes refer only to the reef areas where living coral may be encountered, and does not include sand flats that form behind the larger reefs (Cockle, Geoffrey, Nelly and Picnic Bay reefs). It is difficult to define the area where live coral exists on Cockle Bay reef, and the size is only a rough estimate.

Table 1.
Size of corals reefs around Magnetic Island (in hectares)

Florence Bay	5.1	Gowrie Bay	1.9
Arthur Bay	5.3	Alma Bay	1.0
Geoffrey Bay	31	Nelly Bay	43
Picnic Bay	10	Maud Bay	5.2
Wilson Bay	1.4	Horseshoe Bay	(l.8) est.

Cockle Bay (isolated reef)' 47
Cockle Bay (main Reef) 218, (estimate)

Isolated coral colonies and small coral communities can often be encountered along many of the rocky shores. These may only be considered as reefs if an adequate accumulation of reef material is present. The reefs in Wilson and Alma Bays are probably very close to the lower size limits to be considered as fringing reefs.

Because of their proximity to Townsville and James Cook University, the fringing reefs of Magnetic Island have been well studied by geomorphologists and biologists (e.g. Bull 1982, Morrissey 1980). The majority of studies have, and continue to be, centred in Geoffrey Bay. The high diversity of corals (nearly one third of the species that can be found on the Great Barrier Reef), and the range from exposed to sheltered conditions, together with its general accessibility all contribute to this reefs' popularity.

The present reefs have been in existence for over 6000 years, and although they have a long term geomorphological presence, the species mix may well have changed during this time, in response to climatic and other environmental changes. In the past 15 years two major events that dramatically changed the proportions of coral species on the fringing reefs were observed. The first was cyclone "Althea" in 1971, and the second was the "bleaching event" of 1982.

Many coral colonies were broken and overturned by the storm seas associated with cyclone "Althea". The most significant damage however was caused by the excessive freshwater runoff associated with "Althea" and, a few days later, the rain despression associated with the Gulf cyclone "Bronwyn". The freshwater dilution of the waters around Magnetic Island caused the deaths of many of the shallow colonies (Collins, 1978.). Regrowth of fragmented corals and resettlement of coral larvae on the dead skeletons eventually obliterated the effects of the cyclone after about 10 years.

The cause of the "bleaching event" of 1982 is not known with any certainty. The bleaching of corals was observed on many other coastal reefs in 1982, even as far north as Decapolis Reef near Lizard Island; and on the outer edge reef of Myrmidon. Oliver (1985), has reviewed the bleaching events on the Barrier Reef and concludes that temperature stress, in the summer may cause bleaching.

On Magnetic Island the bleaching caused the depletion, of some species more than others. Pocillopora and Seriatopora were so severely depleted that many hours of searching did not reveal any remaining living colonies. Large areas of plate and encrusting Montipora were also killed - reducing the coral cover on thirty metre transect lines from 40-60% live coral to 0% cover.

In much the same way that the reefs recovered from the cyclone damage, the effects of the bleaching are now not evident on the Magnetic Island reefs. Larval settlement, and the growth of survivors has returned most areas to the same degree of coral cover that existed before the bleaching. It is interesting to note that plate corals regrew in areas previously occupied by plate corals. This suggests that the coral zonation patterns of the fringing reefs are maintained through time, even though the proportions of the individual components may change dramatically with time.

Small scale bleaching of corals has been recorded as a fairly frequent event on the Magnetic Island fringing reefs. The cause of this bleaching is not known, but may be derived from a variety of stress factors e.g. high summer temperatures or rain dilution of sea water.

For many years the effects of the dredging of the harbour channel on the reefs in the Townsville area has been discussed, in the local newspaper. Even within, the last month statements that "there have been two reefs in the area destroyed by dredging" were made. There has not been a single documented study that has shown that dredging has caused any damage on Magnetic Island reefs or even those closer to Townsville such as Middle Reef or Virago Shoal. The reef destruction statements have arisen from unsubstantiated reports in the popular press. Even within Townsville Harbour, with its regular, dredging,, at least 10 species of coral have been identified growing on the breakwater. The continued surveillance of transects on, Magnetic Island Reefs will indicate any long-term changes in coral populations. Should, marked changes be noticed, it would however , not be easy to identify the causative agents. Transect monitoring allows an estimate of short-term natural changes to be assessed, and should prevent the type of popular speculation, that has occurred in the past.

One of the observations that has fuelled the dredging controversy has been the amount of dead coral seen on the reef flats. Studies on Magnetic and other island fringing reefs indicate that live coral cover on reef flats is characteristically less than 10%. The cover of live coral on the reef slope (that is not exposed on low tides) can be as high as that on any Barrier reef. The lack of visibility on these coastal reefs does limit the visual impact of the coral cover. The presence of large macroalgae also gives the appearance of a lowered coral cover.

The fringing reefs of Magnetic Island provide an easily accessible resource to the visitor, but must not be viewed as a substitute for the main barrier reefs, for in comparison they would fall very short. Educational visits seem to be one of the main reasons for people to visit these reefs at the present time. As an educational resource they are invaluable, providing access to a variety of educational levels, from primary school to tertiary level. It is hoped that the proposed snorkelling trails will facilitate the education process and make student and tourist alike more reef aware.

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-Appendix - Magnetic Island Fringing Reefs

This species list has been compiled from records 'of species in the AIMS coral monograph series and various recent collections made by the author. It is not definitive, and represents a preoccupation with some species groups. Corals known to be present on the fringing reefs, but not recently collected or in the process of investigation include:-
Diploastrea, Caulastrea, Cyphastrea, Mycedium, Echinopora and Euphyllia.

Family Thamnasteriidae
Psammocora contigua
Psammocora haimeana
Family Pocilloporidae
Pocillopora damicornis
Stylophora pistillata
Family Faviidae
Favia favus
Favia pallida
Favia maritima
Favia rotumana
Barabattoia amicorum
Favites abdita
Favites flexuosa
Favites pentagona
Favites russelli
Favites bennettae
Goniastrea retiformis
Goniastrea aspera
Goniastrea cf. favulus
Goniastrea pectinata
Goniastrea australiensis
Goniastrea palauensis
Platygyra daedalea
Platygyra lamellina
Platygyra sinensis
Hydnophora exesa
Montastrea valenciennesi
Plesiastrea versipora
Leptastrea purpurea
Leptastrea transversa
Moseleya latistellata
Family Trachyphyllidae
Trachyphyllia geoffroyi
Family Agaricidae
Pavona decussata
Family Siderastreidae
Pseudosiderastrea tayamai
Family Fungiidae
Cycloseris cyclolites
Polyphyllia talpina
Podabacia crustacea
Sandalolitha robusta
Herpolitha limax
Heliofungia actinoformis
Fungia concina
Fungia danai
Fungia echinata
Fungia fungites
Fungia granulosa
Fungia horrida
Fungia paumotensis
Family Oculinidae
Galaxea cf. astreata
Family Merulinidae
Merulina ampliata
Family Mussidae
Scolymia cf. vitiensis
Lobophyllia hemprichii
Symphyllia radians
Family Pectiniidae
Oxypora lacera
Pectinia lactuca

Family **Dendrophyllidae**
Turbinaria peltata
Turbinaria **frondens**
Turbinaria **mesenterina**
Turbinaria reniformis
Turbinaria **stellulata**
Turbinaria bifrons
Turbinaria radicalis
Family Poritidae
Porites lobata
Porites murrayensis
Porites australiensis
Porites **lutea**
Porites **mayeri**
Porites **cylindrica**
Porites nigrescens
Porites lichen
Porites annae
Porites rus
Goniopora djiboutiensis
Goniopora **stokesi**
Goniopora lobata
Goniopora **columna**
Goniopora stutchburyi
Family Acroporidae
Montipora tuberculosa
Montipora **millepora**
Montipora **sp.1**
Montipora mollis
Montipora turtlensis
Montipora **peltiformis**
Montipora undata
Montipora **venosa**
Montipora digitata
Montipora hispida
Montipora **efflorescens**
Montipora stellata
Montipora **informis**
Montipora **foliosa**
Montipora aequituberculata
Montipora crassituberculata
Anacropora **forbesi**
Acropora **vaughani**
Acropora divaricata
Acropora aculeus
Acropora hyacinthus
Acropora latistella
Acropora elseyi
Acropora **valida**
Acropora digitifera
Acropora pulchra
Acropora millepora
Acropora nobilis
Acropora formosa
Acropora tenuis

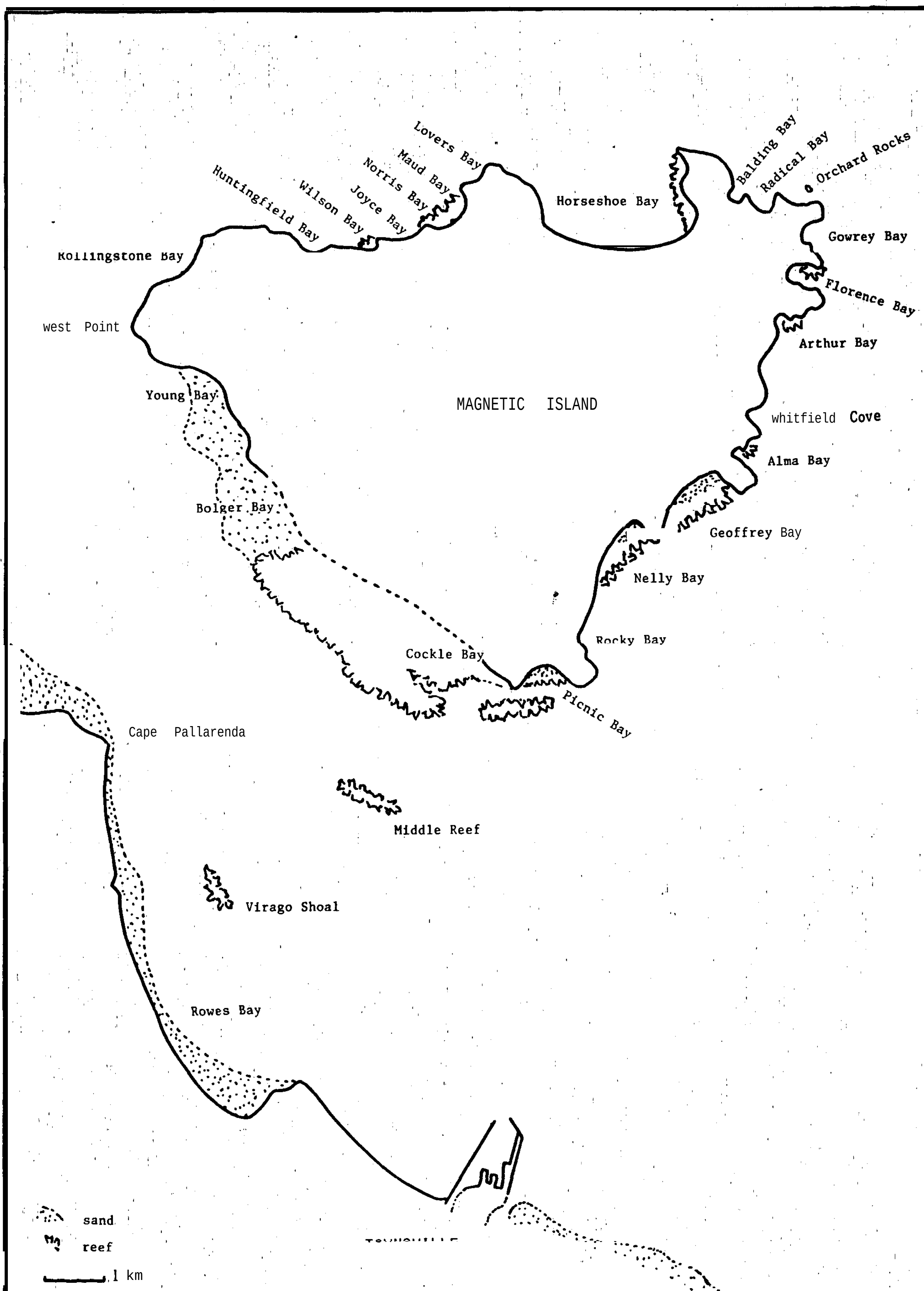

Figure 1 Magnetic **Island Fringing Reefs**

TOWARDS THE DEVELOPMENT OF A SPATIO-TEMPORAL ATLAS OF THE 'HIGH ISLAND' FRINGING REEFS FOR THE SOUTHERN SECTION OF THE GREAT BARRIER REEF MARINE PARK: The application of a new technique for the assessment of fringing reef communities

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ABSTRACT

An integrated technique has been developed to provide a possible standard methodology for the assessment of the distribution and abundance of fish and benthic communities on fringing reefs. To date this technique has been applied to four Islands in The Whitsunday region and maps with colour overlays have been prepared. The overlays describe the community location, the vertical and horizontal distribution of communities, the distribution of substrate types, the distribution and abundances of fish species and the distribution of seagrasses.

An accompanying description of each "site" has been prepared which includes

a) A stylized 3-dimensional profile.

b) A pie diagram providing information on the absolute abundance of hard corals, soft corals, dead standing corals, macroalgae, turf algae, sponges and sand/rubble.

c) Relative abundance, tables for The Order Scleractinia, Subclass Alcyonaria, Phylum Porifera and Macroalgae.

In addition, broad scale patterns of distribution and composition of fish assemblages are discussed and anticipated work outlined. Maps of Brampton, Carlisle, Cockermouth and Goldsmith Islands can be obtained from the G.B.R.M.P.A. in an Atlas, form after 31st January, 1987.

INTRODUCTION

Pressure on fringing reef communities from such diverse human activities as fishing, agriculture, industrial development and tourism (resort development) are steadily increasing. An informative data base is necessary to provide adequate information to assess the' effects of these activities on the marine environment. Initial research providing a base-line by which to monitor community changes through time is essential for management policies to be applied. This report describes a technique designed to provide a suitable data base to act as a base-line for the continued monitoring and-management of the 'High Island' fringing reefs in the southern section of The Great Barrier Reef Marine Park.

The processes leading to understanding the major factors defining the spatial distribution of coral reef communities will ensue only by expanding the scales and perspectives of observation. Therefore an integrated approach was adopted in this study, surveying both fish and benthic communities simultaneously. This approach firstly allows the examination of the nature of the different fish communities and subsequently a comparison of these communities with various biotic and abiotic factors. Secondly, the technique aiiows the examination of possible interactions (e.g. herbivory) between the fish and benthic communities by monitoring these communities on a temporal scale. Recent insight into the organization of coral, reef benthic 'communities, was 'provided by Glynn, (1976), Connell (1979), Hay (1981a), Sammarco (1982a,b), Wellington (1982), Hixon and Brostoff (1983) and Lewis (1985) indicating that physical and biological disturbancesmay be major forcing functions in shaping community structure.

TOWARDS A BENTHIC METHODOLOGY

The complexity of the reefal system and their structural and taxonomic heterogeneity makes the task of describing communities to species level particularly difficult and time consuming. Furthermore, morphological plasticity of certain coral species are evident when subjected to diverse hydrodynamic, photic and sedimentary environments (Veron and Pichon, 1976). Coral community patterns have been demonstrated in quantitative studies of taxonomic groupings above the species level by Done (1982) and Bradbury et al (1985). Their 'visually dominant organisms' and 'life form' attributes were designed in view of these difficulties in taxonomic identification.

Considering the 'typically' adverse water transparency conditions around the Whitsunday Islands (pers. obs.), accurate benthic recording by such methods as manta towing (Done et al., 1982) would be insufficient. After reviewing other methodologies for collecting accurate ecological information 'it was concluded that a new integrated sampling technique be employed with the aid of aerial photographs to analyse -the communities on these fringing reefs. This techniqe is an expansion of the method employed by Veron and Done in 1979 on Lord Howe Island to include the entire benthic community.

Classification to genera and morphological types were adopted after reviewing previous community studies on fringing reefs by G. Bull (1982) and T.J. Done (1982). it was observed that the results of these separate studies in similar areas classified communities varying in species composition, however genera frequently corresponded in both classifications for areas with similar abiotic parameters.

TOWARDS A METHOD OF RECORDING FISH ASSEMBLAGES

In considering a method to monitor coral reef fish assemblages the following questions need to be addressed.

Do all fringing reefs have similar assemblages? If not, can these assemblages be objectively characterised?

Any suitable sampling technique is governed by certain constraints. These include the speed with which the survey can be conducted, and safe working limits for S.C.U.B.A. divers, as well as minimum man power and equipment. As a result a semiquantitative technique has been developed which discriminates the differences in coral reef fish assemblages within and between reefs: Simultaneously the technique provides base-line data to assess the level of fishing **pressure** on these fringing **reefs** by 'using the commonly fished coral trout (*Plectropomus spp.*) as an indicator species.

The sampling technique, which use's a 50x20 inetre transect, is derived from the standardized rapid visual, **technique** developed at the Workshop on Reef Fish Assess-, ment and Monitoring, convened by G.B.R.M.P.A. **in** 1978. This technique is 'modified due to the constraints encountered when assessing reefs of a largely **indistinct** nature (**i.e.** reef flat and reef slope are frequently indistinguishable) and the. generally poor visibility typically encountered while undertaking surveys on fringing **reefs** in the Whitsunda'y area.

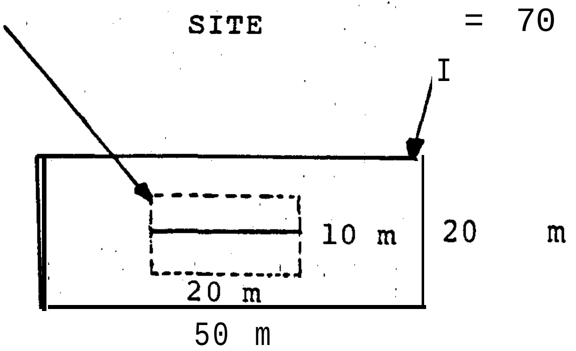
FIELD METHODS

Person 1. Benthos assessment (transect area = $200m^2$)

Average duration for collection of data, = 60 minutes

Person 2. Fish assessment (transect area = $1000m^2$)

Average duration for collection of data = 70 minutes



PERSON 1

SITE, SELECTION AND SAMPLING STRATEGY

1) Preliminary observations were made by distinguishing areas where community boundaries may occur using high resolution aerial photographs as tools for defining topographic features. "Sites" were selected on the basis of visible differences in benthic topography and exposure.

2) A search in the vicinity of the selected sites was made in order to' determine if the selected sites had a relatively homogeneous community and to determine the visible extent of the community. If considerable. variance was detected in a neighbouring area an additional site was selected and surveyed accordingly. "Sites" were mapped using standard navigation techniques i.e. determining the angles between three reference points easily distinguished on the Islands, and subsequently plotting the "site" location.

3) To determine the abundance of the major benthic components a 20 metre line transect using the intercept method (Loya, 1972) was laid along the reef community at a uniform depth. The cover of macroalgae, hard coral, soft coral, dead standing coral, sand/rubble, turf algae, sponges and other major benthic components were recorded (see Appendix 1 for attribute list). A permanent line transect would provide additional insight when monitoring these sites by providing

information on mortality, recruitment and, information on significant changes in growth, rates.

4) A 5 metre search either side of the line transect was 'undertaken. The relative abundance of coral genera within the Order Scleractinia and Subclass Alcyonaria were derived by recording every individual encountered in the $200m^2$ transect area. Similar recordings were undertaken for the Phylum Porifera and the Order Zoanthidea, which varied in taxonomic resolution in accordance with the authors' capabilities in taxonomy.
A special column was set aside for conspicuous macrofauna such as. the giant clams Tridacna, Tunicates and Echinoderms.
All recordings were marked on a large Perspex board which had the Operational Taxonomic Units listed (see Appendix II). Data were obtained through visual assessment and size estimates, the benthic components were assigned a graded score depending on their'maximum diameter.
A broad scale indication of population structures were obtained using four size categories. However, resolution of population dynamics is variable when considering that coral colonies vary in porosity' and growth rates.
'Field recording criteria on Perspex board:

1-50cm 50-100cm + 1-3metres >3 metres

5) An in-situ mapping technique was employed to determine the relative abundance and generic type of macroalgae.

Ten random $1m^2$ quadrats were placed in the site area. For permanent transects, quadrats are placed at specified distances along the line. The quadrats were subdivided by wire mesh into sixteen squares for simplified and more accurate data recording. The macroalgae within each quadrat were identified and traced out in the appropriate recording blocks on the large perspex board.

If seagrasses were present in the quadrats, species type were identified and their relative cover per metre square were estimated.

If macroalgae were prolific and underlying benthic components could not be easily observed, all the macroalgae were removed from each quadrat and the underlying corals identified. Each underlying coral colony was assigned a graded score according to size.

A	B	C	D	E	F	G
0-5cm	5-10cm	10-20cm	20-30cm	30-50cm	50-75cm	75-100cm

6) In addition to defining the composition and cover of communities the bottom types were recorded (i.e. mud, sand, rubble, igneous substrate, carbonate substrate). Furthermore, distinct morphological features were noted (e.g. spur and groove systems) as were the local currents. The exact depth of the benthic communities were determined by preparing tidal curves and interpolating the recorded time and depth for each community using L.W.D. as datum. The relief and the slope angles were also sketched for each "site".

7) In order to'determine intra-community variation replicate "site" surveys were occasionally undertaken'.

Note: In order to determine any major temporal community changes the survey technique can be employed by persons with only elementary knowledge in taxonomy by "scaling-up" the taxonomic categories and by diagramatic assistance on the prepared underwater board.

PERSON 2

SITE SELECTION - similar as person 1, steps 1) and 2) employed.

SAMPLING STRATEGY

A 50 metre tape was placed along the reef'slope at a uniform depth. The observer, to ensure consistency, swam using S.C.U.B.A. in a zig zag (sinusoidal) pattern 10 metres either side of the tape i.e. Belt' transect = $1000m^2$.

The presence of species and their abundance were recorded on a prepared underwater slate as the diver swam along the transect.

Numerically dominant species such, as Pomacentrids and, some Labrids (Haliocheres spp.) and Lutjanids (Caesio spp.) were recorded on a log 5 abundance scale, whilst 'other,, more solitary, demersal, fish species were recorded in absolute numbers.

The log 5 abundance categories follow Sale and' Williams, (1982).

Category

1 fish,= 1	26-125 fish = 4
2-5 fish = 2	126-625 fish = 5
6-25 fish = 3	626-3250 fish = 6
	> 3250 fish = 7

Rare or exceptional species not on the proforma list are also recorded as well as an aesthetic appeal rating made at each site.

Coral trout {*Plectropomus spp.*) are recorded under the following size categories when encountered:.

Juvenile < 40cm

Medium sub-adult 40-60cm

Large adult > 60cm.

The information provided by size frequency data is far more **sensitive** in indicating 'stress in a fished population.

RESULTS

These results refer to the fringing reefs of four Islands in the southern section of the Marine Park, namely Brampton, Carlisle, Goldsmith and Cockermouth Islands. The benthic survey data are stored in the form of maps with plastic colour overlays indicating the vertical and horizontal distribution of communities, distribution of seagrasses and substrate types. This graphic representation makes access and interpretation of data relatively easy. Additional descriptions and stylized profiles have been prepared for each "site"..

An agglomerative hierarchical classification (Williams, 1971) using Bray-Curtis similarity, coefficients identified broad scale patterns in the composition of fish assemblages. This analysis was run for 32 "sites" using the Numerical Taxonomy Package '(N.T.P.) developed by the C.S.I.R.O. The results indicate that differences in fish assemblages are greater between Islands than within Island "sites". Goldsmith Island was found to be most dissimilar from Islands further offshore. "Sites" on' the windward slopes were found to be more similar than those on the more sheltered slopes. Where strong currents were persistent on leeward "sites" the fish assemblages showed similarity to those sites on the windward side of the Islands.

Due to the complex nature of the benthic communities any taxonomic classification': has yet to be undertaken. However distinct 'patterns in the benthic communities are apparent by "eyeballing" the data.

The changes in benthic communities and fish assemblages between Islands appear to follow the broad cross shelf trends identified by Done (1982) and Williams (1982). However fringing reef variability maybe greater than previously thought. The inter-Island variability may mask these cross shelf trends resulting in the need to focus on a smaller scale.

Comparing the benthic communities on the exposed indistinctly developed Goldsmith Island reefs with the well developed reefs on Cockermouth Island, obvious differences in benthic components were observed. Sargassum assemblages with minimal coral cover of encrusting morphologies dominated Goldsmith Island in comparison with the Acropora robusta - hyacinthus - palifera variants on Cockermouth Island. Similarly the fish assemblages on Cockermouth, Brampton and Carlisle Island have species which are described as being more midshelf in distribution than those on Goldsmith (Williams, 1982).

A good example of the fish species distribution patterns is the pomacentrid Abudefduf whitleyi which is absent on Goldsmith Island, moderately common on Brampton and Carlisle, becomes a numerically dominant species on Cockermouth Island. An interesting anomaly is the virtuai absence of Scarids on Goidsmiti-i Isiand where macroalgae were most prolific, whilst a few kilometres to the south east an increasing abundance and diversity of these fishes were observed.

DISCUSSION

The work to date has helped to elucidate broad scale patterns in distribution and abundance of fish assemblages and benthic communities on fringing reefs on southern 'High Islands'.

Further work will involve numerical clustering of benthic communities by coral genera, families and various coral population sizes. Separate clustering on 'macro-" algae - coralcommunities will be divided temporally due to the seasonal nature of macroalgae.

Perhaps the most important analysis yet to be undertaken is the correlation of various biotic and abiotic factors. This will involve multivariant analysis providing information on the possible associations of these various parameters. Further work will also focus on small scale variability and the examination of detailed differences between assemblages within Island reefs.

It is considered by the authors that the communities recorded could represent stages in succession. Therefore fine scale temporal monitoring is of prime importance in determining not only'the effect of infrequent large scale perturbations on the communities but also continuous seasonal perturbations. Insightinto the extent of coral - algae interactions needs to be gained and the possible extent to which they may be mediated by the herbivorous fish guild for any effective long-term management of these reefs.

ACKNOWLEDGEMENTS

The authors acknowledge the Great Barrier Reef Marine Park Authority for funding the development of the procedures described here and S. Domm from the Queensland National Parks and Wildlife Service for initiating the collaboration of different disciplines in the field and valuable field assistance. Also T.J. Done, D. Williams from the Australian Institute of Marine Science: D. Hopley, A. Choat, J. Collins from James Cook University for stimulating comments.

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APPENDIX I

List of Attributes 'and respective Recording Codes employed for Line Transects'

Attribute	Description	Field Code
Scleractinian Corals:		
Acropora	"fine branching"	AFB
	"thick open-branching"	A C B
	"stout shrub-like"	A S S
	"fine shrub-like"	AFS
	"tabulate"	ACT
	"stout"	A C S
	Palifera-type	A C P
	"encrusting"	ACE
	Astreopora	ACM
non-Acropora	identified to genera, with separate -recordings for morphologies	
M - Massive, F - Foliose, E - Encrusting, B - Branching, c - Columnar		
Other Fauna:		
Alcyonacea	identified to genera where possible	SC
Gorgonacea		G
Zoanthidea		Z
Actinaria, Antipatharia, Hydroids		A
Echinoderms, Mollusc, etc.		O
Millepora		M
Algae:		
Turf Algae		T A
Coralline Algae		'CA.
Macroalgae		MA
Abiotic Components:		
Sand		S
Rubble		R
Sand/Rubble Mixture		S/R
Silt		S i
Mud		Mu
Recently dead, standing coral		D C
Water (cracks deeper than 50 cm)		WA,

APPENDIX II

(Operational Taxonomic Units, OTU's)

Organism's maximum diameter: **a** 1-50 cm **b** 50-100 cm **c** 100-300 cm **d** greater than 300 cm

	a	b	c	d
200 Family Faviidae				
Cauiastrea	201	202	203	204
Favia	210	211	212	213
Favites	216	217	218	219
Goniastrea	220	221	222	223
Platygyra	226	227	228	229
Leptoria	230	231	232	233
Oulophyllfa	236	237	238	239
Hydrophora	240	241	242	243
Montastrea	250	251	252	253
Plesiastrea	260	261	262	263
Diploastrea	266	267	268	269
Leptastrea	270	271	272	273
Cyphastrea	276	277	278	279
Echinopora	280	281	282	283
Uoseleya	290	291	292	293
300 Family Acroporidae				
"Fine branching"	301	302	303	304
"Thick **open-** branchins"	306	307	308	309
"Stout shrub-like"	310	311	312	313
"Pine shrub-like"	316	317	318	319
"Tabulate"	320	321	322	323
"Stout" **(gemmifera type)**	330	331	332	333
"Palifera-type"	336	337	338	339
"Encrusting",	340	341	342	343
Astreopora	350	351	352	353
360 Montipora **"foliose"**	361	362	363	364
"Encrusting **free-lip"**	366	367	368	369
"Encrusting no free-lip"	370	371	372	373
"Encrusting with vertical projections"	376	377	378	379
"Submassive"	380	381	382	383
Anacropora	390	391	392	393
400 Family Poritidae				
Porites "Massive"	401	402	403	404
"Encrusting"	410	411	412	413
"Branching"	420	421	422	423
"Lichen-type"	430	431	432	433
Goniopora	440	441	442	443
Alveopora	450	451	452	453
460 Familv Pocilloporidae				
Pocillopora	461	462	463	464
Seriatopora	466	467	468	469
Stylophora	470	471	472	473
Palauastrea	480	481	482	483
Madracis	484	485	486	487
500 Family Aqariciidae				
Pavona "Foliose"	501	502	503	504
"Massive"	506	507	508	509
"Stout"	510	511	512	513
Leptoseris	520	521	522	523
Gardineroseris	530	531	532	533
Coeloseris	536	537	538	539
550 Pachyseris rugosa	551	552	553	554
speciosa	556	557	558	559
560 Family **Siderastreidae**				
Pseudosiderastrea	561	562	563	564
Coscinaraea	566	567	568	569
570 Family Oculfnidae				
Galaxea	571	572	573	574
Archelia	576	577	578	579
580 Family Trachyphylliidae				
Trachyphyllia	581	582	583	
590 Family Thamnasteriidae				
Psammocora	591	592	593	594
595 Family Astrocoeniidae				
Stylocoeniella	596	597	598	599

	a	b	c	d
600 Family **Merulinidae**	601		603	
Merulina		602		604
Clavarina	606	607	608	609
Scapophyllia	610	611	612	613
620 Family **Mussidae**				
Blastomussa	621	622	623	
Cynaria	624	625		
Scolymia	626	627		
Acanthastrea	628	629	630	631
Lobophyllia	632	633	634	635
Symphyllia	636	637	638	639
640 Familv Pectiniidae				
Echinophyllia	641	642	643	644
Oxypora	646	647	648	649
Mycedium	650	651	652	653
Pectinia	656	657	658	659
660 Familv Carovhvlliidae				
Euphyllia	661	662	663	
Catalaphyllia	666	667	668	
Plerogyra	670	671	672	
Physogyra	676	677	678	
680 Family Dendrophylliidae				
Turbinaria **"Foliose"**	681	682	683	684
"Encrusting **free-** lip"	685	686	687	688
"Encrusting no free-lip"	689	690	691	692
Duncanopsammia	693	694	695	
Heteropsammia	696	697		
700 Family Funqia				
Cycloseris	701.	702	703	
Diaseris	706	707	708	
Heliofunqia	710	711	712	
Funqia	716	717	718	
Herpolitha	720	72i	722	
Herpetoqlossa	726	727	728	
Polyphyllia	730	731	732	
Halomitra	736	737	738	
Sandolitha	740	741	742	
Lithophyllon	746	747	748	
Podabacia	750	751	752	
800 Subclass Alcyonaria				
Tubiopora	801	802	803	
Clavularia	804	805	806	
Pachyclavularia	810	811	812	813
Lobophytum	816'	817	818	819
Alcyonium	820	821	822	823
Briareum	826	827	828	829
Cladiella	830	831	832	833
Asterospicularia	835	836		
Sarcophyton	837	838	839	
Capnella	840	841	842	
Sinularia	846	847	848	849
Parenythropodium	850	851	852	853
Stereonephthya	856	857	858	
Nephthea	860	861	862	
Dendronephthya	870	871	872	
Paralemnalia	873	874	875	
Cespitularia	876	877		
Anthelia	878	879		
Xenia	880	881	882	
Efflatournaria	883	884	885	886
Lemnalia	887	888	889	
890 Order Gorqonacea				
Rumphella	891			
Fan	892			
Whip	893			
comb	894			
Order Pennatulacea	895			

APPENDIX II! (cont/d.)

900 Other: Order Zoanthidea	9 0 1
910 Order Actinaria	911
920 Phyllum Mollusca	
Class Bivalvia	
Tridacnidae	921 922 923
Hippopus	926 927
930 Phyllum Porifera	
"Foliose"	931
"Vase "	932
"Cup"	933
"Encrusting"	934
"Submassive"	935
"Cliona-type"'	'936 937 938 939
980 Phyllum Cnidaria	
Class Hydrozoa	
Millepora	
"Branching"	981 982 983 984
"Massive"	990 991 992 993
"Encrusting"	994 995 996 997

A RECONNAISSANCE ACCOUNT OF THE RODNEY ISLAND FRINGING REEF AND ASSOCIATED MARINE COMMUNITIES, SHELBURNE BAY

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INTRODUCTION

Rodney Island, lying just to the east of Round Point, consists of a basement of ferruginous black laterite covered by a red clayey loam and weathered pumice. Around the intertidal zone, the lateritic basement has been exposed by erosion and has given rise to a rocky shoreline. On its eastern side, a gravelly beach is present consisting of pumice and coral fragments while on the western side, silt has accumulated and been colonised by a mangrove fringe.

As a result of this substrate diversity, a number of diverse marine communities are present. From the field work (carried out in the area during 24 October to 1 November 1984) and on the basis of Landsat imagery, four distinct marine communities can be recognized around the island, including open shoreline mangroves; coral fringing reef; intertidal sandflats; and soft-bottom benthic communities. Each of these communities is briefly described below.

DESCRIPTIONS OF THE MARINE COMMUNITIES

Mangroves

Around Rodney Island, mangroves range in height from 2 - 10 metres. Sonneratia alba and Avicennia marina are the outer species, forming a narrow seaward zone. Stands of Rhizophora stylosa form a more or less continuous zone landward of the Sonneratia/Avicennia zone while a zone of mixed species forms the landward fringe. Several species are common in the landward fringe including Excoecaria agallocha, Osbornia octodonta, Pemphis acidula, Lumnitzera racemosa, Aegialitis annulata, Scyphiphora hydrophyllacea and Ceriops tagal.

Coral Reefs

Several fringing reefs occur in the study area, with the largest around Rodney Island.' The description of this reef is divided into the reef flat and the reef slope as the organisms of these two zones differ considerably and warrant separate description.

Reef Flat

The gently sloping reef flat consists of large areas of coral rubble interspersed with small pools and areas of living corals. The coral cover increases from approximately 10% near the landward margin to approximately 80% on approaching the reef slope. In places, particularly near the shoreline of Rodney Island, the underlying Pleistocene laterite lies at the surface and it, is covered in milky (Saccostrea amasa) and black lip (S. echinata) oysters.

The rubble areas are dominated by'algae including Chlorodesmis fastigiata, Hydroclathrus clathratus and an unidentified species of Sarsassum. The black holothurians, Holothuria atra and H. leucospilota are common on sandy rubble areas and in the shallow sandy pools amongst the coral. The middle reef flat consists of numerous micro-atolls of Favia aff. abdita, up to 1.5 m in diameter. Other hard corals, particularly towards the reef slope, include Seriatopora hystrix, Pocillopora sp., Acropora spp., Symphvllia sp. and the mushroom coral Funaia funsites. Soft corals are not abundant but sporadic patches of Sarcophyton trocheliophorum and Lobophytum sp. were observed.

Reef Slope

Around most of Rodney Island, the reef slope drops off abruptly into 6 or more metres of water. However, on the north-western side of Rodney Island, the reef slope deepens gradually and consequently a large reef slope community occurs' here. Underwater visibility never exceeded 6 m as a result of suspended particulate matter and an abundance of plankton.

The reef slope is dominated by soft corals, seawhips and hydroids.

Mean cover estimates derived during the dives were as follows: hard corals - 10%; soft corals - 60%; hydroids - 20%; algae and sand - 10%. The soft corals include Sarcophyton trocheliophorum, Dendronephthya sp., Xenia elongata, Junceela sp. and Ctenocella aff. pectinata. Hard corals include Acropora pulchra, Acropora hyacinthus, Turbinaria sp., Pocillopora sp., Platygyra sp., Lobophyllia sp., Goniopora sp., Favia speciosa, Polyphyllia sp. and Oulaphyllia sp.

Numerous algae were observed including Chlorodesmis fastigiata, Dictyota sp., Sargassum sp., Dictyopteris sp., Codium duthiae, Caulerpa racemosa, Caulerpa lentillifera, Caulerpa cupressoides, Halimeda macroloba, Bornetella nitida, Neurymenia fraxinifolia, Lenormandiopsis lorentzii and Callophycus serratus.

According to Kraft (1984), Rodney Island is the only known collecting site for the alga Callophycus serratus in Australia, although it is known from the Philippines and New Caledonia.

In addition to the above, the following organisms were common: stinging hydroids (Lytocarpus philippinus), fire coral (Aslaeophenia cupressina), nudibranchs (Ceratosoma aff. cornigerum, Dendrodoris tuberculosa, Gymnodoris ceylonica), featherstars (Himerometra sp.), painted lobsters (Panulirus ornatus), a long thin holothurian (Synaptula sp.) and various sponges.

Fishes were abundant and the following were the most numerous: tuskfish (Choerodon schoenleinii, C. venustus), painted sweetlip (Spilotichthys pictus), cod (Epinephelus tukula, E. merra), surgeonfish (Acanthurus xanthopterus), batfish (Platax pinnatus), anglefish (Chaetodontoplus douboulayi), sweetlip emperor (Lethrinus chrysostomus, L. nebulosus), spinecheeks (Scolopsis temporalis), stripeys (Lutjanus carponotatus), fusilliers (Caesio chrysozonus), coral trout (Plectropomus maculatus), goatfish (Parupeneus indicus) and grubfish (Parapercis cylindrica). In addition a number of chaetodontids and pomacentrids were common but detailed identifications were not made.

Intertidal Sandflats

Extensive intertidal sandflats occur between Rodney Island and the mainland. The sand is predominantly siliceous, very fine and with a very low organic content, rendering it almost white. The surfaces of the sandflats are generally level although sand ripples (fine and coarse) are'discernible running parallel to the shoreline.

No macroscopic plants were found on the sandflats; two factors are likely to be involved i.e. the sandflats are mobile and exposure during low tides inhibits plant growth at least during the summer months. Plant debris such as mangrove leaf litter and stranded seagrass and algal material was common and it seems likely that this material is a source of organic matter. for, the infauna inhabiting these sand flats.

General observations showed the following macroscopic species to be commmon: Seastars (Archaster typicus), sand dollars' (Decauonale sp.)and the following molluscs: Oliva caldania, Nassarius pullus, Clypeomorus moniliferous, Clypeomorus brevis and Mactra dissimilis. All of these species are detritivores, presumably feeding on the organic matter in the sand.

In addition to this macroscopic fauna, an infauna exists which is not readily apparent. Quantitative sampling of surface sands using 200 cm^2 samples and a 1 mm sieve was carried out along a, transect across to Rodney Island. The data show that'a diverse' fauna of amphipods, isopods, gastropods and bivalves occur in the sandflats. The species diversity and abundance reach maxima in the mid to lower tide levels.

At high tide, numerous fish occur over these sandflats, feeding on the detritivorous infauna and detrital matter. The most abundant species observed include: Mullet (Liza vaigiensis), black-tipped shark (Carcharinus melanopterus), rays (Himantura uamak, Taeniura lymna, Acrobatus marinari, shovel-nosed rays (Rhinobatos batillum), flathead, (Platycephalus cf. indicus) and whiting (Sillago sp.).

soft-bottom Benthic Communities

These have been arbitarily subdivided into three, namely the seagrass areas that occur just below low water mark adjoining the intertidal sandflats, the deeper sparse seagrass/soft coral areas, and the deep areas of sand and rubble that predominate below approximately 10 metres. All three grade into each other but they are described separately below because of their different appearance.

Seagrass communities

Extensive areas of seagrasses occur in the study area extending down from mean low water. The seaward extent of these communities cannot be accurately mapped but they extend approximately to the 5 metres depth contour at low water.

Several species occur in these communities including *Halophila ovalis*, *Cymodocea rotundata* and *Halodule uninervis*; *Halophila minor* (= *H. ovata*) also occurs but it is confined--to the areas less than 2 metres deep at low water. These communities vary in density and are often patchy and they rarely exceed 10 cm in height . Occasional algae also occur but these are a minor component.

Seagrass/Soft coral communities

These communities occur around Rodney Island at a depth ranging from 5 - 10 metres at low water. Soft coral cover (mainly *Xenia* and *Dendronephthya*) comprises about 30% in these communities with the remaining sandy areas supporting sparse stands of seagrasses including *Halophila ovalis* and *Halophila spinulosa*. Large fan-like sponges also occur, often covered in the striped holothurian, *Synaptula* sp. Other conspicuous invertebrates include seastars (*Protoreaster nodosus* and *Pentaceraster* sp.), the holothurian, *Bohadschia* sp, and the painted lobster *Panulirus ornatus*.

Sweetlip emperor (*Lethrinus* spp.), trevally (*Caranx* sp.) and a burrowing goby were the only fish observed during the survey of this community.

Sand/rubble community

This community extends down from approximately 10 metres. Rubble and coarse sand comprise the substrate and except for a few species of algae and hydroids, few organisms were observed.

REGIONAL PERSPECTIVES

Shelburne Bay contains extensive seagrass beds, mangroves, fringing reefs and vast tracts of sandy heath hinterlands. The tropical climate and clear waters, the largely sandy hinterland and the large bay sheltered from the prevailing south-easterlies combine to form a coastal system unique 'in Australia. It comprises an area of primary dugong habitat, contains a sizeable population of the endangered saltwater crocodile and the rare mangrove palm (Nypa fruticans) and it supports regional crayfish and barramundi fisheries, respectively based on the fringing reefs and estuaries of the area. In addition, the offshore areas are trawled for prawns.

The Rodney Island - Round Point area comprises the eastern extremity of Shelburne Bay and on a smaller scale, displays the diversity of habitats that characterizes Shelburne Bay. Extensive sandflats and seagrasses occur in the area and a well-developed fringing reef surrounds Rodney Island while the mangrove fringe and the fig forests of Rodney Island support large numbers of Torres Strait pigeons, a species of restricted distributionin Australia.

Nevertheless, none of the marine community types found in and around Rodney Island (or in Shelburne Bay generally) are rare but the combination of all of these in a relatively confined area has produced a unique system of high scientific value.

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CAPE TRIBULATION FRINGING REEFS AND MONITORING PROGRAM

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The coastline in the vicinity of Cape Tribulation is generally acknowledged as being among the most scenic in Australia. Fringing reefs occur along much of this coastline between the mouth of the Daintree and Bloomfield Rivers (Figures 1 and 2).

As part of the Cairns Section of the Great Barrier Reef Marine Park, these reefs were zoned Marine National Park 'A' and Marine National Park 'B' in 1983 to provide them with some degree' of protection. With these zonings, limited fishing is allowed in MNP'A', but extractive activities are not' permitted in MNP'B'. (Figure 2.)

In late 1984 a new unsealed road linking Cape Tribulation and Bloomfield was opened to the public. The road was the subject'of considerable controversy between,conservation groups opposed - to its construction and local and State governments equally determined to see the road built (Davis, 1985). One of the major concerns about the new road was its potential to adversely affect the adjacent fringing coral reefs through increased sediment run-off, (e.g. see Borschmann, 1985).

Little is known of the geology, geomorphology and ecology of these reefs. This deficiency, combined with the lack of knowledge about the potential effects of increased sediment concentrations on fringing reefs, prompted the initiation of an investigation to provide a sound basis for the determination of possible management needs which might arise from the presence of the road.

To do this, it was decided to establish a research'and monitoring program on the Cape Tribulation reefs. This was done af'ter' detailed consultation with the scientific community and taking into account a range of matters related to cost effectiveness; lack of existing information, integration in the overall monitoring program etc., (for details of the program development see Dutton and Craik, submitted). The final program consisted of two research projects and two monitoring projects.

The research projects are designed to provide information on the sediment regime from the mainland catchments through the, fringing reefs to inshore areas. The monitoring projects are designed to compare characteristics of biological communities (e.g. coral, fish, coral recruitment) at'a number of sites some of which are subject to sediment run-off from the road. The program will continue until 1988.

The initiation of the work was preceded by a preliminary investigation (Ayling and Ayling, 1985) to enable refinement of the'survey design.

Table 1 summarises the four research and monitoring elements of **the program.** Preliminary information gained as a result of these studies will be presented in subsequent papers in this workshop by the investigators. As a result of this major research and monitoring initiative, not only should information be provided which will assist in determining appropriate management actions, but a considerably greater understanding of the dynamics of mainland fringing reefs will have been obtained.

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Dutton, I.M. and G.J.S. Craik. submitted. Assessing the effects of sediment discharge on fringing coral reefs. Coastal Zone Management Journal.

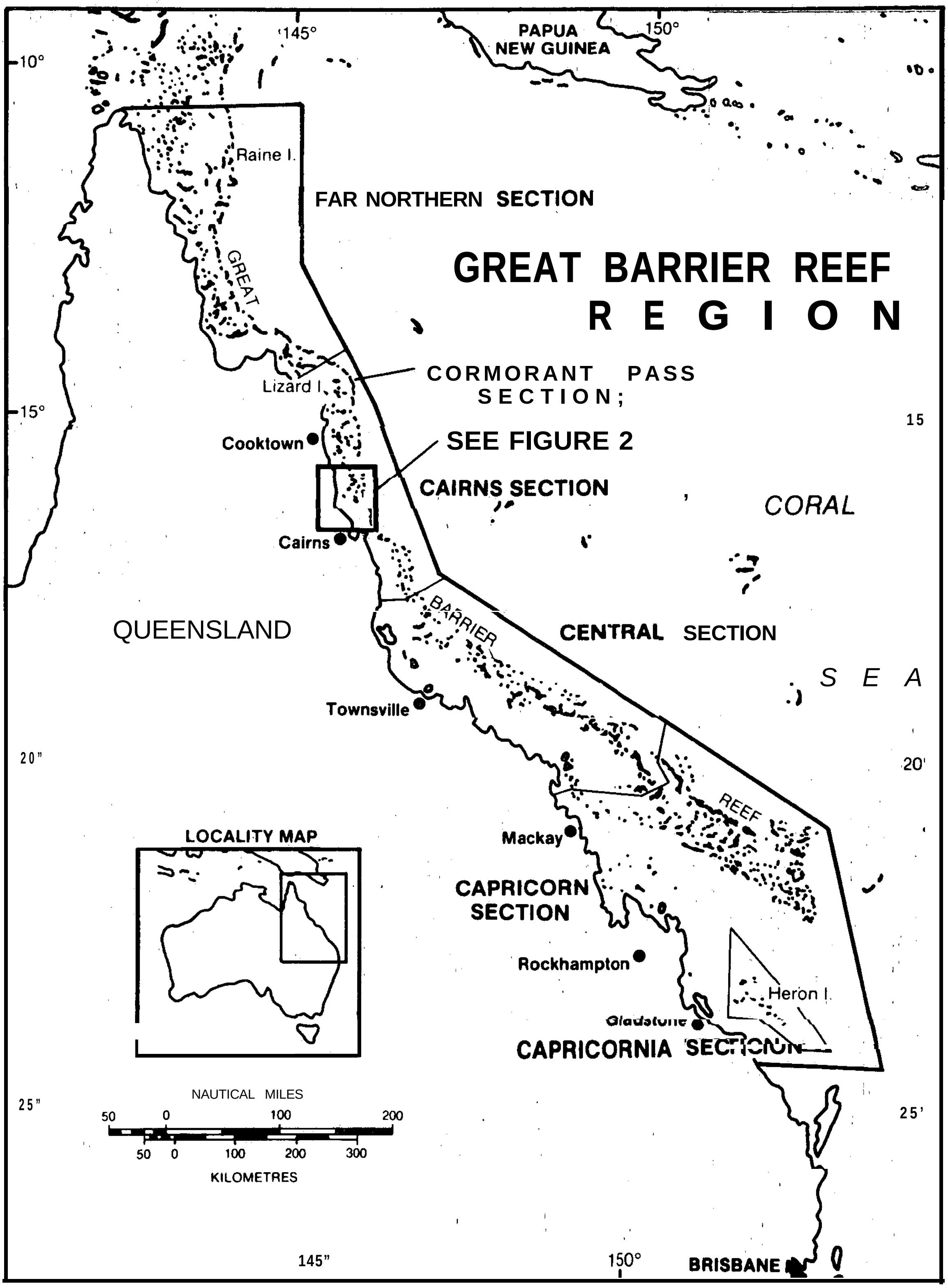

Figure 1. Great Barrier Reef Region Showing Location of Cape Tribulation Reefs,

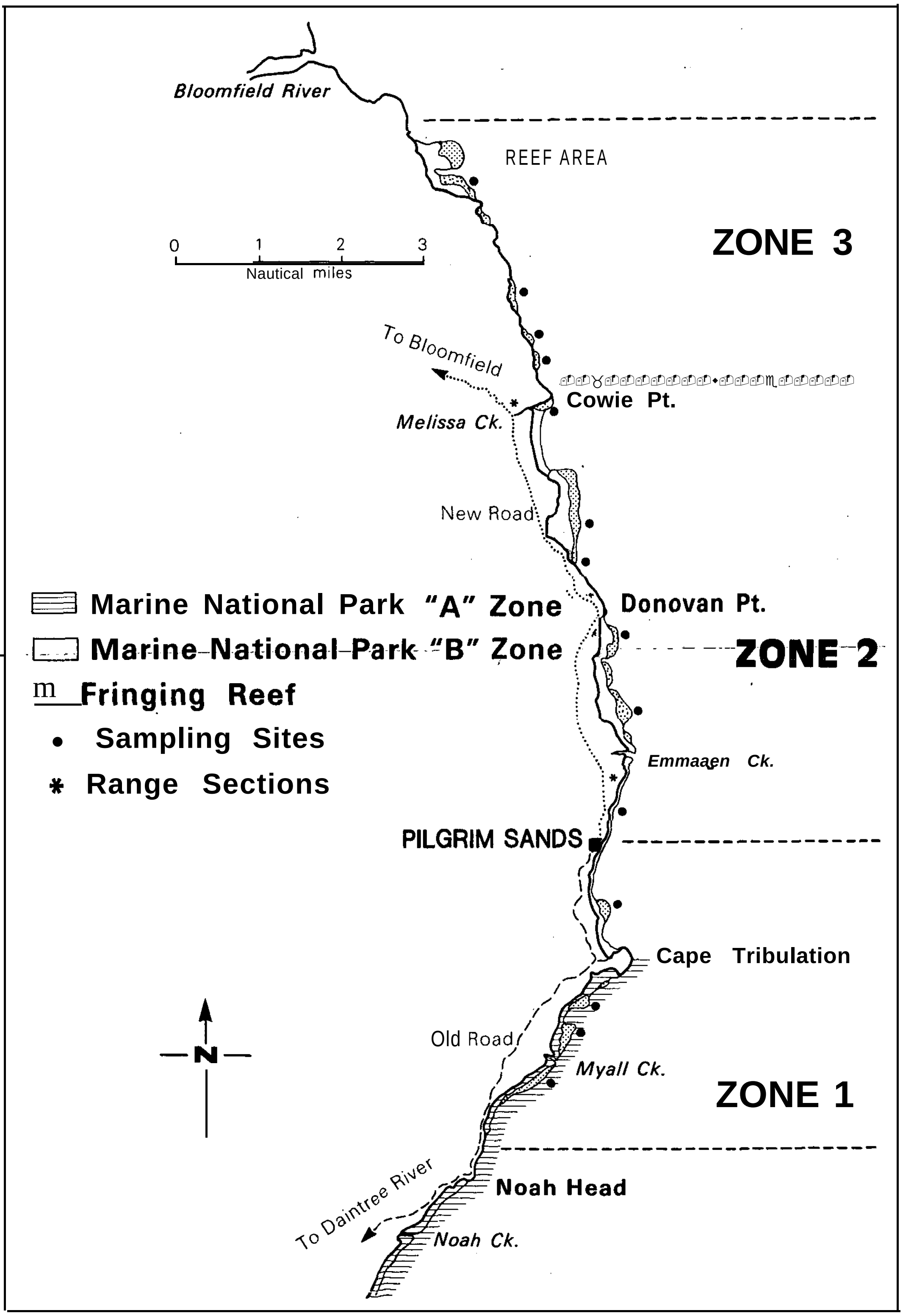

Figure 2. Coastal Detail

TABLE 1: CAPE TRIBULATION RESEARCH AND MONITORING PROGRAM

PROJECT	OBJECTIVE(S)	RESEARCHER(S)	METHOD(S)	DURATION	COST EST. ($A)
Research					
a. Effects of disturbed rain-forest catchments on adjacent fringing reefs - Cape Tribulation area	(i) to evaluate the impact of unsealed roads and related earthworks on fringing reefs in the Cape Tribulation area. (ii) to measure changes caused by the roadworks, both within catchments and in the nearshore zone.	Assoc Prof. D. Hopley (James Cook Uni.)	*Literature Review *Monitoring of: . rainfall . stream level and sediment level . catchment characteristics . reef flat hydrodynamics . inshore sediment levels *Calibration with other studies	3 years	$ 38,500
b. Sedimentary setting of fringing reefs Donovan Point	(i) to document geological sediment facies. (ii) delineate shallow stratigraphy of peri-reef sediments. (iii) Core and recover datable material from reef and off-reef deposits.	Dr. D.P. Johnson Prof. R.M. Carter Mr. J. Hills (James Cook Uni)	*Literature Review *Sidescan sonar mapping *Seismic mapping *Coring and sediment sampling *Radiocarbon dating of core material	1 year	$ 5,500
Monitoring					
a. Monitoring Coral Recruitment-Cape Tribulation cringing Reefs	(i) to determine whether these are significant variations in coral recruitment between selected sites. (ii) to assess whether runoff from the new road has affected recruitment rates	Dr. V. Harriott Mr. D. Fisk (Private Consultants)	*Placement of sets of settlement plates at each monitoring site (each plate covered by Platygyra and a small colony of Acropora palifera and 6 monthly analysis *Survey of permanent grids	-3 years.	$15,300

PROJECT	OBJECTIVE(S)	RESEARCHER(S)	METHOD(S)	DURATION	COST EST. ($A)
b. Monitoring Cape Tribulation Fringing Reefs	(i) To determine whether the Cape Tribulation to Bloomfield Rd. is having/has had an effect on corals, fish and invertebrate fauna of the adjacent fringing reefs.	Dr. A.M. 'Ayling Dr. A.L. Ayling (Sea Research)	*Initial survey and selection of sites • 6 monthly surveys of fixed sites -line transect surveys -stereo photography -measurement of large colonies -50 X 20m coral trout counts -incidental observations *Overall data analysis	3 years	$ 2,200 (initial) $87,500 (main)

IS SILT RUN-OFF AFFECTING CORAL COMMUNITIES ON THE CAPE TRIBULATION FRINGING REEFS?

Tony M. Ayling and Avril L. Ayling
Sea Research

INTRODUCTION

There was considerable controversy during 1984 over the decision to construct a coast road through rainforest from Cape Tribulation to the Bloomfield River in Far-North Queensland. This unsealed road was completed in late 1984 and subsequent observations during the 1985 wet season showed that there was heavy local run-off of silt into coastal waters from the road. There was concern that this silt run-off could cause permanent damage to the fringing reef communities in the area. Sea Research was contracted by the Marine Park Authority at the end of 1985 to make a'three year study on the fringing reefs in the Cape Tribulation area to determine if the observed silt run-off was affecting the coral communities.

The 25km stretch of coast between Noah Head and the Bloomfield River includes'about 13km of fringing reef much of which is based on deltaic gravel fans. The intertidal portion of these reefs is over a metre above the level of low spring tides. From low tide level the reefs fall steeply to the sediment bottom at depths between 3 and 6m (low water spring), with a reef width of between 10 and 70m.

The Cape Tribulation coast is characterised by steep rainforest covered hills falling directly to the sea from over 1000m. Rainfall is high, averaging over 4,000mm per year, with annual totals of more than 6,000mm not unusual. Most rainfall occurs between January and April and during this period 24hr falls sometimes exceed 50Omm.

Between April and October SE trade winds blow onshore, stirring up the shelf sediments and' holding a wide band of turbid water against the coast. Water visibility in these prevailing conditions ranges from 50cm to less than 2m; during extending calm periods water visibility is usually only between 2 and 6m, although it may occasionally exceed 10m.

The main problem faced was how to resolve the question of whether any damage detected was resulting from the run-off of silt in view of the absence of any comprehensive pre-road biological data from the area. As the road was constructed in late 1984,there had been a full wet season of run-off before this study started. It was decided that the Cape Tribulation coast could be divided into three locations, two of which'could be used as controls for the third in relation to this problem.

Location 1. Coastline from Noah Creek north past Cape Tribulation, adjacent to the long-established section of the road that runs from the Daintree River to 2km north of Cape Tribulation (control 1).

Location 2. Coastline from 2km north of Cape Tribulation to Cowie Point where the newly constructed road runs adjacent to the coast and where silt laden,run-off from the road was observed during the 1985 wet season.

Location 3. Coastline from Cowie Point to just south of the Bloomfield River where the new road is diverted inland and direct run-off is unaffected by any road construction.

There are further problems with this approach; it could be argued that silt run-off may also, be , affecting the adjacent control areas, but these are unavoidable.

METHODS

After a preliminary assessment of all reefs between Noah Head and the Bloomfield River four similar sites where the reef reached a depth of at least 4m at low tide were chosen at each location. Each site was restricted to a homogeneous length of reef less than fifty metres long having broadly similar coral communities. Four sites were used within each location to give some in&cation of the natural variation present in the area.

As a preliminary to the main survey the depth stratification of the coral communities was measured at two sites by running five replicate 10m intersect line transects to measure the abundance of corals and other encrusting organisms at four depths. These surveys indicated that there was a marked depth stratification in the reef community. The intertidal reef flat supported a low algal turf but was largely devoid of hard corals. The large brown alga *Sargassum* occurs in a dense band from about mean low tide level down to lm and then decreases in density down to about 3m depth. Hard corals increase in abundance with increasing depth, approaching 70% cover below 5m. This level of coral cover is high compared with off-shore reefs where cover in the richest areas is only 30-50%. In addition the species composition of the hard coral community changes with depth. It was decided to restrict the main *survey* at each site to *the Montipora/Acropora* depth strata between about 2 and 4m depth; this strata was present at all sites.

Only one component of the survey will be discussed here.

At each site five permanent 20m line transects were marked with stakes every 5m and recorded for coral cover. A fiberglass tape was stretched tightly between the stakes and the intersection of this tape with each coral colony beneath it was recorded in cm. From this a measure of percentage cover can be made and if necessary an estimate of the size frequency of the population from which the intersections were drawn can be made.

The permanent transects were set up and surveyed initially in October/November 1985 and resurveyed in September 1986.

RESULTS

In the 1985 survey the mean percentage cover of hard coral for the 5 permanent transects at each site ranged from 33.2 to 62.6 (see table 1). Comparison through time shows that there has been a considerable reduction in coral cover at ALL sites between Oct 85 and Sept 86 (mean reduction of 24%). This, however, was due to the small tropical cyclone Manu that broke up just south of Cooktown on 26-27 April 1986 and resulted in winds of around 40-50 knots in the Cape Tribulation area. Examination of the sites in early May showed considerable coral damage down to about 4m depth, especially in the most northerly location 3 sites that were closest to the cyclone.

Two factor analyses of variance indicates that while there were significant differences between sites in locations 1 and 2 there were no differences in live hard coral cover between locations, either before or after the cyclone damage. This suggests that there has been no influence in the new road location 2 over and above that of the cyclone that may have been caused by siltation. In fact the mean reduction in coral cover in location 2 was 16%, less than in location 1 (24%) or location 3 (32%).

DISCUSSION

At this early stage of the study we have detected no evidence of hard coral death due to siltation at any of these sites, either from the permanent line transect measurements reported here, or from the other survey components or from general observation in the area.

The picture of these reefs that emerges to date can be summarised in the following general points:

Hard corals are more abundant on these fringing reefs than on most off-shore reefs: the grand mean cover of hard corals on these sites was initially 50.8 ± 9.0%, compared with 23.0 ± 10.9% on a selection of 42 reefs in the Central Section of the GBR Marine Park, and 22.6 ± 12.8% on 38 reefs in the Capricorn Section.

The corals that grow in the area are silt tolerant and must normally cope with a high silt content and severely reduced light penetration for long periods when the SE trade winds are blowing. Most of the corals are dark brown in colour, presumably to maximise light absorption.

These fringing reefs are able to cope with regular, often *severe* disturbance. Tropical cyclone Manu, although it caused an overall reduction in coral cover of 24%, was a minor episode and such events probably occur with a return time of about five years - extremely severe episodes have occurred in the Cape Tribulation area at least twice this century: in 1911 and 1934.

Preliminary observations suggest that many of the corals grow very rapidly and can regenerate from small broken fragments after episodes of damage. Others, such as *Porites* colonies, are massive enough to survive high wind episodes and heads up, to 8m in diameter have been found in this area.

Table 1. Cape Tribulation Fringing Reefs: Comparison of Hard Coral Cover Before and After the 1986 Wet Season and TC Manu (26-27th April 1986)

Recorded as mean % cover from five permanent 20m intersect line transects at each site

		Nov. 1985 mean	Nov. 1985 st.dev.	Sep. 1986 mean	Sep. 1986 st.dev.	Change
			5.5			
Location 1	Site 1	40.4	5.4	29.3	6.9	-27%
	Site 2	53.4	[illegible]	45.7	10.3	-14%
	Site 3	62.6	11.6	48.1	13.9	-23%
	Site 4	56.0	12.5	38.3	8.9	-32%
Location 2	Site 5	33.2	12.7	25.0	17.7	-25%
	Site 6	53.2	9.4	47.4	6.9	-11%
	Site 7	58.6	7.9	44.9	[illegible]	-23%
	Site 8	39.4		37.6	6.8	-5%
Location 3	Site 9	54.2	17.5	41.4	8.4	-24%
	Site 10	51.9	9.1	37.1	6.6	-29%
	Site 11	47.3	[illegible]	29.1	[illegible]	-38%
	Site 12	59.1	5.3	38.1	8.5	-36%

RECRUITMENT AND MORTALITY OF JUVENILE CORALS ON THE FRINGING REEFS NORTH AND SOUTH OF CAPE TRIBULATION OVER ONE YEAR.

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ABSTRACT

Patterns of coral spat recruitment onto settlement plates and turnover of juvenile corals in mapped quadrats were examined at 6 reefs, near Cape Tribulation. There were no significant differences between the number of coral spat recruits at southern, central, and northern zones of this region. The taxonomic composition of spat varied between the three zones. The abundance of spat on the fringing reefs was comparable to that found on midshelf reefs near Cairns, although the taxonomic composition was different.

The abundance of different taxa of the juvenile corals closely reflected the relative abundance of adult corals at each reef, but was not closely correlated with the taxonomic composition of coral spat. There were dramatic changes in juvenile corals over the one year period which can be attributed to the effects of two cyclones that passed close to the area in February 1986.

No evidence was found from one year's data that the consequences of a new road in the central zone adversely affected juvenile corals or the availability of coral larvae, but any possible effect from the roadworks would have been masked by the effects of the cyclone.

INTRODUCTION

We present here the first year's results of a 3 year program to investigate coral spat and juvenile recruitment patterns on fringing reefs in the Cape Tribulation area of North Queensland. The aim of the program is to determine if the recent construction of a road on a section of the coastline adjacent to some fringing reefs has affected the juvenile corals on the reefs. It is possible, that increased sediment levels due to run-off might adversely affect coral reproduction or recruitment processes without resulting in significant death of established corals. This could result in a slow, long-term decline in the viability of the fringing reef coral communities, so a study of recruitment patterns might detect such changes before they were discernable in the established coral community.

This paper also compares the results from the Cape Tribulation region with the results from a study of recruitment on some mid-shelf reefs off Cairns, to the south of the fringing reefs.

The study of the fringing reefs commenced 10 months after completion of the road and after the first wet season had finished. No obvious mortality of the largercoral colonies had been observed at that time (A. Ayling, personal communication).

Very little work has been published on coral population dynamics of fringing reefs. Heyward and Collins (1985) reported on reproduction and population dynamics of a common fringing reef coral Montipora ramosa(=digitata), from Magnetic Island. Harriott (1983,1985) studied reproductive ecology, population dynamics and recruitment of corals on a patch reef which was part of the fringing reef surrounding Lizard Island. Other studies focused on zonation (Bull, 1982; Morrissey, 1980), geomorphology (Hopley et al, 1983), and reproduction of some common species (Babcock, 1984).

METHODS

Sites

Six reefs were selected in 3 zones, with two reefs in each of the zones (figure 1). The southern zone includes a group of reefs where the adjacent coastline has been extensively cleared and a coastal road has been in existence for at least 10 years. The central zone reefs are most likely to be affected by the new road section which is close to the coast and has some steep gradients with numerous streams. The northern zone reefs have a hilly coastline and the road turns inland in this region, so there is no run-off from the road onto the fringing reefs.

Settlement experiments

Two settlement racks were placed on each of the 6 reefs, with each rack having initially, 3 types of plates. There were 4 plates cut from a massive Platygyra colony with 2 smooth cut surfaces, 2 plates where one surface was the outer surface of the Platygyra colony, and 1 large piece of Acropora palifera. The Platygyra plates were bolted in pairs above and below the weldmesh rack, and the Acropora plate was tied to the top of the rack with wire (Harriott and Fisk, in press).

Many plates were lost from the racks in the summer period so a common denominator of 3 plates (one pair of smooth plates and a single lower plate with the outer Platygyra surface) were sampled from each rack. Spat on upper and lower surfaces of each plate and on 2 of the 4 sides were counted and identified to family level. Racks are replaced at approximately 6 month intervals corresponding to the end of summer and winter periods.

Turnover of juveniles

Juveniles were defined as colonies with mean diameters of less that 10cm (from 2 perpendicular measurements). All juveniles were mapped and measured in 3 x 1sq.m. quadrats which were within a 10m radius of the settlement racks on each reef. Quadrats were mapped in November 1985 and again in October 1986. Only 1 of the two reefs in the most northern zone was relocated and mapped in October 1986.

RESULTS

Recruitment on settlement plates

During the summer period (October 1985 - April 1986) over 2000 spat were recorded on the 6 reefs. In contrast, during winter (April 1986 - October 1986), only 5 spat were found on the 8 racks which were recovered. The following results refer to the summer recruitment only.

The total number of spat per rack ranged from 30, to 450 (mean = 151, S.D. = 108) (figure 2). There,was no significant difference in number of recruits per rack between the 3 zones (analysis of variance, on log transformed abundance data, F=2.61, P(F)=0.13). The number 'of spat from the families Poritidae and Faviidae were. relatively consistent between reefs but the number of acroporids varied greatly (figure 2). The proportion of all spat represented by the families Pocilloporidae and Poritidae did not vary significantly between zones (analysis of variance, arcsin transformed proportions (F=2.95, P(F).-0.1; and F=3.07, P(F)=0.1 respectively). However the proportions of Acroporidae and Faviidae of the total numbers were significantly different between the zones (analysis of variance, arcsin transformed proportions, F-20.75, P(F)<0.001 and E-7.76, P(F)=0.01 respectively). This variability was due to the larger numbers of these two families in the northern zone (figure 2).

Comparison with mid-shelf reefs

The density of spat on the Cape' Tribulation plates was comparable to the density of spat on some offshore mid-shelf reefs for the same time period. The mean number of spat per rack was 151 (S.D. =108) for the fringing reefs, and for comparable plate sets, the offshore reefs averaged 96 per rack (unpublished data).

The location of spat on the plate sets was different for the Cape Tribulation plates from that found at Green Island on the mid-shelf (table 1). Nearly 80% of all spat recorded on the fringing reef plates were found on the two vertical surfaces ofthe settlement plates, compared with the 23% to 27% found on the comparable vertical surfaces on the plates from Green Island. In addition, significant numbers of spat were found on the upper surface of the Cape Tribulation plates but no recruitment, occurred on the upper surface at Green Island.

There were differences in the taxonomic composi-tion of spat 'on the fringing compared with mid-shelf reefs (figure 3). The major differences include a greater proportion of Faviidae and a reduced proportion of Pocilloporidae on the fringing reefs, compared to those offshore.

Dynamics of mapped juveniles

In' November 1985, a total 'of 28 genera were recorded in the 18 sq. m. 'of permanent quadrats, with between 7 and 18 genera present at any one reef. The most abundant genera in decreasing order of abundance were: Acropora, Hydnophora, Galaxea, Pocillopora, relative abundance of the familiess Acroporidae and Pocill was consistent on all reefs, with' acroporids always most abundant while. pocilloporids were always rare. In contrast, 'Faviidae and Poritidae were highly variable 'between reefs.

Significant changes in the numbers of juveniles were recorded between 1985 and 1986 (table 2). Similar nett colony numbers for the 2 years were recorded in the central and northern zones but the two southern reefs had noticeable nett reductions in colonies between the first and second census. The number of recruits into permanent quadrats ranged from 6 to 58 per reef (combining the 3 quadrats). Many of these recruits were fragments of small colonies attached to larger segments of reef material which-were. moved into the quadrats by wave action.

Overall, mortality rates were high (39%-76%; table 2), but these are probably overestimates since many fragments appear to be removed from the quadrats rather than killed outright, and the outcome from fragments outside the quadrats cannot be determined.

Spat and juvenile abundance compared to total populations

Overall, the Acroporidae are the most abundant family in the spat, juveniles, and total coral estimates, though the spat are under represented, compared to the other two categories, in the two southern reefs (figure 4). Pocilloporid adults are not abundant and the spat and juveniles reflect total colony abundances., Faviidae are always over represented in the spat compared to the juveniles and total numbers, especially in the southern reefs. On half of the reefs, poritid spat are in higher proportions than the juveniles and total estimates, with the other half of the reefs showing more or less equal proportions of all 3 categories. The other families represented do not seem as a group to vary appreciably in their proportional representation at any of the reefs.

DISCUSSION

The first year of results has shown some interesting patterns with regard to spat type and distribution. The following two years of the study will show if these patterns are consistent or show inter-annual variation. Characteristics likely to be consistent over time include: the preponderance of spat settlement over the summer period consistent with offshore mass spawning patterns (Babcock *et al*, 1986); and the dominance.of Acroporidae and possibly Faviidae in the spat, because of the dominance of these families in the established coral communities of all the fringing reefs in this area. Though faviid spat are apparently over-represented in relation to the relative abundance of the juveniles and total numbers in the shallow study areas, adult faviids are abundant in deeper water at most reefs (Ayling, this workshop), and this may account for their abundance as recruits.

The first year's study showed no variation in number of recruits in three zones likely to be affected to different degrees by the runoff from the new road at Cape Tribulation.

No clear correlation can be made between total coral numbers and composition and local spat densities and composition. This suggests that the reefs of Cape Tribulation receive more or less a mixed pool of larvae, depending on particular water movement features over the few weeks that most larvae stay in the plankton. Temporal variation in the number and composition of settled spat is documented in the literature (Wallace, 1985), so it will not be surprising to find a different pattern in the summer of 1986-87.

Coral spat at Cape Tribulation settled preferentially on vertical and upper surfaces in contrast with recruits on offshore plates. This may reflect differences in factors adversely affecting successful settlement at similar depths in the two environments. The preference for vertical surfaces in the fringing reefs may be a result of a compromise between avoidance of heavy sediment load and avoidance of very low light levels in the normally turbid water. Very few spat were found between and under the plates on the fringing reefs, where ambient light would be very low, while the spat on the mid-shelf reefs were most abundant in these positions.

Moderate numbers of spat were also found on the upper surfaces of plates from the fringing reefs while none were found in that position on offshore plates. Though sediment load in the water is more obvious in the fringing reef, grazing pressure from fishes appears to be low (A. Ayling, personal communication,)., and grazing by various organisms is one factor that has been proposed to reduce recruitment on upper surfaces in shallow reefs (Harriott, 1985). It is possible that initial recruits on the upper surfaces at ,a fringing reef will not survive subsequent sediment load.

The mortality rate of juveniles in the mapped quadrats was higher than other published estimates for shallow reef corals (Connell, 1973; Bak and Engel, 1979; Harriott, 1983). As well, within a 1 year sampling period there can be as much as a further 30% turnover (Harriott, 1983). The very high mortality rates reported here are largely due to the effects of a small cyclone which passed close by in February 1986.

Branching and foliose Acroporidae tend to dominate the study sites and these most abundant growth forms are adept at recovery from fragments. The Cape Tribulation area is in an area where periodic moderate to high disturbance takes place so fragmentation is probably important in maintaining a dominance in these areas (Highsmith, 1982). This raises the question of whether fragmentation might be the dominant form of recruitment in at least the shallower, areas. In support of this, is the generally loose nature of the substrate and the presence of strong seasonal winds. We will attempt to evaluate the relative contributions of fragmentation (an asexual process) and spat, recruitment (largely sexual) to the community in the continuing programme.

We found no evidence that the effects of the recently constructed road are affecting the juvenile or spat recruitment patterns. However, the effects of cyclone activity on the dynamics of the juveniles would have masked any possible effect from sediment runoff. The study will continue for two more seasons covering a further two wet seasons, and should allow evaluation of the reefs under non-cyclonic conditions.

ACKNOWLEDGEMENTS

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Table 1: Settlement orientation of coral spat on settlement plates at Cape Tribulation and Green Island. "Top" is uppermost surface on a pair of plates, "middle" is the 2 surfaces between, pairs of plates, "bottom" is lowermost surface.

Surface	Cape Tribulation			Green Island	
	Zone 1	Zone 2	Zone 3	Backreef	Forereef
Top	8%	5%	3%	0%	0%
Middle	10%	10%	13%	47%	18%
Bottom	3%	4%	11%	29%	55%
Sides	80%	80%	72%	23%	27%

Table 2: Recruitment and mortality rates for juveniles (mean diameter< 10cm) at six reefs.

Taxa		South		Central		North
		Z1/1	Z1/2	Z2/6	Z2/17	Z3/11
Acroporidae	No. Recruits	26	27	16	0	25
	No. Dead	75	55	22	3	18
	Initial No.	97	119	28	1 0	22
	Mort. Rate	77%	46%	79%	30%	82%
Pocilloporidae	No. Recruits	2	1	0	1	2
	No. Dead	8	5	0	0	1
	Initial No.	8	10	2	3	1
	Mort. Rate	100%	100%	0%	0%	100%
Poritidae	No. Recruits	0	3	5	0	3
	No. Dead	0	0	10	0	8
	Initial No.	0	7	16	0	12
	Mort. Rate	0	0	63%	0	67%
Faviidae	No. Recruits	i	0	3	1	6
	No. Dead	9	1	6	3	8
	Initial No.	10	3	18	8	11
	Mort. Rate	90%	33%	33%	38%	73%
Other Families	No. Recruits	0	5	5	4	22
	No. Dead	4	13	4	3	9
	Initial No.	13	1 7	17	13	12
	Mort. Rate	31%	77%	24%	2 3 %	75%
Totals	No. Recruits	29	36	29	6	5 8
	No. Dead	96	74	42	9	44
	Initial No.	128	156	81	34	58
	Mort. Rate	75%	47%	52%	27%	76%

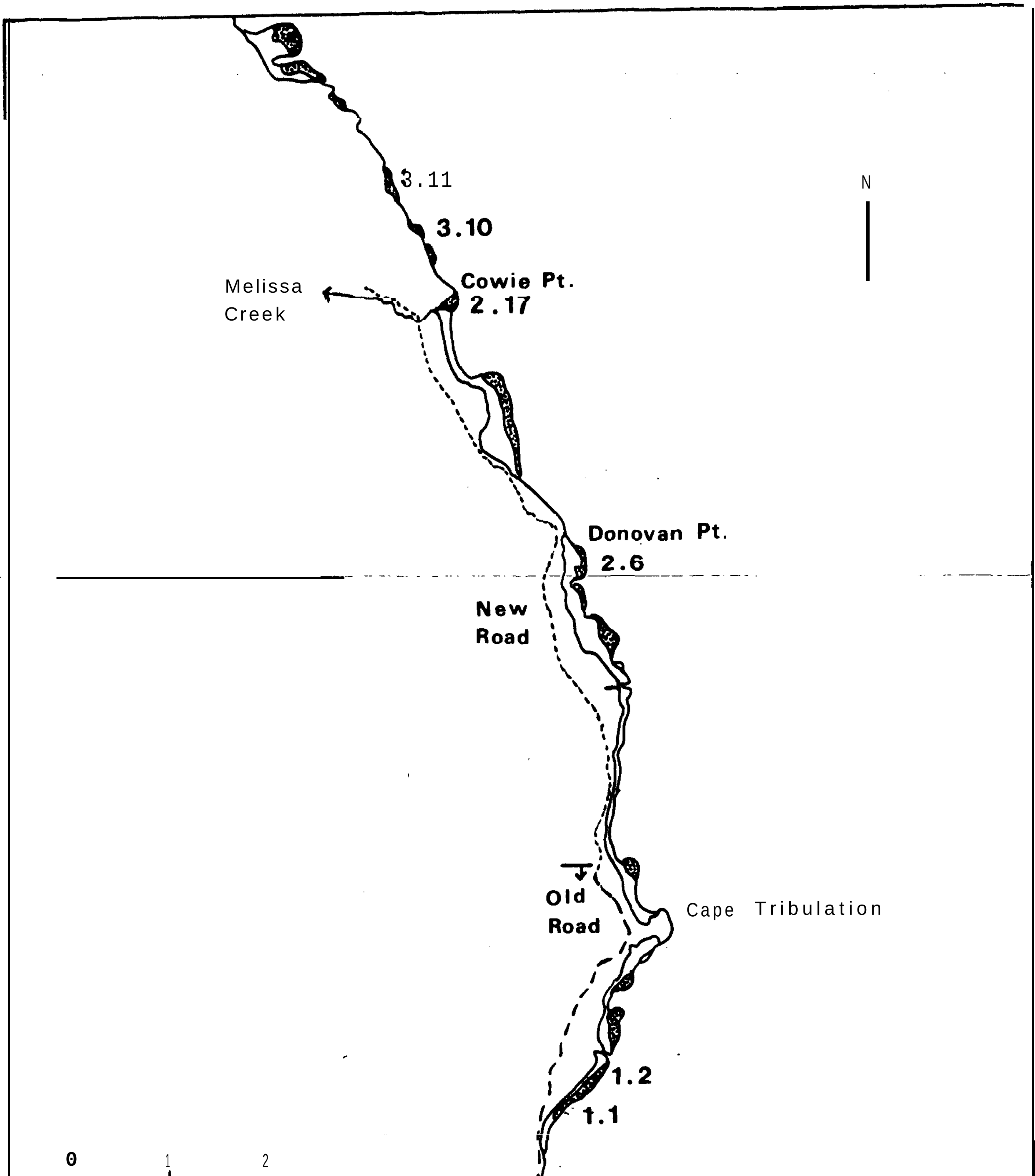


Figure 1: Diagram of the study area showing the 6 fringing reefs in zones 1,2, and 3. The numbers fdr each reef are those given by A. and A. Ayling in a complementary study.

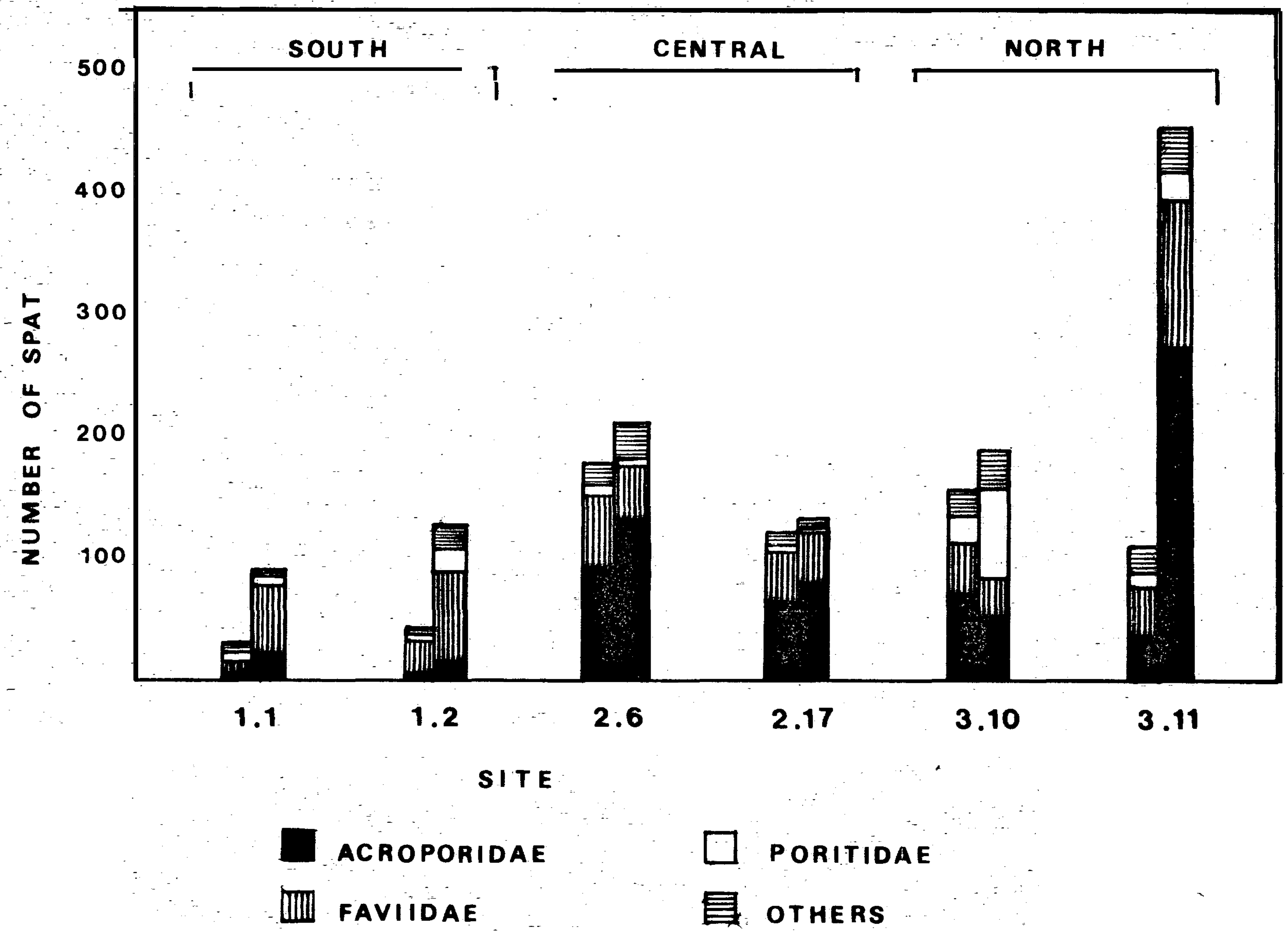


Figure 2: Histogram of the abundance of spat in different families at pairs of settlement racks on the 6 reefs sampled.

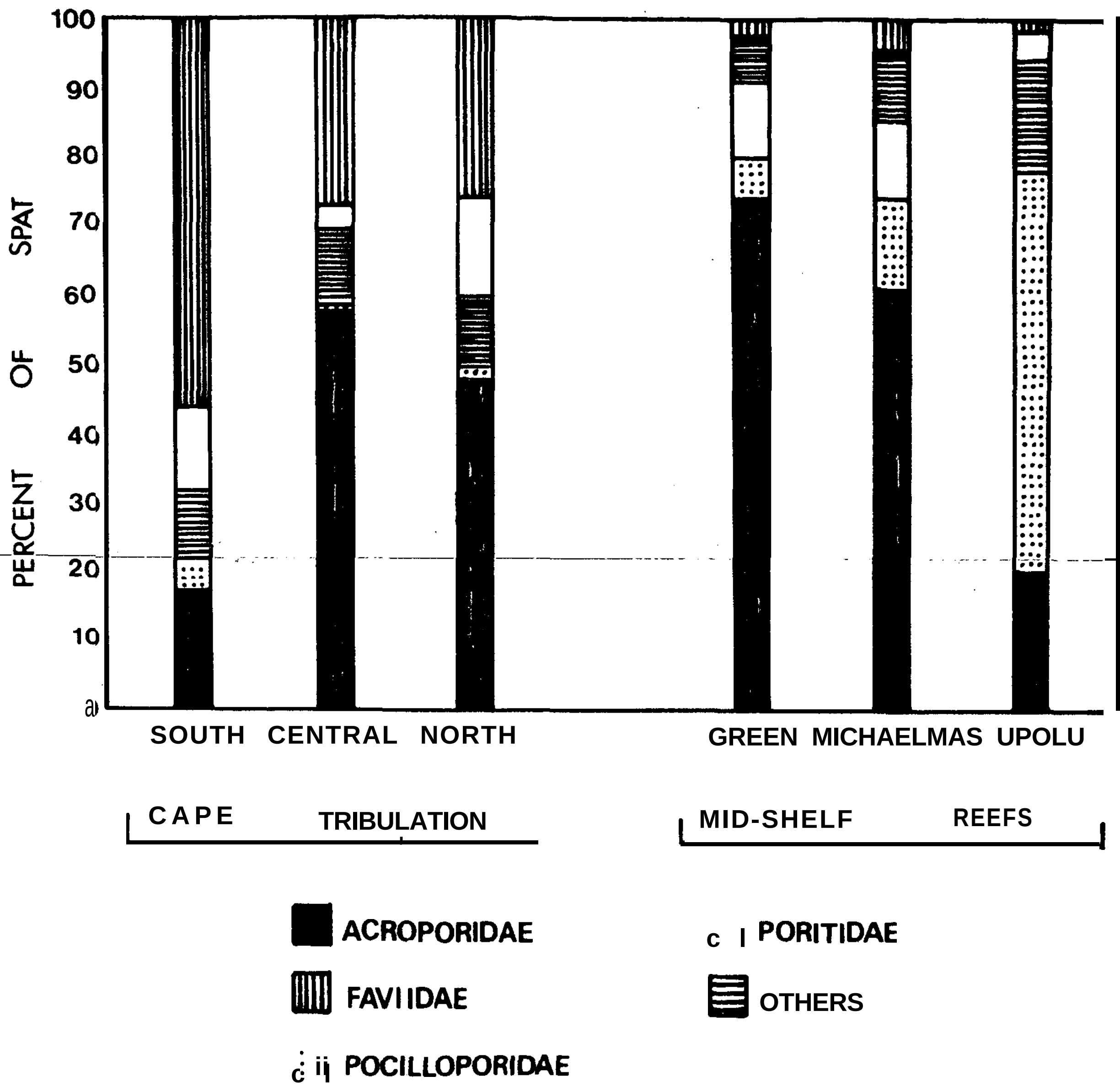
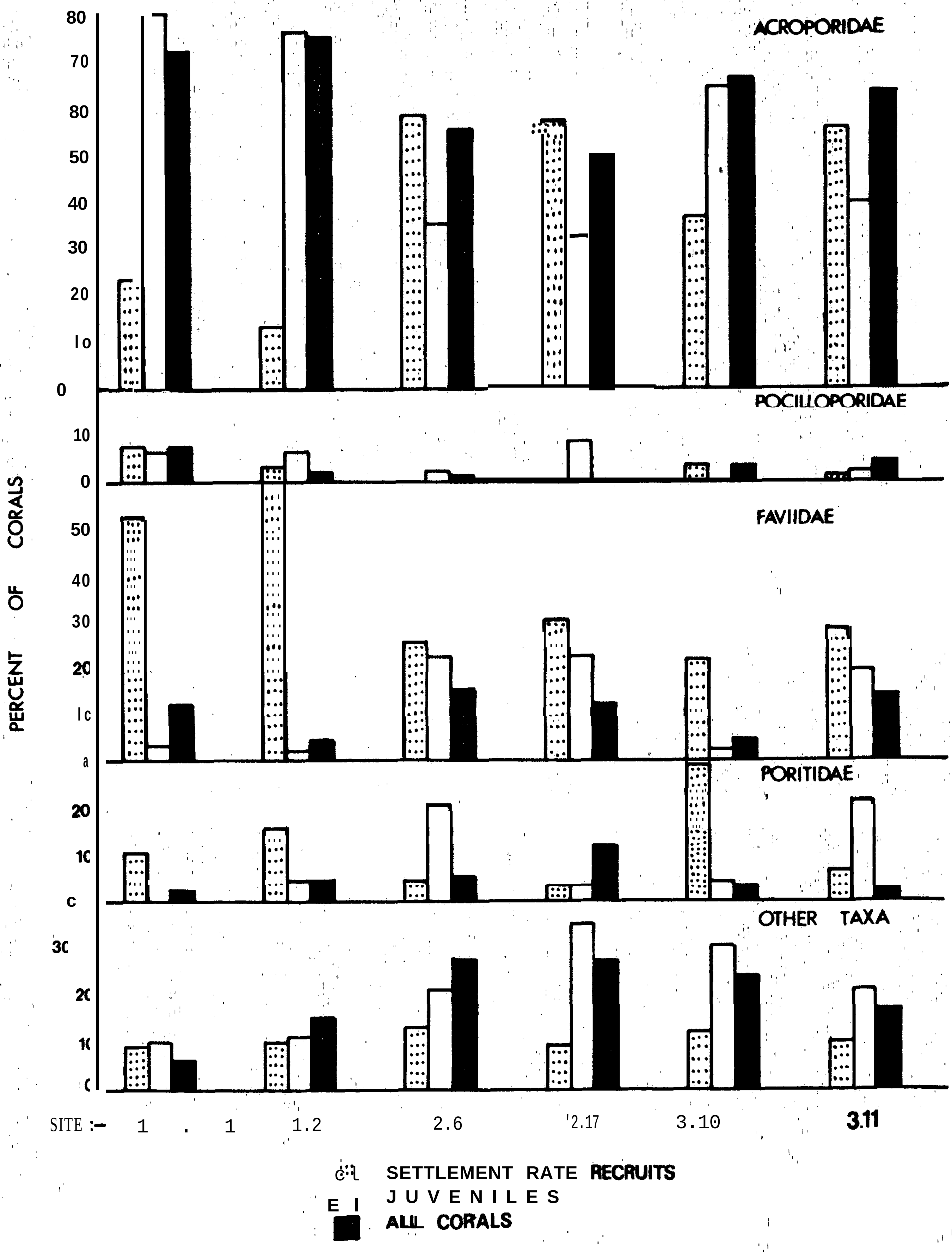


Figure 3: The relative abundance of different spat families in the 3 zones at Cape Tribulation and at 3 reefs offshore from Cairns.

Figure 4: The percentage of corals in different families at each of the 6 sites for established corals (data provided by A. and A. Ayling), juvenile corals (<10 cm mean diameter) and coral spat on settlement plates.



STRUCTURE AND GROWTH OF THE CAPE TRIBULATION FRINGING REEFS - PRELININARY CONCLUSIONS

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ABSTRACT

During May and June of 1986, nine boreholes were drilled into three fringing reefs near Cape Tribulation (16°05'S, 145°28'E). Maximum depth drilled was 8.3 metres, and cores from the boreholes reveal a fluvial fan gravel foundation. Petrographic study of thin sections of core material indicates both aragonite and high-magnesian calcite cements. Samples recovered show no extensive recrystallization of aragonitic skeletal constituents. This evidence implies that' the reefs have not been exposed subaerially for a significant period of time, and are probably younger than Pleistocene age. Sample recoveries range from 25 to 40 percent of total depth drilled. From top to base, the typical vertical sequence is algal veneer, coral framestone, mixed terrigenous-carbonate detritus, basal coral framestone and gravel foundation. Surveying of the reefs shows an average reef front elevation of .5 metre above Mean Low Water Springs. This data, plus the paucity of live coral growth on the reef flat in favor of coralline algae, indicates a slightly higher past sea level or isostatic adjustment.

The project is ongoing, with chronology of reef growth to be determined by radiocarbon dating and radiographic banding study.

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Checklistof corals from the Daintree Reefs

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Summary

One hundred and forty-one species,' belonging to 50 genera of scleractinian corals were recorded from the Daintree reefs during a three day study, November 1985.. Of these, Alveopora gigas, Alveopora marionensis and Psammocora sp. have not been previously recorded from 'the Great- Barrier Reef. The absence of any previous record of Alveopora' gigas from any eastern Australian locality except the Daintree reefs is extraordinary as this' species forms large conspicuous colonies with large and very'distinctive polyps.

Acanthastrea echinata	rare, recorded from Ayling's specimen only
Acropora aculeus	rare
Acropora anthocercis	rare, difficult to recognise
Acropora brueggemanni	very common and widespread
Acropora cerealis	uncommon
Acropora cytherea	patchy
Acropora danai	in one area only
Acropora divaricata	common,, most colonies are a distinct purple
Acropora donei	patchy
Acropora elseyi	patchy, abundant at one site
Acropora formosa	patchy
Acropora grandis	rare or very patchy
Acropora humilis	uncommon
Acropora hyacinthus	uncommon
Acropora kirstyae	rare
Acropora latistella	patchy
Acropora microclados	uncommon
Acropora microphythalma	very'common in some areas
Acropora millepora	uncommon but very distinct salmon pink
Acropora nasuta	patchy
Acropora palifera	very common
Acropbra paniculata	rare

Acropora samoensis	common
Acropora selaqo	'patchy or uncommon
Acropora subulata	very common
Acropora tenuis	common, very distinct
Acropora sp.	very common and widespread
Acropora val ida	very common in shallow water
Acropora vauqhani	patchy
Acropora willisae	common in shallow water
Alveropora qiqas	common, not previously recorded from eastern Australia. This species forms large, conspicuous colonies at the Houtman Abrolhos Islands.
Alveopora marionensis	common, not previously recorded from the GBR
Astreopora moretonensis	common, forms stubby branches on flat plates
Astreopora myriophythalma	rare
Barabattoia amicorum	uncommon, hardly seperable from Favia
Blastomussa wellsi	rare
Caulastrea furcata	rare
Coeloseris mayeri	from Ayling's specimens, not seen by Veron
Coscinaraea columna	very-common and widespread
Cyphastrea microphthalma	common, forms big knobby colonies
Cyphastrea serai lia	common
Duncanopssamia axifuqa	uncommon
Echinophyllia aspera	very common and widely distributed
Echinopora qemmacea	common
Echinopora horrida	rare, recorded from Ayling's specimens, not seen by Veron
Echinopora lamellosa	very common and widespread
Euphyllia ancora	uncomon, very distinctive
Euphyllia qlabrescens	uncommon, very distinctive
Favia favus	common
Favia lizardensis	uncommon, forms large colonies
Favia pal l ida	common
Favia speciosa	rare
Favia veroni	uncommon, distinctive
Favites abdita	uncommon
Favites complanata	uncomon or patchy
Favi tes f lexuosa	rare
Favi tes halicora	uncommon

Favites pentagona	very common
Favites russelli	rare
Funqia fungites	very commony
Funqia paumotensis	common
Funqia repanda	very common
Funqia simplex	uncommon
Funqia valida	common
Galaxea astreata	common
Galaxea fascicularis	very common, forms very large colonies
Goniastrea australensis	probably common
Goniastrea fawlus	uncommon
Goniastrea palauensis	common
Goniastrea pectinata	uncommon
Goniastrea retiformis	common
Goniopora columna	common, has large oral cones
Goniopora djiboutensis	common, forms flat sheets
Goniopora lobata	common
Goniopora minor	patchy
Goniopora stokesi	rare, from Ayling's specimens, not seen by Veron
Goniopora stutchburyi	uncommon
Goniopora tenuidens	common, forms large colonies
Heliofauqia actiniformis	rare
Herpolitha limas	common in some areas
Hydnophora . exesa	very common
Hydnophora pilosa	rare
Leptastrea pruinosa	common
Leptastrea purpurea	common
Leptoria phryqia	rare
Leptoseris mycetoseroides	'patchy
Lobophyllia hemprichii	common or patchy
Merulina ampliata	very common
Montastrea annuliqera	rare
Montastrea curta	uncommon
Montastrea maqnistellata	rare
Montipora aequituberculata	common, colonies small
Montipora crassituberculata	uncommon
Montipora foliosa	uncommon, colonies small
Montipora grisea	probably rare

Montipora hispida	very common
Montipora hoffmeisteri	uncommon, cryptic
Montipora informis	rare
Montipora nodosa	common
Montipora spumosa	uncommon
Montipora stellata	very common and widely distributed
Montipora undata	uncommon
Montipora verrucosa	uncommon
Moseleya latistellata	
Mycedium elephantotus	from Ayling's specimens, not seen by Veron
Oulophyllia crispa	from Ayling's specimens, not seen by Veron
Oxypora lacera	very common
Pachyseris ruqosa	common at one site only
Pachyseris speciosa	very common
Pavona cactus	rare - from Ayling's specimens, not seen by Veron
Pavona varians	uncommon
Pavona venosa	very common
Pectinia lactuca	very common and widespread
Platyqyra daedalea	common
Platyqyra lamel l ina	uncommon
Platyqyra pini	common
Platyqyra sinensis	common
Platyqyra verweyi	identification doubtful, rare
P leroqyra si nuosa	rare
Pocillopora damicornis	common
Podabacia crustacea	common
Polyphyllia talpina	common
Pori tes annae	common
Porites lichen	common, lacks distinct colouration
Pori tes lutea	very common, forms large colonies
Porites mayeri	common, colonies become columnar
Psammocora contigua	patchy
Psammocora profundacel la	uncommon
Psammocora superficialis	patchy, forms unusually large colonies
Psammocora sp.	common, upright flattened branches. Not previously recorded from eastern Australia
Psuedosiderastrea tayamai	uncommon, distinctive
Sandalolitha robusta	uncommon

Seriatopora hystrix	common in isolated patches
Stylocoeniella quentheri	uncommon, cryptic
Stylophora pistillata	common, forms unusually fine branches
Symphyllia aqaricia	rare
Turbinaria bifrons	uncommon
Turbinaria conspicua	
Turbinaria mesenterina	the most common Turbinaria
Turbinaria patula	rare
Turbinaria peltata	patchy
Turbinaria reniformis	common

THE FRINGING REEF PARADOX: OPPORTUNITIES AND CONSTRAINTS

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ABSTRACT

The fringing reefs of the Great Barrier Reef Region are amongst the most biologically diverse of any of the reefs of the Great Barrier Reef Region. That diversity and other attributes, particularly the accessibility of these reefs provides many opportunities for human use, and yet, paradoxically, also imposes many constraints on use. This paper discusses the attributes of fringing reefs, their uses and how these interact in terms of development constraints and opportunities. The paper concludes that with further vertical and horizontal integration of existing approaches to planning and development of fringing reefs, the opportunities they afford for a wide range of uses, could be optimised.

INTRODUCTION

"Among many who visited a "Great Barrier Reef" island resort, the Reef's image waned when they were confronted with the practical difficulties of getting to see or learn something about the reef ..... Unless they had the good fortune to choose Green or Heron Island they found that the Reef could be up to 40 arduous miles by boat, if the tide was right. If it wasn't, they had to 'be satisfied with a glimpse of a "fringing reef" near their resort from a glass boat."

(W. Franklin, in an address to the workshop on Tourism and the Great Barrier Reef, Mackay, 1979)

Fringing reefs are seemingly among the more enigmatic natural features of the Great Barrier Reef Region. For example, some scientists have noted (e.g. Steers and Stoddart, 1977) that they are the simplest of the three main reef types while others (e.g. Veron and Pichon, 1976). have recorded their benthic fauna as being the most diverse anywhere in the Region. Similarly, fringing reefs may be highly attractive, although in many cases (e.g. Cape Tribulation reefs) the prevalence of turbid conditions may restrict reef viewing. Many other contrasts could be drawn.

The distribution of fringing reefs within the Region is much less anomalous, with two principal areas of distribution described by Hopley (1982) - mainland fringing reefs and island fringing reefs. The mainland fringing reefs occur intermittently along the coast between Cape Conway (near Proserpine) and the Daintree River. 'North of the Daintree, they are more continuous, although there are still significant areas of coastline (particularly near river mouths) where no reefal development has occurred. The island fringing reefs display similar variation both geographically and in terms of local development.

The fringing reefs of the Great Barrier Reef Region are used extensively for a range of 'activities. The predominant uses are those associated with recreation and tourism. This is reflected by the historical development of tourism infrastructure in the Region, where the accessibility of fringing reefs made them ideal focii for offshore tourist development.

In recent, years, particularly since the advent of high speed catamaran services to the outer reefs, the range of reef oriented recreational opportunities offered have been greatly increased, possibily 'resulting in a decline, in the recreational'significaqce of fringing, reefs to tourists. As later sections of this paper point out, , however, fringing reefs remain a 'very important setting for a range of uses. A challenge 'facing both 'managers. and operators, is to ensure that. the opportunities afforded by fringing reefs are maximised while ensuring that those uses do not diminish the qualities of the resource on which they are based.

ATTRIBUTES OF FRINGING REEFS

Fringing reefs occupy, a particular niche within 'the broader spectrum of Great Barrier Reef resources. Their wide distribution, high level" of accessibility 'and diverse biophysical attributes combine to facilitate a wide range of potential uses. However , unlike many of the mid-shelf platform reefs, fringing reefs tend to exhibit,marked local variation in terms of their in-situ attributes. Thus in any assessment of .the development potential of a given fringing reef, or section of fringing reef, some assessment -should be made of the, relative significance of key attributes such a,s:

(a) Geological Structure - the variable evolution of many fringing reefs as noted by Hopley (1982) may be an important factor' in terms of influencing:

- the topography of the reef - e.g. steep windward slope,
- the composition of the reef - e.g. depth to rock, and
- the geological history of the 'reef - e.g. influence of sea-level variations.,

(b) Geomorphological Processes - many factors combine 'to affect the ongoing growth of fringing reefs. Important, geomorphological processes include:

- erosion - e.g. stability of the reef structures,
- sedimentation - e.g. infill/burial of surface features, and
- zonation - e.g., variations in processes in different areas of a fringing reef.

(c) Meteorological - climatic conditions and processes are fundamental influences in the development, maintenance and attractiveness of fringing reefs. Important, elements include:

- temperature - e.g. the limiting effects of low temperatures on some coral species,
- rainfall - e.g. effects on reef flat biota of i'ntense downfalls (and subsequent lowered salinity), and
- cyclones - e.g. potential for disturbance/past influence .

(d) Oceanographic - oceanographic processes are 'another,' fundamental', influence on fringing reef, development, maintenance and use. Important elements include:

- currents - e.g. speed and direction,
- tides - e.g. height and variability, and
- waves - e.g., height,, period and variability, relative to aspect/exposure.

(e) Biological - the ecological patterns and processes prevalent on fringing reefs are often quite distinct from those associated with other reef types. This in turn affects their development, functioning and relative attractiveness. Major elements to be considered include:

- biological community - e.g. algal/coral cover,
- productivity - e.g. growth rate and seasonality, and
- dynamics - e.g. variability in recruitment.

(f) Resilience - the ability of an ecosystem to recover from impact or perturbation is a complex question, but one which may be vital to management of an activity in a particular setting. Various studies have shown fringing reefs to be resilient to the extent that their communities are capable of adjustment to highly variable environmental conditions. In considering the resilience of any fringing reef community, the major question faced by management is whether a proposed activity will affect the ability of the community to recover. Account should also be taken of the time scale(s) for recovery.

(g) Accessibility - Accessibility is regarded as an important distinguishing feature of fringing reefs. Pigram (1984) notes, however, that recreational access implies much more than mere mobility or a tourist's technical capacity to reach a desired site. It is related to that space which the potential visitor perceives as available or attractive for recreational use. Factors influencing visitor perception include:

- comfort/safety
- attitudes/past experiences,
- information levels/awareness, and,
- social/legal conventions.

Other important factors for both recreational and other uses include:

- the setting of the fringing reef (see (i) below),
- proximity to centres of demand, and
- ease/convenience and cost of access.

(h) Management - the management regime for fringing reefs in the Great Barrier Reef Marine Park is complex, Nearly all of the fringing reefs are included in the Great Barrier Reef Marine Park. These reefs lie within both Commonwealth and State Government jurisdiction. The predominant management technique currently applied by both Commonwealth and State agencies (or under development) is zoning. This involves a "strategic" scale planning approach, supplemented as necessary by other development controls (e.g. permitting of activities)

(i) Hinterland - the nature of land use adjacent to fringing reefs, or uses in catchments which may affect fringing reefs may be important influences on the development, maintenance and use of those reefs.

Some important considerations include:

- the physio-chemical pathways for influence, e.g. point/non-point source run off;
- the land use setting of the fringing reef, e.g. whether the fringing reef is a barrier to a mainland/island site, or whether e.g., a coastal land use affects the relative attractiveness of the reef, and
- the level of demand for fringing reef-based or oriented, activities from adjacent areas (e.g. tourist resort).

(j) Competition between uses - fringing reefs are characterised by a range of resources and thus, are attractive for a range of uses. The ability of potential uses to coexist and/or separately exploit particular resources depends on considerations such as:

- the resource requirements of the use - e.g temporal aspects especially,
- the "sustainability" of the use - e.g. level of extraction/consumption, and
- the intrinsic requirements of a use - e.g. ability to tolerate other uses.

USES OF FRINGING REEFS

The ten attributes discussed above are indicative of the, complexity of factors which must be considered in any assessment of the suitability of fringing reefs for a range of uses. That same complexity also serves to explain the wide diversity of uses of fringing reefs. Data on demand for most uses is limited. However, the following are regarded as major historical or present uses of fringing reefs in the Great Barrier Reef Region:

- fishing, both recreational and commercial, is widespread on fringing reefs in the GBR region, particularly those that are highly accessible from major mainland island centres (e.g. Geoffrey Bay, Magnetic Island).

- coral, shell and aquarium fish collecting occurs on a range of fringing reefs, although data on historic/present levels is limited.

- mariculture - in recent years increasing attention has been paid to, the potential for mariculture in some fringing reef locations. The principal species of interest at present are three species of giant clams (<u>Tridacna gigas</u>, <u>T. derasa</u> and <u>Hippopus hippopus</u>).

- mining and the recovery of minerals, which is prohibited within the Marine Park, although historically, a range of developments involving removal of reefal materials for construction purposes has occurred.

- dredging in the immediate area of fringing reefs is limited in extent, and now subject to permission. Permission is now also required to dump dredge spoil, although it is claimed that historically, spoil dumping may have adversely affected some fringing reefs (e.g. Smith, 1978).

- recreation and tourism use of fringing reefs in the Region is extensive and includes both active and passive uses. There is considerable variation in the extent to which tourism operations make use of fringing reefs. Some reefs form an important component of the recreational attraction of particular tourist operations (e.g. Fitzroy Island), while other reefs provide an incidental setting to tourist activities (e.g. Dunk Island). The increased accessibility of offshore platform and barrier reefs in recent years may also have led to a decrease in recreational attractiveness and hence usage of some fringing reefs, although inadequate data exists to assess the extent of that change.'

- conservation of fringing reefs in the Region in terms of habitat protection/preservation is now provided for in the context of the zoning plans for the Great Barrier Reef Marine Park and through complementay State Marine Park zoning plans.

- use of fringing reefs for educational purposes is extensive, although, like tourism and fishing, data on use characteristics and levels is limited. Educational uses include occasional and regular excursions to selected reefs (principally near major mainland centres) and in the case of Orpheus Island, permanent facilities have been established for educational/research activities.

- research use of fringing reefs tends to be highly variable. This is highlighted by the lack of data on fringing reefs in the Great Barrier Reef Region generally. In recent years, research effort on some island and mainland fringing reefs (e.g. Cape Tribulation) has increased in response to perceived threats from hinterland activities.

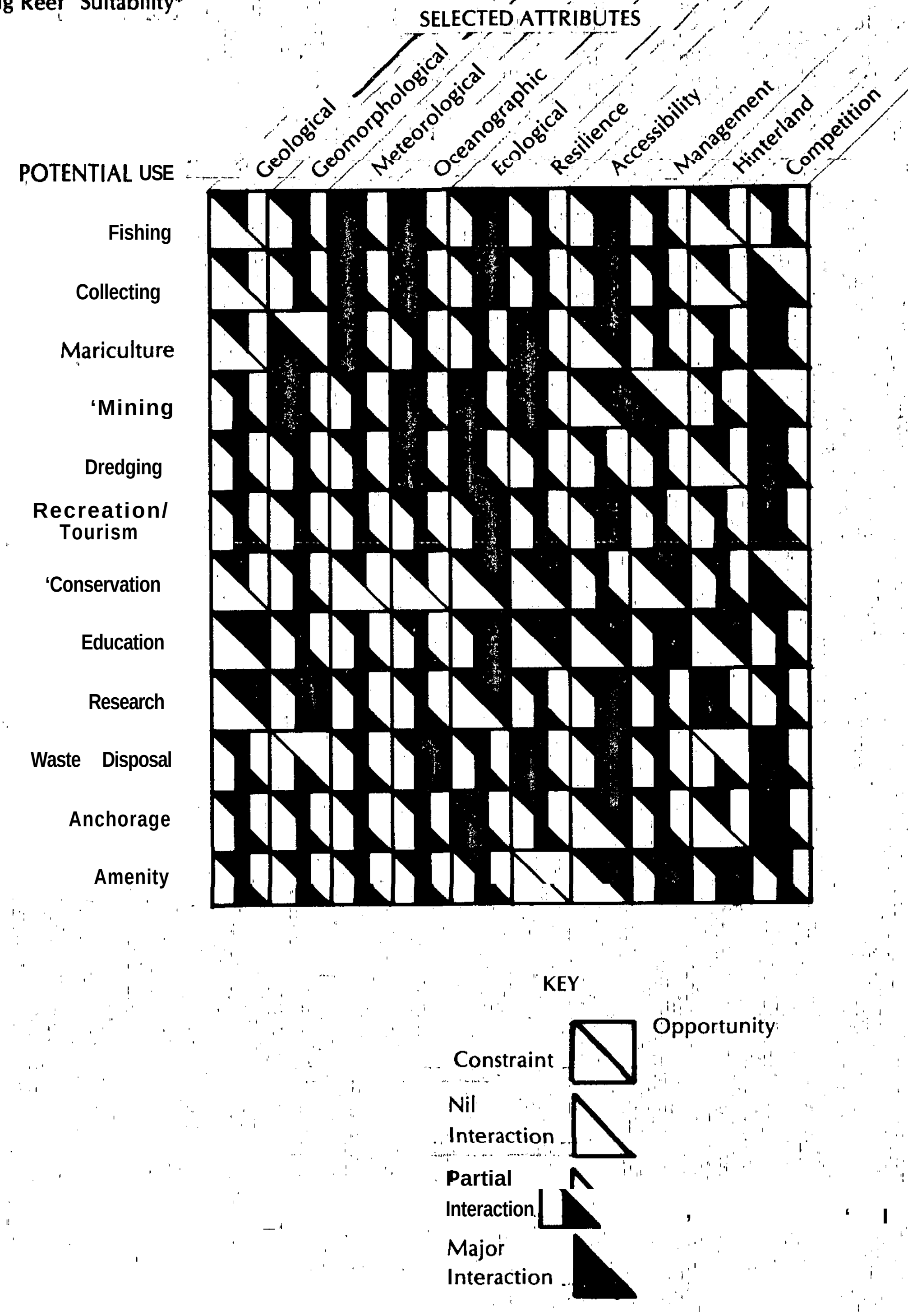
- waste disposal is a minor activity impacting fringing reefs which may be locally important, and consists predominantly of outfall releases of sewage and plant/process wastes, and of dumping of wastes such as kitchen scraps. These activities are subject to permission under the Great Barrier Reef Marine Park Regulations.

- use of fringing reefs for anchorages is extensive, and includes random anchoring, set moorings and limited boat channels and harbour works. These activities often prevail where fringing reefs are an attractive setting for cruising activities (e.g Butterfly Bay) or to facilitate access to island/mainland locations.

- "aesthetic" uses of fringing reefs include protection/reservation of areas for amenity purposes. They are rarely overt, although care is often taken in siting facilities to 'take account of the value of protecting/enhancing the visual amenity of a fringing reef setting (e.g. Hayman Island resort development).

Table 1

Table 1: Assessment of Fringing Reef Suitability*



* See explanatory text

SUITABILITY OF FRINGING REEFS

As indicated above, the suitability of fringing reefs for particular uses is highly variable. There are many factors which need to be taken into account in assessing suitability. One method of assessing suitability is to define how resource attributes may affect a use in terms of whether those attributes represent a constraint or an opportunity.

Table 1 outlines a broadly-based matrix approach where some key attributes and uses discussed previously are assessed in terms of whether the interaction represents a constraint, or an opportunity, or a combination of both. The table reveals the varying extent of influence of- various attributes on different uses. The table is too broad in scope to be applied to specific developments or reef settings, however, it serves as a broad guide to the types of considerations which must be taken into account in planning for use of fringing reefs. The table also indicates that, in many cases, an attribute may rrepresent both a constraint and an opportunity, This apparent paradox is largely explained by the variable requirements of different uses and by the simplistic design of the matrix. The matrix thus has only limited practical application to development planning for fringing reefs as it does not identify specific aspects of an attribute which may influence the interaction, nor does it specify the relative strength/influence of any interaction.
3

The matrix therefore underlines the need to apply appropriate development planning techniques to clearly elicit the type and strength of interaction&

Despite the above limitations, the matrix is a useful basis for comparison of use/resource interactions and provides a framework for more in-depth analysis by identifying key interactions and uncertainties. Kenchington and Hudson (1984) outline a range of further analytical techniques appropriate in this context.

RECREATION/TOURISM EXAMPLE

An illustration of how the matrix can be applied to assessment of recreation/tourism uses of fringing reefs is set out below. It is clear from this illustration how the ten factors which are constraints can also be opportunities.

1. As indicated by Hopley and Partain (this volume), there is a diversity of geologic structure in fringing reefs. This can provide a variety of recreation opportunities. A wide exposed reef flat may be appropriate for reef walking and shell collecting (such as on Middle Island reef near Bowen). However, the opportunity provided by that type of structure could be a constraint to a semi-submersible operation. A reef with a steep drop-off such as in the Palm Island group would provide a better opportunity for a semi-sub operation, providing excellent views of coral.

2. Certain geomorphological processes can provide constraints to iong-term deveiopment or use of a fringing reef. ii a fringing reef is prone to erosion or sedimentation, it may not be a reliable venue for a tourist operation.

3. A good example of the paradox of opportunity and constraint is revealed in meteorological conditions. The relative safety and shelter provided by many fringing reefs, also means that they are located in areas that are prone to cyclones and a rainy season that can limit the viability of a commercial operation.

4. Oceanographic, processes such as tides,' demonstrate the variation in opportunity available, for different activities, depending on the tide On the same reef, one may enjoy snorkelling and water skiing" during "one. part, of the day, but reef walking during another, when it is low tide. However', the constraint is that because,tides vary daily and 'seasonally,, one cannot. count on consistently being able to do, 'certain activities at the'same jtime every day.

In this 'respect, most successful tourist operations have found that they need to offer a variety of activities and to be flexible in scheduling activities. From a design point of view, floating pontoons and, stinger nets may be more successful than more rigidly engineered structures.

5. Biological processes such as the type of algal/coral 'cover and' seasonality of growth can have a major impact on recreational use.' Most tourists, have a greater appreciation for coral than for algae. If a massive algal bloom is anticipated at'a certain time each year, this may be a constraint. On the other hand, as Colfelt (this "volume) mentioned, through educating the public to appreciate algae or that "dead" reef flat, , this could be turned into an, opportunify.

6. The relative resilience (or ability to recover) of fringing reefs 'to variable environmental conditions' means that they can offer a 'consistent opportunity in many way's'. At reasonable levels, fringing reef corals can cope occassionally with lowered salinity which follows rainfall and the run-off from coastal streams. Similarly they can clear reasonable levels of silt which'settles from coastal 'run-off. But when fringing reefs become covered with a blanket of silt, they provide a surface more suitable for plants than hard corals (Hopley, 1985). In this respect they are more susceptible to long-term or chronic "damage" from siltation or pollution. One could suggest, that they have adapted to cope with natural variation impacts rather than man-made impact.

7'. An inherent characteristic of fringing reefs is their general accessibility to the coast and consequently, in many' cases their proximity' to 'centres of recreation demand.., The ease and cost of access, perception of safety and other user requirements will deter'mine the degree of use. With a trend in tourism of 'expanding into, many places previously considered"wilderness, accessibility may become less meani'ng'ful., The resort lodge recently constructed at the top of Cape York means that previously inaccessible fringing', reefs are now more accessible. The zoning of fringing' reefs off Cape Tribulation took account of the fact that it was 'the only si'zeable., mainland fringing reef in the Cairns Section that was inaccessible at'.. the. time,.

8. To an average user, the system of management of the Great Barrier Reef Region is incredibly complex, involving a 'number of different agencies and possibly a number of different zonings. The complexity of management and necessary restrictions may be viewed as a constraint by tourists and recreational users. The opportunities that management "provides, however, for interpre'tatidn, education and better conservation of the resource must outweigh the' constraints. Management must be appropriate to the reefs and their use and to their users.

9. The, hinterland offers physical support,, to use of fringing reefs by the, development of tourist infrastructure. It also places stress on the fringing reef, environment,'in different ways, from potential waste disposal to increased visitor impact.

10. Depending on the size of the fringing reef most tourist uses can coexist with other uses with little problem. Conflicting uses such as seaplane landings near areas used for snorkelling, can be resolved by proper management. Mariculture is an example of virtually exclusive use of a part of a fringing reef. This would not necessarily have to conflict with tourism however, as an opportunity could be provided for education/interpretation on some mariculture operations.

It can thus be seen how factors affecting the suitability of fringing reefs for tourism can be paradoxical.

RESOURCE OPTIMISATION

Other papers at this workshop will discuss resource-use interactions in more detail, and techniques for optimising those interactions. Many such techniques exist, at all planning levels. Appropriate to this discussion are those techniques which seek to maximise opportunities and minimise constraints.

Table 2 below sets out three categories of techniques within three planning levels as examples of methods for achieving optimal use while minimising potential disbenefits. Such techniques may be applied by government or industry or, ideally, both (according to factors such as location, nature of use, ability to control and motivation for involvement).

Table 2: EXAMPLES OF TECHNIQUES FOR OPTIMISING USE OF FRINGING REEFS

PLANNING LEVEL	TECHNIQUE Direct Regulation	Indirect Regulation	Site Management
Strategic (Regional)	Zone Use	Inform Users	Restrict Activities
Developmental (Industry/Area)	Management Plan	Alter Setting	Restrict Use Density
Site (Local)	Control of facilities	Signage	Focus Use

Effective implementation of the techniques set out in Table 2 requires a consistency of approach betwen planning levels and the type of technique within each level. Horizontal integration is particularly important, as there is considerable interdependence between activities and fringing reef settings and hence, the types of opportunities provided to users. Pitts (1985) has discussed this interdependence in terms of the recreational opportunity spectrum (ROS) concept. The ROS concept is based on the premise that there is a continuum of opportunity states ranging from what Pitts terms 'modern' to "primitive" setting. Figure 1 depicts the continuum, using appropriate reef examples.

While the ROS concept i,s not overtly used in planning for the conservation and development of the resources in the Great Barrier Reef Region at present, its rationale and f ramework appears to be highly appropriate to optimising recreation and tourist "use of fringing reefs., The ROS concept is based on 'the premise that quality in outdoor recreation is best assured through provision of a diverse set of opportunities. Clark and Stankey "(1979) note that to achieve this, the spectrum offers a framework within which to explicitly vary situational attributes (access, density, etc) to produce different settings.. From these. settings, recreationists participating in different kinds and styles of activities derive different satisfactions and, ultimately, benefits. The technique thus accepts and systematically provides for diversity, thereby 'mirroring. the characteristics of fringing reefs, as discussed previously.

Table 2 also illustrates that vertical integration between planning levels is also desirable if the opportunities afforded by fringing reefs are to be realised. Achievement of this inte'gration is complicated by factors such as the division of jurisdiction, the' nature of the use(s) and the motivation/requirements of developers and users. It is, however, likely that as the strategic framework for, planning of the resources of the Great Barrier Reef Region is' completed through development and implementation of various zoning plans, then both managers and developers/operators will be able to "fine tune" other planning levels.

CONCLUSION

Fringing reefs are among the most diverse of the resources of .the Great Barrier Reef Region. In seeking to maximise the potential benefits of the uses of any particular fringing reef, careful assessment needs to be made of the attributes which contribute to the overall use potential of that reef.

Current planning and management methods recognise this need in part, by taking account of relevant attributes in the preparation of zoning plan, in the formulation and review of development proposals and in the operation of existing ventures. It is suggested, however, that with further attention to vertical and 'horizontal' integration of planning and development, the opportunities afforded by fringing reefs could be further optimised.

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Setting

'PRIMITIVE' ← → 'MODERN'

Overnighting on a cruising yacht anchored alone in an isolated lagoon	Overnighting with 20 others on a mother-ship moored in a lagoon and serviced daily by a seaplane: from the mainland	Overnighting with 400 others on a floating hotel and casino permanently moored in a lagoon and rising six storeys above the water

Description

Opportunities for self reliant recreation in a natural environment away from the sights and sounds of people and direct management control. A high degree of challenge and risk.	Opportunities for recreation in the company of others but in an environment that is still largely isolated from the sights and sounds of people and obvious human intervention. Basic facilities are provided and some on-site management controls are necessary.	Opportunities for organized recreation in a 'resort' environment. Although the natural backdrop remains, use levels are high, sophisticated facilities are provided and obvious on-site regulation of use is necessary.

FIGURE 1: THE CONCEPT OF THE RECREATION OPPORTUNITY SPECTRUM

Source:.Pitts (1985)

An Overview of **Fishing** Activities **in** the Great Barrier Reef Region:
Recreational & Commercial

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Introduction

This paper describes the scope and scale of reef fishing activity and looks at some of the management rules 'under which those fisheries are conducted. It makes the case that fisheries law is managing adequately. As a corollary it shows that other management regimes imposed in this area are too wide in scope and downgrade fisheries use of the reef area in ways which should be considered quite unacceptable.

In the description of reef fisheries and their management the whole basis of present fisheries controls recognizes the "common property" nature of the reef resource. - we all own it and we thus all have a responsibility to and for it. Further, the priorities for management seek to balance the needs of different users within the overriding constraint of Conservation. This way the overall benefit of the resource to society in'general is maintained and the level to which exploitation of sustainable populations may be allowed is established.. It will be emphasised later'how some current management regimes imposed on the reef area work to the detriment of fisheries, by leaning far too heavily towards the conservatism of the "preservationist".

This submission not only describes the fisheries but outlines management programmes already in place. In this process management and the nature and scale of fisheries will be put in focus and a plan for more rational management of the reef with respect to its fishery component presented. It highlights the fact that fisheries law is managing the fishery to, the maximum extent achievable - further"' incursion is not only'not desirable but counter productive.

The Management Function

The philosophy of management starts with the basic premise that fisheries populations are a "common property resource", which by popular acceptance implies that access is open to the community at large, and acknowledgement that this resource must be conserved. This is the role of fisheries management. 'But with a "common property resource" such as fisheries, the priorities for management, should define a focus among issues such as maximisation of people's enjoyment of the area, economic yield and species and environment preservation. The function of fisheries management is a combination of these factors - to balance the needs of different users of the resource, within the overriding constraint of conservation, in maintaining and enhancing the overall benefit of the resource to society in general. Consequently, exploitation of sustainable populations is acceptable for social and economic reasons.

When considering fisheries management in relation to the reef region under the present overriding influence of Great Barrier Reef Marine Park Authority law, people exploiting the resource may be classified either as "takers" or "preservers". The following outline summarizes the sectors within the "takers" category and illustrates the measures adopted in management of each sector.

Fishing Activities

Otter Trawling

The trawl sector which targets prawns and scallops with bugs and fish by-catch, is purely commercial and completely outside the reef environment. Of' 1 300 trawlers licensed to operate in Queensland waters,,', approximately four, **hundred,** worth over $100 **million,** derive income solely from the reef region, and a reasonable **estimate,** using income and output **multiplier** analysis, can be made of the value **to** society of this sector, and this will be discussed later.

A typical **15-16m** vessel would tow 3 or 4 nets, carry **10-15 000** litres of diesel fuel, with a crew of two plus skipper, capable of working rough weather up to 30. knots. Snap freezing with dry refrigeration processes tiger, king and endeavour prawns to a very **high** quality standard for export and, local consumption and an estimated 20 tonnes would be landed in a good year worth approximately $300 **000** at todays' prices.

And **yet,trawling** is prohibited in all Marine Park Authority 'Zones except General Use A. Under fisheries law, this sector is strictly regulated 'under a tight management regime. The control measures adopted include limitation of vessel length to a maximum **20m,** gear restrictions, freeze on licenses, and limited entry. To **become** Master Fishermen, trainees are required to complete a 3 year apprenticeship and an accredited training course, an integral part of. which is principles of fisheries management. Minimum size regulations have been adopted in the **scallop** fishery, and nursery or **stock** replenishment areas have been declared closed **to all** trawling.

Thus it is evident that the framework exists to manage this *sector* without **the need** for wide-scale prohibitive zoning.

<u>The reef line fishery</u> targets a relatively small number of species including coral trout, emperor species (including sweetlip), and wrasse. Approximately 150 commercial fishermen work the reef as a major part of fishing activity. A typical "reefie" works 2-3 week trips, does 8-10 trips a year, refitting over December/January. He uses a dry freezer, and markets fillet packed in 2kg-10kg boxes. To this we should add the small number of non licensed amateurs (30-40) who take substantial amounts, although it is estimated that a large number (approximately 200) of non-licensed fishermen sell some catch. The total catch from this sector would probably have a value of $15 million at the boat. At this stage there are no restrictions on recreational fishermen other than to control sale of fish caught which are excess to personal requirements. The facility does exist, by way of permit, to allow much sought-after product to reach the market through commercial channels. This provides a measure of quality control and a system for monitoring the extent of selling by amateurs.

The commercial sector is restricted by limiting vessel access to the fishery, and both sectors are subject to fishing gear restrictions and minimum size regulations.

<u>The pelagic fishery</u> targeting principally mackerel, ranges from Bramble Cay in the Torres Strait to the N.S.W. border, and the same management principles apply as in the demersal fishery. It is estimated that some 40 fishermen use this as their major fishery although most licensed fishermen will bait a line at one time or another. Recreational fishermen are restricted in sale of product and commercial fishermen are restricted by vessel entry into the fishery thus providing a sound flexible framework for monitoring the industry and amending regulations

as the situation demands. As'with the line 'fishery, the pelagic sector is subject to gear restrictions and minimum size'regulations..

The marine aquarium fish collecting industry

Until recently, this sector has not been widely exploited. However, domestic demand has increased dramatically and the marketing sector of this industry <believes this will be sustained. With the recent decline in the value of the dollar, exports of our native marine aquarium species are more attractive overseas, and imports from competitors such as the Philippfnes are more expensive.. This has led to a jump in commercial catching activity and applications for permits to batch professionally. Catching is usually in water to 10-12 metres and. targets the colourful small specimens of the reef. The yield from this fishery could be of the order of $6 million annually. However, a few species are highly prized overseas and valued accordingly. The consequent pressure and targeting of these species in readily accessible areas may affect population distribution, and this aspect is under examination. Commercial operators are restricted by permit requirements and gear restrictions, and at this point, 56 permits have been issued.

The permit system also gives us 'records of catch. The major species targeted are: angelfish, chaetodons, wrasse, damselfish, anemone fish, trigger fish, surgeonfish, and various small species of shark and ray.

Coral, shell grit and star-sand collecting

These activities are grouped together, for management purposes as the material involved is of biological origin. This is classified as a development industry. As such, commercial operators are subject to a permit arrangement and are strictly limited geographically and by volume.

Beche-de-mer

At present there have been five permits issued for the harvesting of beche-de-mer by allocation of one degree square areas in which to harvest. From a commercial point of view, the development of this sector is unlikely, and Vicki Hariott's report on feasibility would support this view. There is no appeal for recreational collectors for this animal.

Trochus

Trochus shell, likewise holds little attraction for recreational collectors. There is, however, a commercial market for this shell. Effort in this sector is controlled by minimum size legislation, minimum and maximum size permit restrictions, and geographic and volume limitations. At present, two permits for trochus harvesting have been issued and there is some enquiry for extension of this effort.' Effort in this and the Beche-de-mer fishery are strictly controlled in recognition of a wide concern that the species are under some threat.

Shell Collecting

This activity, together with coral, shell-grit and marine aquarium fish collection carries no restrictions if the purpose of collection is non-commercial. Hobbyists, aquarists etc. are entitled to collect sufficient for personal requirements, unrestricted and unlicensed. However; commercial'shell collecting does require a permit issued under the Fisheries Act.

Issues

1. Restrictive Zoning of Fishing Activities

It becomes evident, on examination of fishing activities in the reef region, that of the thousands of marine species identified as endemic to this region, very few, maybe 20 species, are exploited commercially. This must be borne in mind in the development of reef management regulations in relation to maintaining and enhancing the overall benefit of the resource to society in general. It makes no sense to prohibit the harvesting of a resource which does enhance the economic and social well-being of the overall community, when the' level of harvesting does not demonstrably affect the regenerative capability of the target species. Further, current studies are tending to confirm the thesis that trawling in reef areas does not affect reef biota. A distinction must be drawn at this stage, from a fisheries perspective, between reefs and waters surrounding them. Within the former the Reef Marine Park Authority has a responsibility to oversee, management programmes since reef species 'are an integral part of the reef ecosystem. With the latter, it'does not. The biota endemic to the" sand and mud environment off the coastline and inside the Continental, Shelf are not reef species, **and consequently** are the responsibility of State fisheries agencies. And yet we see vast tracts of such waters have been closed off to some or all forms **of** fishing activity, commercial and recreational, depending on classification. The cost to society of this **"zone"** philosophy is measured in terms of under-utilization of sustainable yields with consequent financial disadvantage in the commercial sector, and deprivation of the recreational sector of sport and enjoyment, which also carries a significant financial cost, when one considers the immense economic value of the recreational fishing sector, of which the following table is an indication.

STATISTICS **RELATING** TO SHALL BOAT **RECREATIONAL FISHING** 1985 PRICES

Estimated **Regional** Expenditure

Region	$M
GBR	52
SEQ	54

Estimated Regional Income Generated

GBR	**27**
SEQ	14

Estimated **Regional Employment** Generated

GBR	1 400
SEQ	1 400

All that is achieved by such prohibition is to deprive the market of product and recreational fishermen **of** sport and/or concentrate pressure on areas 'adjacent to the prohibited zone. If there is perceived to be a conflict between commercial use and maintenance of the marine **environment in** a **relatively** undisturbed state: Reef Awareness Areas and Reef Research Areas would appear to satisfy the requirements of the latter.

2. Management Goals

Fisheries management seeks a balance 'between 'conflicting! needs. It seems' that this laudable aim 'does not carry over to current reef management practice. Management of the reef region under the present overriding influence of Great Barrier Reef Marine Park Authority law classifies people who use the reef as either "takers" or "preservers", as mentioned earlier. It seems to us that the "preservationist" cause is allowed undue weight in zoning determinations. The above summary has demonstrated the degree to which the "takers" from, the reef are already subject to control. The "preservers" are not similarly constrained and this lack of constraint leads to an unacceptable level of exploitation. It may seem a contradiction in terms to class "preservers" as "exploiters" but this is not the case. The category of "preservers" is defined as the sector of society whose desire it is to observe, in unlimited numbers, the environment in its undisturbed state. This is a form of exploitation, which impacts on the region, albeit in a different way from the "takers", but impacts nevertheless in the form of uncontrolled trampling on the reef, uncontrolled and over heavy diving activity on some reef areas and alteration of behaviour patterns through the intrusion of man etc. In the role of balancing the needs of users, fisheries management acts as the interface between "takers" and "preservers". In this context, the "takers" sector has become strictly regulated under State fisheries legislation. In some areas of' operation, restrictions have been severe, almost draconian, to ensure that the balance, of exploitation and sustainable yield is maintained. It would seem appropriate for these' concerns' to have more emphasis when' zones were being determined and for constraints on fishing activity to receive more balance in the allocation.

State fisheries agencies make use of a variety of control measures in the implementation of management programmes. These include a freeze on Master Fishermen's licences, a freeze on vessel licences, vessel size restrictions, fishing gear restrictions, minimum size regulations, protected species legislation, limited entry, and declaration of fisheries reserves and sanctuaries. This is the framework for sound, responsible fisheries management throughout Queensland, of which the reef region is an important sector and thus fringing reefs must be considered as 'an integral part of the overall reef for. management purposes. The measures available have provided the flexibility needed to develop programmes to manage the diversity of sectors within the umbrella of aquatic resources, whether they be barramundi or marine aquarium fish, otter trawling or reef line fishing.

The Commonwealth Government, on the other hand, whilst adopting a high profile with regard to fisheries management in the reef region, has developed no such programmes to address the individual nature of each fishery within the region. Management policy consists of "close it, lock it up, zone it".

3. <u>Inconsistencies in Permitted Use</u>

In pursuit of our Fisheries Management goals, managers have frequently to defend constraints imposed by another agency e.g. Great Barrier Reef Marine Park Authority, and the inconsistencies in this law make this defence difficult. Fishermen are uncomplicated people, but they are astute at picking anomalies in application of a given set of laws and these inconsistencies reflect on the credibility of the whole process and are thus undesirable.

To cite an example, I refer to the classification of the Shelburne Bay region from the coastline to outside the outer reef limits as Marine National 'Park 'B' 'Zone which prohibits fishing in all forms, whilst permitting, amongst other activities, construction of mooring facilities or marinas, establishment of tourism facilities, harbour works, beach protection works, other works, and discharge of wastes, from fixed structures.' Zoning of this region would seem pointless, to prohibit fishing activities within the area when the objectives of the Zone have been compromised by permitting the above activities.

To illustrate the point further, I refer to this table.

Table: Examples of the impacts of State Marine Park Zoning on fishing and other activities in Far Northern Section

ACTIVITY	ZONES GUA	GUB	MNPA	MNPB	PRES. ZONE
1. Fishing					
Trawling	/	X	X	X	X
Commercial Netting	/	/	X	X	X
Commercial Line Fishing	/	/	/	X	X
Spearfishing	/	/	X	X	X
Amateur bait nets	/	/	/	X	X
Recreational line fishing	/	/	/	X	X
Crabbing	/	/	/	X	X
2. Selected Other Activities					
Mariculture	/	/	/	X	X
Tourist Development	/	/	/	/	X
Educational Development	/	/	/	/	X
Harbour Works	/	/	/	/	X
Marinas (private)	/	/	/	/	X
Dredging (private)	/	/	/	/	X
Reclamation	/	/	/	/	X

/ - Approved activity or activity which can be permitted by a responsible authority.

X - Not permitted

Trawling, which constitutes the major economic commercial fishing activity in the reef region, is permitted only in General Use A Zone, and all forms of fishing are prohibited in Marine National Park B Zone. However, all other activities listed are permissible, many of which would affect the natural resources of the area far more than fishing. It would appear strange that the major activity in the reef region in terms of social and economic benefit derived from the resource, is prohibited in large tracts, but development of any tourist facilities, marinas, dredging, discharge of wastes etc. are permitted, with permission of the responsible agency.

By way of comparison, this table outlines State legislation in relation to fisheries management and protection.

Table: Examples of the impacts of State-declared Reserves and Sanctuaries on **Fishing and other activities**

ACTIVITY	WETLAND RESERVE	FISH HABITAT RESERVE	FISH SANCTUARY
Fishing Activities			
Otter Trawling	/	/	X
Commercial Netting	/	/	X
Commercial line fishing	/	/	X
Spearfishing	/	/	X
Amateur bait netting	/	/	X
Recreational line fishing	/	/	X
Crabbing	/	/	X
Marine Aquarium fish collection	/	/	X
Selected Other Activities			
Mariculture	X	X	X
Tourist developments	X	X	X
Educational developments	X	X	X
Harbour Works	X	X	X
Marinas (private)	X	X	X
Dredging (private)	X	X	X
Navigation Channel maintenance	/	/	/
Reclamation	X	X	X
Discharge of wastes	X	X	X

/ - permitted
X - not permitted

It is evident from this table that, where environment; marine life, breeding grounds and **stock replenishment areas require** protection, this **is** achieved. No, commercial" development is allowed - no **tourist** developments, marinas, private dredging or airstrip **construction,** no discharge of wastes. Fishing activities are permitted where the objectives of the reserves are not compromised and the activities are controlled by minimum size regulations, gear restrictions etc. No activity of any description is permitted within fish 'sanctuaries. A permit may be issued by the Minister for some of the above **"not** , permitted" activities <u>only</u> if **it** is considered that the activity is necessary or desirable for the preservation and proper management **and** in an applicable case the public enjoyment of the area. An example would be construction of a public boat ramp or jetty. Private development requires revoking of the sanctuary or reserve by the Legislative Assembly, which is the most watertight control possible.

<u>Responsibility for **Fisheries Management**</u>

The community has accepted in' principle the concept of **"user pays"** in 'relation to the provision of Government services; This concept makes' the particular Government Agency more accountable to the section of the community which utilizes these services and pays for them through permit fees, **licence** fees, inspection fees etc. 'Thus, the costs of implementation and enforcement of management **programmes** are offset by the" community making use of the 'resource. In the present situation **of** multi-Departmental responsibility for fisheries management, the **duplication** of costs to the community could be avoided, by the administration of all fisheries related matters by one fisheries management organization. I

It is accepted that. an industry of such diversity, of such economic importance to Queensland and Australia, will have internal and external conflicts. However there exists within the State the management framework to address all issues as they arise, and these issues. are resolved in consultation with all interested parties, be they commercial or recreational, political, conservationist, developers or Government Departments. This resolution is achieved by democratic process, consultation and review, in keeping with the basic philosophy of balancing the needs of resource users in maintaining and enhancing the overall benefit of the resource to society in general.

TOURIST DEVELOPMENT AND FRINGING REEFS

Sally Driml

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Tourism is the major commercial activity within the Great Barrier Reef Region and is currently showing impressive growth. So, what is the connection between fringing reefs and tourism? This paper explores this interrelationship.

The focii of this paper are the two major vehicles for commercial tourist access to the Great Barrier Reef Region - island tourist resorts and commercial passenger vessels. Mainland fringing reefs are not considered in order to limit the scope of this paper, to something manageable but it must be noted that there, are a number of mainland sites with current and potential recreation importance,including Cape Tribulation reefs, King Reef and Dingo Beach. Also not covered is private recreational use which occurs from motor boats and yachts.,

HOW IMPORTANT ARE FRINGING REEFS TO TOURISM?

This question is central to the paper (and this workshop) because if the current role of fringing reefs can be established then the potential for the tourism/fringing reef relationship can be explored. Unfortunately the question is not easily answered given current knowledge, however this paper seeks to canvass the issues.

Of 21 resort islands within the outer boundaries of the Great Barrier Reef Region, only 3 are coral cays. The remainder are continental islands with varying degrees of fringing reef development. Thus island resort tourism is very much focussed in locations with fringing reef resources. Of the over 280 commercial passenger vessels operating in the Great Barrier Reef Region, around 60% operate to areas where fringing reefs are present. The overwhelming majority of these vessels operate in the Whitsundays where bare boat sailing is growing in popularity, as are day trips amongst the islands.

Altogether, the availability of resort and vessel infrastructure in the vicinity of fringing reefs provides an estimated 1.5 million visitor days per annum (800,00 on vessels, 700,000 at resorts), or 75% of the total estimated visitor days provided by island resorts and commercial passenger vessels in the Great Barrier Reef Region in 1984/85. (Driml in prep.)

It would be most unwise to claim that all this tourism occurs because of fringing reefs. A number of factors combine to create demand for tourism and facilities just as a combination of variables govern supply of facilities.

On the demand, side, we must explore what influences people to travel and what attracts people to holiday on the Great Barrier Reef in particular. As with any group of people we find a variety of reasons for their destination choice.

Underlying and determining consumers' -travel behaviour are a number of economic' variables which influence the demand function including the price of the holiday, price of other destinations,etc. Currently the exchange rate is affecting the price of holidays in Australia vis a vis overseas holidays.

Why do people visit the Great Barrier Reef? Evidence from tourists staying on resort islands is that in response to the question "what were the two most important features that attracted you to this island?", the features nominated were placed in the following rank order:

1. Warm sunny weather
2. Barrier Reef
3. Relaxing quiet place
4. Beach, water activities
5. Entertainment

(Cameron McNamara 1986)'

The top ranking reason has nothing to do with the Great Barrier Reef but has everything to do with the tropical location. The Barrier Reef does figure as the next most important attraction. However this begs an important question - what do respondents mean by the Reef? Do they mean the outer coral reefs, fringing reefs or islands? Did the people answering this question expect to see coral reefs on their holiday and did they in fact see any,?

Many questions exist as to tourists' attitudes to and perceptions of the "Great Barrier Reef" and some of these are being addressed by research currently underway, commissioned by the Great Barrier Reef Marine Park Authority. Meanwhile we must look to the evidence provided by reef use patterns.

That a variety of demands exists is now well established in tourism literature. It is important to note that tourists are no longer grouped simply by demographic variables (age, income, etc.) but may meaningfully be grouped according to their attitudes to and demands of a travel experience. This is important with regards to activities chosen on holiday. Within the Great Barrier Reef Region there is a range of resort types and activities available. Resorts show market segmentation ranging from the young people's market to 'exclusive' executive hideways. Day trips cater for yet other markets including less affluent people on driving holidays to North Queensland. Activities range from those appealing to the adventurous (SCUBA diving,, paraf lying) to those suited to sedate tourists (sunbaking, reef walking).

To sum up, on the demand side there are a variety of attractants to tourists who visit the Great Barrier Reef, one of which is the reef itself. We must look for further evidence of whether fringing reefs play a large or an insignificant part overall in attracting tourists to the resorts and boat trips.

On the supply side, were fringing reefs important in decisions to locate resorts on continental islands? Historically, many of the island resorts have developed on islands which were previously used for agriculture. Location and access are obviously important. The continental islands are generally closer to the mainland than coral cays. Also as tourist destinations have developed, a clustering of resorts has occurred, particularly in the Whitsundays.

None of this has anything to do with fringing reefs. In fact fringing reefs prove an obstacle to boat access to some resorts. However the bottom line is that resorts will only stay in business if they attract tourists and fringing reefs may have something to do with the attraction of these island resorts:.

'ACCESS TO FRINGING REEFS:

What of access to and activities 'on fringing reefs? Island resort guests and boat passengers do visit fringing reefs. The extent to which visitors to particular resorts can access fringing reefs varies with the extent of reef, topography of the island, and facilities to visit the reefs. What tourists see depends very much upon the visibility of the water. This is -generally poorer closer to the mainland and areas of runoff, and varies with weather conditions. The 'aesthetics' of reefs within the Great Barrier Reef in the eyes of tourists often has nothing to do with ecological diversity but depends upon the presence of' colourful coral and fish.

Island Resorts

Fringing reefs may be accessed from island resorts simply by reef walking, swimming, snorkelling, or diving from'the island. Most continental islands have some' coral formations with attendant fish. Organised trips including diving courses may be arranged, and resorts may provide "hardware" for viewing coral in the form of glass bottom boats and semi-submersible vessels.

Some island resort operators prefer to concentrate on reef access to "outer" reef sites and do not place much emphasis on their local fringing reefs.

Bareboating

The majority of bareboat sailing (where groups hire a boat and follow their own itinerary) occurs in the Whitsundays, within the area defined by the concentration of islands. This is an areh rich in fringing reefs. Bareboat parties are encouraged to visit a. number of different anchorages. They are in a prime position to access the fringing reefs of the area, and they do so.

Parties are'supplied with information on anchorages and sites to visit - particularly through the publication '100 Magic Miles of the Great Barrier Reef' by David Colfelt (1985) which- has descriptions of the locations and quality of reefs.

Day Trips

Again the Whitsundays is the focus' of daytrips where fringing reefs are important, but day trips also run to Great Keppel, Fitzroy, Magnetic and Lizard Islands (the latter, 'by air). The trips which offer perhaps the best opportunity to experience fringing reefs are to the underwater observatories on Hook Island in the Whitsundays and Middle Island in the Keppel Islands. A semi-submersible vessel is now operating on the fringing reef around Black Island (Bali Hai) in the northern Whitsundays. The 'semi-sub' trip lasts for an hour and offers close views of this reef. A 'semi-sub' was also operating on the Fitzroy Island Reef for some time but has been moved to an 'outer' reef site.

Other, trips offer opportunities to swim, snorkel and dive on fringing reefs.

Camping Trips

Island drop-offs and "safari" trips involve visitors camping on islands from where they may access fringing reefs. Again, the majority of these are in the Whitsundays.

'TRENDS IN TOURISM

Commercial tourism via island resorts and commercial passenger vessels is growing. The tourist industry in North Queensland has seen notable growth in the last three seasons in particular and is becoming increasingly important in the North Queensland economy. Some pertinent figures are quoted below.

Island Resorts

In 1984/85, the 24 island resorts of the Great Barrier Reef Region attracted 151,000 visitors who stayed 790,000 visitor nights (Cameron McNamara 1986). The annual increase in visitor nights has averaged 11% from 1976/77 to 1984/85 and accelerated with a 17.5% increase in 1984/85 over the previous year (Australian Bureau of Statistics). The current stock of rooms is around 1600. Expansion plans in this sector are impressive with a doubling of the number of rooms reported to be in progress or planned. (Peat Marwick Mitchell 1986). The expenditure by guests of island resorts was around $84 million in 1984/85, an increase of 33% in real terms over the previous year (Cameron McNamara 1986).

Commercial Passenger Vessels

A recent survey of this industry found 280 vessels operating in 1984/85. The number of vessels operating has more than doubled in 5 years. (Hundloe 1985). The types of services included as commercial passenger vessel services are day trips., extended trips which operate on regular schedules or on demand, bareboats, water taxis, ferries and "floating hotels".

The number of visitor days carried was estimated at 1.2 million, and passenger expenditure was at least $35 million in 1984/85. (Driml in prep.). Two growth areas are bareboats and large catamarans. Bareboats are virtually restricted to the Whitsundays where 151 were operating in 1986 (Whitsunday Marketing Services 1986), and the numbers have increased from 52 in 1981. (McGinnity 1981)

The f'irst large catamaran was introduced in 1982 and now 15 are operating in the Great Barrier Reef Region providing over 400,000 visitor days per annum. These vessels carry up to 300 people and travel at speeds of around 25-30 knots. Six of these vessels travel to platforms on outer reefs,where coral viewing is the main aim of the excursion. The other catamarans operate to resort islands.

The most obvious trend in tourism, as emphasised above, is an increase in all aspects of tourism. Fringing reefs are important in this context because they contribute to the attraction and because they may come under increasing pressure especially, given,, the concentration of resorts on continental islands and the boating activity in the whitsundays.

RECREATION TRENDS

A discernable trend in reef recreation is a trend towards nature #appreciation. Interest in seeing the, reef itself has been facilitated by the introduction of technology via high speed catamarans, 'semi-subs' and the proposed floating hotel. Attention seems to have shifted to "outer reef" experiences which offer clear water and attractive reefs. However the majority of visitor days are still spent in the vicinity of fringing reefs.:

Whilst the number of people who undertake recreational fishing continues to grow, non-extractive recreation is growing at a faster rate. The 1980 survey of charter boats found 75% of vessels cited fishing as a primary activity (Hundloe 198-5) while in 1985, the proportion of'boats involved in fishing was 55%. (Driml in prep)'.

Although the trend toward reef based recreation has to date generally by-passed fringing reefs and focussed on "outer" reefs, it could be speculated that this trend towards nature appreciation could lead in time to a "rediscovery" of fringing reefs. The application of new.reef access technology in the form of 'semi-subs' may be a first step in this direction. Other applications of technology and-interpretive efforts may include,, snorkel trails, reef walking platforms, undersea tunnels, all of which may be associated with island resorts adjacent to fringing reefs'.

CONCLUSION

A significant amount of the tourism in the Great Barrier Reef Region occurs within the vicinity of fringing reefs via island resorts and commercial boating. Just to what extent this tourism is attracted by the fringing reefs per se is not known, and probably never will be precisely. Coral reefs are important amongst the number of factors that combine to make the Great Barrier Reef Region attractive to tourists,.

Participation in activities on fringing reefs is much lower than the estimated visitor days spent in the vicinity of fringing reefs, indicating a potential for this, resource to be more heavily used. Demands for use will increase if the trend for tourism to increase continues, as is expected. The other potential source of increase in use is a shift in attitudes of visitors to express more interest in learning about and experiencing all aspects of coral reefs. Technological change will facilitate increasing use of fringing reefs by making access easier.

The potential of fringing reefs as a tourist resource will be 'realised if tourist operators recognise the demands'of tourists for information on and access to reefs and act upon these demands utilizing developing technology.

The long term existence of fringing reefs as a tourism resource,, of course depends upon appropriate management of tourist levels and impacts. The Great Barrier Reef Marine Park Authority and Queensland National Parks and Wildlife Service have 'an important role to play in interpretation of fringing reefs and management of recreational use to appropriate levels.

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PAPER PRESENTED TO THE GBRMPA'FRINGING REEF WORKSHOP, SCIENCE, INDUSTRY AND MANAGEMENT, 23 - 25 OCTOBER 1986.

DEVELOPMENTS IN GIANT CLAM MARICULTURE RELATED TO FRINGING REEFS

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ABSTRACT

Recent new data and the recognition that natural stocks of giant clams are declining dramatically through over-fishing have produced interest in the mariculture of giant clams. Heslinga et al. at the Micronesian Mariculture Demonstration Center have successfully developed extensive methods for rearing Tridacna derasa, including ocean-nursery and grow-out culture in a reef lagoon environment. Research at James Cook University has been concentrated on the mariculture of T. gigas and is based at the University's research station on Orpheus Island. T. gigas is the largestand fastest growing species of giant clam and it occurs naturally on fringing reefs, which are more accessible than reef lagoons in the Great Barrier Reef region. A number of biological problems for mariculture of T. gigas have been overcome, including selection of brood-stock, spawning induction and heavy mortality of the early juveniles during the nursery phase. In a comparison of growth and survival of T. gigas juveniles in four positions for holding them during the ocean-nursery phase, the intertidal benthic position gave near maximum growth rates and very high survival. A protected fringing reef gave much better growth rates than an exposed fringing reef -despite greater turbidity at the former site. Initial testing of the juvenile clams' tolerance of intertidal exposure suggests that they can tolerate 4 hours mean exposure per day without strongly adverse effects. A major research effort is now being made to develop large-scale systems for mariculture of T. gigas in the intertidal fringing reef environment. To date, the only mariculture industry involving fringing coral reefs is with benthic algae and so giant clam mariculture represents a new method of using this environment.

INTRODUCTION

Giant clams (Family Tridacnidae) are the iargest living bivalve molluscs. As such, they would seem to be of intrinsic interest to marine biologists. Yet surprisingly little research., was done on them until quite recently and this allowed some popular misconceptions to prevail. One of these misconceptions is that they are dangerous animals: "killer clams" has'been a popular name. Another misconception is that giant clams are very large because they are very old (Comfort, 1957). In some centres on the Great Barrier Reef, tourists may be shown a very large living specimen of Tridacna gigas that was "here when Captain Cook sailed past". In fact, careful measurements of the growth rates of giant clams have shown that they grow rapidly and that the largest species, T. gigas, grows most rapidly (Munro and Heslinga, 1983). Another recent discovery was the degree to which giant clams, known for some time to contain symbiotic algae, Symbiodinium species (e.g. Yonge, 1936), are effectively phototrophic through their heavy dependence on the algae (Trench, Wethey & Porter, 19.81).

A further impetus.for research on giant clams has been the declining stocks through much of their Pacific distribution, 'including recent extinctions of the larger species, T. derasa' and T. gigas, in some regions (Wells, Pyle and Collins, 1983). This has been partly from excessive fishing of their local'reefs by Pacific peoples, for whom giant clams are part of the traditional diet. It is also from Taiwanese fishermen who have scoured the Pacific in recent decades collecting the adductor muscles from the larger species (Carleton, 1984). The more remote reef. complexes of the Great Barrier Reef were included in this 'Ta,iwanese activity until more effective preventative measures were implemented (Dawson, 1984, 1986).

The findings regarding rapid growth and autotrophy of giant clams, together with the heavy overfishing of natural stocks led to the realisation that there was potential for the mariculture of giant clams. The demand for giant clam productscouldthen be supplied from farmed clams and depleted natural populations replenished. Mr. Gerry Heslinga at the Micronesian Mariculture Demonstration Center (MMDC), Palau, and Dr. John Munro, at the University of Papua New Guinea and then the International Center for Living Aquatic Resources Management (ICLARM), were two biologists who recognised this potential for mariculture (Munro and Heslinga, 1983). John Munro initiated the International Giant Clam Mariculture Project, an international collaborative program for research on giant clams, which a number 'of institutions in the Pacific region were invited to join.

The successful rearing of the early stages of three species of giant clams by Nancy Beckvar at MMDC was also a crucial step for increasing interest in giant clam mariculture (Beckvar, 1981). Subsequently, at MMDC, Gerry Heslinga developed methods for the spawning and rearing of larvae, juveniles and adults of _T. derasa_ to commercial size (Heslinga and Watson, 1985). Heslinga was able, within a few years, to take giant clam mariculture from the laboratory stage to potentially commercial-scale production. He is now planning for annual productions at MMDC of 100 tonnes whole weight of T. _derasa_, 6 years of age (Heslinga, Watson and Isamu, 1986). To achieve this production level requires one hectare of shallow reef lagoon.

Heslinga et al. at MMDC have developed low technology methods for the mariculture of T. _derasa_. They rely on the lunar pattern of spawning in Palau and, after establishing a large group of broodstock in a shore-based tank, await spontaneous spawning. The fertilized eggs and larvae ar'e then, reared 'extensively. That i's, the eggs are transferred to another tank with coarse-filtered seawater and the resulting larvae rely, for their feeding on natural blooms of algae in the static conditions. Water flow through the tank is resumed after the late-stage larvae have settled onto the tank floor. Unfiltered lagoon water is supplied to the juvenile clams and at five months of age the juvenile clams are removed from the tank floor, cutting their byssal attachments to the tank surface. They are-. transferred to fibreglass trays containing basalt chips. Three. to four months later the trays of 30-40mm shell length juvenile clams are transferred from the seawater system to the ocean-nursery in the field. The trays are covered with plastic mesh to -exclude predators and they are placed at about 5 m depth on a coral sand and rubble substrate in the lagoon adjacent to MMDC. After two years, the juvenile clams, 100-120 mm shell length, are large enough to be virtually free of predation and their protective meshes are removed (Heslinga and Watson, 1985).

MARICULTURE ON FRINGING REEFS

The mariculture technology developed for T. derasa at MMDC, is very appropriate and successful for that species and to the MMDC environment, where 'protected coral reef lagoon conditions adjoin the land-based mariculture facility. Lagoon conditions in the Great Barrier Reef (GBR) are more inaccessible. They , "generally occur behind the reef platforms of mid to outer shelf' patch reefs. This means that, in order to use the reef lagoon conditions in the GBR region, the ocean-nursery and grow-out phases of giant clam mariculture would generally have to be sited well offshore. This has disadvantages in terms of weather limited accessibility, of security, and of costs in time and fuel for regular maintenance. The land-based phases of giant clam mariculture would be well separated from the ocean phases, probably necessitating two staff units during the long periods of the year when there are concurrent land and ocean-based activities.

These problems are overcome if the ocean-phases of mariculture are conducted on fringing reefs adjacent to a land-based mariculture facility.

The system developed at MMDC is not necessarily applicable to fringing reefs and *T. derasa* does not occur on fringing reefs in the GBR region. *T. derasa* seems to require more oceanic conditions than the other five species in the GBR. In extensive observations in the Palm Islands, north of Townsville, *T. gigas*, *T. squamosa*, *T. maxima*, *T. crocea* and *Hippopus hippopus* were commonly found on the fringing reefs, but only three specimens of *T. derasa* were found, although *T. derasa* is common in the lagoon of Bramble Reef, the nearest patch reef offshore from the. Palms (unpubl. observations, JCU giant clam group).

Another factor against *T. derasa* is that it grows more slowly than *T. gigas* (Munro and Heslinga, 1983). While growth rate is not the only criterion in selecting suitability for mariculture, it is obviously an important factor.

RESEARCH AT JAMES COOK UNIVERSITY

Giant clam mariculture research at James Cook University (JCU) is part of an international collaborative project funded by the Australian Centre for International Agricultural Research

(ACIAR). There are four overseas organizations collaborating with JCU and funded by ACIAR: Fisheries Division, Fiji; University of Papua New Guinea; and two Universities in the Philippines, Silliman University on Negros Island and University of the Phillipines at Dilliman. The Project commenced in mid-1984 and is planned to run for three years. Concurrently, ICLARM is involved in the development of a pilot hatchery for giant clams in the Solomon Islands and results from this Project will be implemented at the pilot hatchery.

Giant clam research at JCU has mainly focused on *T. gigas* because, as outlined earlier, it is the fastest growing tridacnid species. However, several other species are being reared and studied for comparative purposes: *T. derasa*, *T.* squamosa and *Hippopus hippopus*. The mariculture research is conducted at the JCU Orpheus Island Research Station, north of Townsville.

The research findings will be outlined under a series of headings below.

Reproduction

Histological studies of *T. gigas* from Great Barrier Reef waters confirm the findings of Braley (1984) of an annual reproductive season with highest proportions of ripe eggs during summer months. It appears that there may be repeated partial spawnings during summer. This leads to spawned-out animals with no evidence of a second onset of gametogenesis during the spawning period. The seasonality of gametogenesis means that induced spawnings of *T. gigas* for mariculture must be conducted during the summer months.

Selection of broodstock is especially important for *T. gigas*. The large size of adults of this species (up to 400 kg and more) and their low densities in the field make it impractical to collect large numbers of broodstock, 'using the strategy that some of them will be ripe individuals. The development of a gonad biopsy technique, so that individuals with ripe gonads can be identified in the field (Braley, 1984; Crawford, Nash and Lucas, in press), was thus an important step in the mariculture process.

Spawning

At the commencement of this Project, one of the major drawbacks for using *T. gigas* in mariculture was inabilility to induce them to spawn. The only observed spawnings of this species were spontaneous (Munro and Heslinga, 1983).

The breakthrough in spawning induction came from reports of the role of serotonin (a neuro-transmitter substance) in spawning induction in scallops and some other bivalves when injected directly into the gonad (Matsutani and Nomura, 1982). This method was found to work with tridacnids (Braley, 1985; Crawford et al., in press). Brood-stock clams are induced to spawn by an injection of 1mM serotonin solution into the gonad. It appears that the effect of serotonin is to cause the gonad musculature to contract and expel gametes. The. clams engage in normal expulsive contractions as the gametes are released; although the serotonin stimulus for gamete release initially by-passes the central nervous system. The response to serotonin injections is not predictable even in clams with ripe gonads: but, by using this technique on a group of selected clams, it has been possible to regularly obtain eggs and sperm from *T. gigas* brood-stock - a major advance for mariculture of this species.

Giant clams are usually simultaneous hermaphrodites. They shed sperm soon after stimulation and then eggs an hour or so later (apparently to reduce selfing). In our procedures, the sperm and eggs are collected as they are released: eggs are collected in large'plastic bags placed over the clam's excurrent aperture as it expels the eggs in a dense suspension. The gametes are mixed fo'r cross-fertilization and the numbers of resulting zygotes are estimated. The fertilized eggs are then distributed at known densities to hatchery tanks (Crawford et al., in press).

Hatchery phase

Larvae of T. gigas have been cultured using intensive and extensive methods. Intensive methods are those used in commercial bivalve mollusc hatcheries : micro-filtered seawater, daily water changes, feeding with cultured unicellular algae and controlled temperature, etc. Good survival through larval development has been obtained with this method (Crawford et al., in press). It is more reliable than extensive culture,,but it has the disadvantages of requiring much greater inputs of labour and technical facilities. Larvae of T. gigas have also been cultured extensively, i.e. large numbers of eggs,are added to outside 3,000 1 tanks with static seawater and essentially left to develop, following similar methods to those at MMDC. The only management used in these extensive cultures is some additions of unicellular algae (Isochrysis galbana - Tahitian strain) for food and, a water change if bacteria bloom excessively. Some batches of extensively cultured larvae have been discarded because of virtually total mortality.

The period of larval development-of giant clams (about 8 days) is short compared to other commercial bivalves such as oysters and scallops. This is a distinct advantage for their mariculture, as larval development is the most technicallydemanding phase of the bivalve life-cycle. The larvae have quite modest requirements of algal food. Thus they appear to be good candidates for development of an artificial diet, which would obviate the need for algal culturing facilities. Artificial diets (microencapsulated food particles) have been developed for penaeid larvae, but not yet for bivalve larvae (Langdon and Siegfried, 1984); so the development of a microencapsulated diet for giant clam larvae would be a major breakthrough.

Nursery phase

The late-stage larvae, pediveligers, are transferred to outside tanks from intensive culture or allowed to settle in their hatchery tanks in extensive culture. The newly-settled juvenile clams are 0.2 mm shell length and it is some months before they are visible on the tank surfaces where they have settled. The juvenile clams must commence their symbiotic relationship with zooxanthellae soon after settlement and the recently-metamorphosed juvenile clams are "inoculated" with zooxanthellae obtained from pieces of mantle tissue of adult clams (Crawford et al., in press). This proceedure saves maintaining cultures of zooxanthellae.

In the first batch of T. gigas juveniles reared in early 1985 there was very heavy mortality between settlement and 5 mm shell length (Crawford et al., in press). Less than 1% of the original pediveligers survived this period. The minute size of the juvenile clams compared to the dimensions of the nursery tanks made it impossible to observe the occurrence of this mortality and to identify the causal factors. Overgrowth by benthic algae,' which thrive in'the strong sunlight conditions required by the juvenile clams with their autotrophic zooxanthellae, was suspected of reducing light and water exchange for the juvenile clams. Some benthic predatory invertebrates may also have been involved in the mortality.

Improving survival through this'nursery phase was another step to be made in developing mariculture techniques for *T. gigas*. This was achieved during the rearing of batches of juveniles in summer 1985/1986 by using prepared substrates and a regular cleaning regime to control the growth of benthic algae. Two substrates were prepared on the bottoms of nursery tanks; a dried lime-sand slurry and a thick layer of Carborundum beads (Mullite) glued with polyester resin to a fibro base. Survival after several months was approximately 17% and 8% on the carborundum bead and lime-sand surfaces, respectively, compared with approximately 5% on an untreated fibreglass tank base (control). This level of survival through early juvenile development achieved on the Carborundum, bead surface'is quite acceptable by the standards of commercial bivalve hatcheries.

Ocean-nursery phase

At approximately 20+ mm shell length the juvenile clams are ready to be transferred from the land-based nursery tanks to the field. At this size they are easy targets for predators and must be held in' protective containers (ocean-nursery phase).' Also, because of their dependence on light they must be held in two-dimensional systems. The usual methods of culturing filter-feeding bivalves in the field, e.g. suspended on lines or stacks of plates, are three-dimensional systems and inappropriate for giant clam juveniles, where only the upper-most individuals would receive enough light. It is also because of this two-dimensional culturing that there is need to conclude the nursery phase as early as possible and to get the juvenile clams into,the field despite the additional. hazards from predators. As the juvenile clams grow, their requirements for tank space can only be met by the expensive option of adding to the number of tanks in the seawater system, to increase the available surface area; not by the less expensive option of having deeper tanks and increasing the volume.

As described earlier, Heslinga et al. at MMDC, Palau, rear juveniles of T. derasa on the subtidal substrate of a reef lagoon. This is quite successful, but it is the only method of culturing in the ocean-nursery phase that they have tested. For rearing juveniles of T. gigas at Orpheus Island, fringing coral reefs and, adjacent areas were used, and four alternative me'thods for holding the clams were tested in an initial small-scale study. The juvenile clams were placed on granite chip substrates in perforated plastic trays (freezer trays) , 55 x 30 x 9 cm, covered with 26 mm plastic mesh. The four methods of holding the clams in trays were: 1. on frames suspended from floats: 2. on racks 1 m above the bottom; 3. on the bottom subtidally; and 4. on the bottom intertidally. The potentially favourable features of a floating system arethatthe clams are keptnearthe surface in high light levels and away from their benthic predators. Racks have the same advantages ofhigherlightlevelsthanonthe bottom and protection from.predators. The intertidal situation has potential advantages of accessibility without the need for diving (Munro, 1985b) and of high light intensities. However, there are potential disadvantages of intertidal rearing in terms of mortality from exposure and of lowered growth rates as the clams' metabolism is disrupted during exposure.

The floating, rack, subtidal and intertidal (FRSI) study outlined above was conducted at three locations on the fringing reef in Pioneer Bay, adjacent to the research station. This bay is on the western side of Orpheus Island and faces towards the mainland. It is sheltered from the prevailing easterly winds and thus is more protected but more silty than the environment on the eastern side of the island. Some trays of clams were also established on the fringing reef at the northeastern side of Orpheus Island on the bottom subtidally and intertidally for comparison with those in Pioneer Bay. The clams on the northeastern reef experienced stronger wave action, lower turbidity and, presumably, greater water turnover than those in Pioneer Bay.

The results of the FRSI study revealed that the floating trays, surprisingly, showed poor survival and growth of clams. Racks were best for growth, with mean growth increments of greater than 10 mm per month during the summer months, and they showed good survival of clams. Survival was high in the subtidal benthic trays, but growth rates were lower than on the racks: while growth rates were high, near 10 mm per month, and there was no mortality (excluding equipment failures) in the intertidal benthic trays. The mortality in the floating and rack based trays appeared to be largely from small parasitic gastropods of the family Pyramidellidae. These ectoparasites settle from the plankton onto the clam shells and feed on the clam's blood and tissues by inserting their long proboscis between the valves. Numbers of them can be found on some infected juvenile clams and in these individuals the tissues progressively shrink until they die. The pyramidellids also occurred on similar sized juveniles in the seawater system, but they were not observed on the clams in benthic trays in either the subtidal or intertidal zone. It appears that small benthic predators', which must be able to pass through the 25 mm mesh covering the trays, normally control the pyramidellids, and that in the seawater system and above the substrate in the field these predators are absent. Gerry Heslinga at MMDC has-also found that pyramidellids do not trouble benthic juvenile clams in the field, but occur on tank-held clams (pers. comm.). It is paradoxical that, in the field situations that seemed potentially free of predators, the clams suffered high mortalities because a predator of their ectoparasites was apparently also absent. Studies of the biology and epidemiology of the pyramidellids are planned.

In addition to their influence on growth and survival, the four methods of holding *T. gigas* juveniles during the ocean-nursery phase were assessed in terms of their practicability: cost and ease of construction, propensity for equipment failures, ease of maintenance and levels of fouling (affecting the amount of maintenance). The benthic intertidal method was superior in each of these, with the exception of propensity for equipment failures. The one weakness of the intertidal situation was exposure to strong wave action during heavy seas. Thus, when Cyclone Winifred passed north of Orpheus Island in February 1986, causing strong winds into Pioneer Bay from the north, three of the twelve trays in the intertidal zone were torn from their bases and carried away, while none of the subtidal trays were lost (the floating trays were taken out before the cyclone struck). Intertidal systems must be securely fixed to the substrate to resist periods of strong wave action.

Comparing 'growth rate data for the two fringing reef localities, it was found that, despite the lower turbidity and generally more oceanic conditions at the northeastern fringing reef site, the juvenile clams there were growing substantially slower than those in the equivalent positions in Pioneer Bay. This was especially the case'for the intertidal position on the northeastern reef. The detrimental factor here was disturbance of the clams by wave action, which'was especially strong at the shallower site. It is not clear how disturbance adversely affects the clams, but sensitivity to movement appears to be also implicated in the poor results for growth from the floating position in the FRSI study.

The three intertidal positions of trays in the FRSI study were at approximately 0.6 m tidal height above chart datum and further groups of T. gigas were put out higher in the intertidal zone' of the fringing reef of Pioneer Bay to test their tolerance of exposure. Initial results over the winter months indicate that levels up to 0.8 m tidal height have no, pronounced effect on growth and survival of these juvenile clams: however, clams at approximately 1.2 m tidal height survived but showed no' growth. The difference between 0.8 m and 1.2 m tidal levels in terms of mean daily periods of exposure during the winter months is from approximately.4 to 9 hours, respectively, per 24 hour period or from 3 to 5.5 hours, respectively, during daylight hours. It seems that ocean-nursery phase juveniles of T. gigas can tolerate mean daily periods of exposure up to 4 hours per 24 hour period without strongly deleterious effects on their growth and survival.

'The intertidal zone of protected fringing reefs is obviously,' very suitable for the ocean-nursery culture of T. gigas in the GBR region, both in terms of being a favourable environment for the clams and also in terms of the' logistics of commercial mariculture. Also, for the development of giant clam mariculture in Pacific countries (the objective of the ACIAR-funded Project), the intertidal zone has obvious advantages where SCUBA facilities are unavailable or inappropriate. Thus, a major research effort is being made at OIRS to develop intertidal systems for the ocean-nursery and later grow-out phase of T. gigas.

Two kinds of large protective containers are being assessed as alternatives to the trays that were used in the initial studies. These are "boxes" and "lines". Boxes are containers 2.3 m X 1.2 m X 0.2 m with a hinged lid made from a sheet of galvanised steel mesh, 6mm diameter steel and 100 mm mesh size, and enclosed with a finer protective mesh. They are being tested both intertidally and subtidally. The protective meshes used on the subtidal boxes include "chicken" and "trellis" galvanised wire meshes, but only plastic meshes are being used in the intertidal zone, because of higher levels of corrosion. Lines are 30 m long containers, 1.1 m wide and 0.2 m high, made from two 30 m rolls of plastic mesh: one roll makes the base and the other the lid. The lines are held in place with metal stakes and subdivided with internal partitions into 2 m long compartments. The reason for compartmentalising the lines is to restrict the movements of any predators that may penetrate into the line.

Grow-out phase

The largest T. gigas juveniles reared are now greater than 100 mm (at age 20 months) and during this 1986/87 summer will be transferred to the grow-out phase, i.e. removed from the protective containers and placed on the surface of the fringing reef in Pioneer Bay. The size at which they are large enough to be virtually free of predators will thus be determined. The shells of T. gigas in this size range are thinner and thus more easily crushed than those of T. derasa and this may well require that T. gigas be reared to a larger size before the grow-out phase.,

Recently a permit was obtained from GBRMPA to set up a small ocean-nursery and grow-out site in the lagoon of John Brewer Reef, within the area of the "Reeflink" operation. This will serve for a comparison of growth and survival in the lagoon of a mid-shelf reef versus the fringing reef culture at Orpheus Island. Inspite of all the advantages of fringing reef culture and the apparently good results obtained to date, the possibility exists that fringing reefs are sub-optimal environments for T. gigas compared to reef lagoons and this possibility must be tested.

IN CONCLUSION

As mentioned earlier, T. gigas is not the only giant clam species that inhabits fringing reefs and the techniques being developed at OIRS are not only applicable to T. gigas. In other: parts of- the Pacific region particular giant clam species have economic significance. For example, H. hippopus and especially H . porcellanus are important in the shell trade, in, the Philippines and there is interest in the mariculture of,the smallest giant clam species, T. crocea, in southern Japan'where it is prized as a delicacy (Murakoshi, Aramaki and Hirata, 1984; M. Yamaguchi, pers. comm.) These three'species typically occur in shallow conditions on fringing reefs.

To develop ,the commercial mariculture of giant clams requires more than solving biological problems and efficient' production methods. It involves investigating the existing and potential markets for giant clam products, research on product 'development, and research on sociological and economic aspects of giant clam mariculture. Such studies have been undertaken or initiated by the Forum Fisheries Agency, ICLARM and ACIAR (e.g. Dawson, 1986; Munro, 1985; Tisdell, 1986).

Development of a mariculture industry for giant clams on fringing coral reefs in the Pacific region would represent a major new mode of use of these reefs. There are currently industries based on culturing benthic algae, e.g. Eucheuma and Caulerpa species, and industries based on culturing animals near fringing reefs, e.g. pearl oysters, Pinctada species; but none yet based on culturing benthic animals on fringing coral reefs.

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SHELL COLLECTING ON THE GREAT BARRIER REEF -FIRST IMPRESSIONS

Bryony Barnett

ABSTRACT

'Shell collecting is a popular activity of visitors to the Great' Barrier Reef, including members of shell clubs, tourists and casual visitors to coastal beaches. The majority of collecting is intertidal and is focused on accessible reefs during peak low tides, in the winter season in Queensland. High impact areas are the coastal fringing reefs and the offshore reefs (zoning permitting) within easy access of home ports.

The most concientious collectors are specimen shell collectors with a tendency to collection of live material. Many belong to shell clubs which advocate conservative *collecting. Less discriminating are the 'casual collectors with a preference 'for visible, colourful shells, dead or alive. Commercial collectors account for a small percentage of shells removed from the Great Barrier Reef.

The most popular shells are the cowries (Cypreaeidae), cones (Conidae), volutes (Volutidae), murex (Muricidae), and strombs' (Strombidae). The impact of collecting on molluscs is governed by the biology of species (population size, reproductive strategies, behaviour) and the techniques and frequency of collection.

As an extractive activity, management is seen to be necessary, the emphasis being on sustained yield of the resource. Proposals can only be made with a sound knowledge of the biology of the major target 'species. Meanwhile, user education, directed particularly at the casual collector/tourist is recommended.

INTRODUCTION

The reefs of the Great Barrier Reef Region are known to support' over 4,000 shell-bearing mollusc species. The distribution patterns vary according to factors such as the physical'nature of the reef, the local climate and proximity to the coast and human settlements. Mollusc shells have long been appreciated by man for their aesthetic appeal, particularly by shell collectors. Today those who exploit the resource may be broadly categorized as follows.

1. Commercial shell collectors. This category includes retailers who collect shells for sale or manufacture into shell products and souvenirs, trochus fishermen and trawlermen.

A recent, short-term survey of the shell trade in Australia' (Willan, 1986) found that the percentage of business derived'from the sale of Australian marine mollusc species ranged from 1% in Queensland to 100% in West Australia. Queensland dealers interviewed by McGinnity (1986) revealed that the majority of shells in stock were imported from the Philippines, India and New Guinea, and the limited number of Australian shells sold were obtained from trawlers or self-collected. At present there are no full-time commercial specimen shell collectors operating in the Great Barrier Reef Region. Only two fishermen hold licences to fish trochus on the Great Barrier Reef, most of which occurs on the seaward side of offshore reefs (Nash, 1985). A small number of prawn trawlers fishing outside reef areas are known to retain shells for purchase by dealers and specimen shell collectors. There is anecdotal evidence of low numbers of regular visitors from the southern states who spend several months of each year on the Queensland coast for the purpose of shell collecting for resale.

2. Specimen shell collectors are those whose prime objective is that of making a collection of good quality shells, local or worldwide, representative of selected taxa. The individual interests of specimen collectors vary, ranging from the scientific to the aquisitive and competitive approach. Collections vary accordingly, with competitive collectors being more interested in the taking of live material in pursuit of the "gem" specimen for potential display. Shells are obtained by personal collection, purchase and exchange. Many such collectors belong to shell clubs and discussion groups of which there are eleven on the Queensland coast, with active membership totalling approximately 150.

3. Casual collectors, exemplified by the beach walker, reef visitor, tourist, diver and sailor is attracted to the more showy, colourful specimens, dead or alive. They may include people at holiday resorts or visitors on charter boat cruises, who indulge in casual collection of shells as an activity secondary to others.

3. Researchers. Only a small number of people are at present conducting research on molluscs on the Great Barrier Reef. In each case, collection targets a single species from specified sites and all collection information is recorded systematically.

WHEN, WHERE AND WHAT DO THEY COLLECT?

Collecting sites favoured by specimen shell collectors are coastal reefs and accessible inshore reefs. In addition, most shell clubs organize at least one club trip per annum to more distant reef locations. Trips conducted by Queensland shell clubs during the past 3 years averaged one 2-3 day trip per annum, on a charter vessel, with 8 to 13 collectors. Trips were timed to coincide with low water Spring tides, giving the reef walkers 2-3 hours of collecting on exposed reefs. A "shelling season." is recognized, covering the monthly low tides (May-September). For 3-4 days each month the low tides result in good infra- and sub-littoral exposure during the daytime, allowing access by walking and wading. Committed shellers will plan their activities and holidays around these dates in order to take advantage of every opportunity to pursue the hobby and will focus on specific sites known to be productive, often travelling considerable distances. A limited amount of night shelling occurs at the summer low tides. In aii cases shell collecting would be the prime objective of a reef visit by such people.

The most popular shells collected by specimen collectors; all gastropods, are the cowries (Cypraeidae),' cones, (Conidae), volutes (Volutidae), strombs (Strombidae)', olives (Olividae), mitres (Mitridae) and murex (Muricidae). With the development of a collection more obscure shells are sought or specialization in a particular group may occur. Fewer people appear to be interested in bivalves as a collector group and the popularity of these shells is highest with more scientific collectors.

Collecting by casual reef visitors and tourists is usually incidental to other activities. Areas most likely to be subject to this form of collecting are fringing reefs close to settlements, tourist resorts, caravan parks and camping sites, and reefs frequented by charter boats. Collecting by this group is, on the whole, less discriminating than that by club members.

Many casual collectors would be unable to identify the shells they are collecting and may be unaware that most shells contain a live animal. The loss of interest as the molluscs decompose is exemplified by repeated reports of shells discarded in resprts and caravan parks. Shells most likely to be taken are the most visible and readily available specimens on fringing reefs and sandbanks- cowries, strombs (including the popular spider shell, Lambis lambis) and olives. Highly patterned cone shells are also popular but likely to be collected with more caution. Much of the material collected by the casual collector, including beach specimens, would be considered of unsuitable quality for the specimen collector.

HOW DO SHELLERS COLLECT?

Shell collecting involves extensive wading, reef" walking, overturning of rocks and boulders and shallow digging and raking. In extreme cases coral heads are broken in the search for specimens. Most club collectors, however, claim to adhere to a "collecting code":

- do not break coral to look for shells,
- return all overturned rocks with care,
- take only sufficient shells for your ownneeds,
- do not remove juveniles, shells on eggs or egg-cases,,
- leave adult shells with scars and breakages to breed,

the emphasis being on sustainable yields 'of the resource.

On the whole the code is observed, but many such collectors will admit to collecting extra shells for the purpose of resale and exchange and it is likely that the discovery of a rare shell will result in its removal. whatever the condition. The interest' in obtaining morphological and colour variants means that most private collections will contain several specimens of each species. The collectors' attitude to shells is influenced by the relative "rarity" value, this itself being governed by availability on a local and worldwide scale.

There is widespread concern from club members that the casual collector exhibits destructive collecting behaviour, often failing to return rocks to their original position, removing juveniles and shells on eggs (albeit in ignorance), and overcollecting. There have been repeated records of unecessary wasteage of such shells which have been rejected by collectors once the animal' decomposes. Likewise, 'the few semi-commercial collectors, frequenting accessible coastal fringing' reefs at, every opportunity are believed to abuse the collecting code for the purposes of monetary gain.

IMPACT OF SHELL COLLECTING

What is the potential impact of shell collecting on the reef? The two major points of concern are:

. depletion through overcollection,
. depletion through habitat destruction,

and the attendant effects on the environment from which the animals are removed.

It has been stated (Wells and Alcala, 1986) that most marine molluscs, with the exception of volutes, have a wide distribution and planktonic larvae and are therefore unlikely to be threatened with extinction through overcollection. At this stage there is insufficient evidence to support or refute this statement. Most specimen shell collectors would argue that their practices ensure minimal habitat disturbance and conservative extraction. There is a reluctance of this group to admit that their extractive activities have a detrimental effect on the environment and any observed decrease in numbers is attributed to "natural fluctuations". The clubs tend to police activities within the groups, discouraging collecting behaviour contrary to the code. The interest of the northern clubs in exchange and sale of shells, however, does lead to excessive collecting by some members.

By comparison the casual collector is more likely to be party to habitat destruction through failure to return boulders and lack of care in reef walking. Overcollection may occur by large numbers of individuals being attracted to the same species, or by the semi-commercial collector taking all the shells found.

There is anecdotal evidence of depletion on a local scale at a number of sites on the Queensland coast as a result of both overcollection and habitat destruction. The detrimental effects of shell collecting worldwide, on the Kenya coast, in Guam, Hawaii and Forida, have been discussed by Evans et al. (1977), Hedlund (1977), Mills (1977) and Abbott (1980) respectively.

An assessment of the impact on molluscan populations is only valid in relation to the biology of the species concerned. Biological characteristics which effect the vulnerability of a species include:

. Life-history and reproduction: growth rate, size at maturity, larval duration and recruitment potential.
. Concealment strategies: camouflage, refuge and burrowing.
. Distribution and dispersion: intertidal and subtidal; shallow and deep water, scattered and clumped.

To date there is a paucity of literature on molluscan biology at the species level. The emphasis has been on the commercially exploited species Trochus niloticus (Nash 1985), tridacnid clams (Yonge 1975, Heslinga 1979) and the red-lipped stromb, Strombus luhuanus, which has been the basis of a traditional fishing industry in the Gulf of Papua for centuries.

The biology of specimen shells is less well documented though long-term shell, collectors, through their combined experiences, share a good understanding of the characteristics of many species, and will agree that, even after years of observations it is difficult to define any behaviour patterns for most species. A major area of concern has been the volutes (Volutidae), the largest of which is the popular bailer, shell Melo amphora, which reproduce by direct development. Eggs are laid in capsules from which the young emerge directly. As a consequence local populations, develop distinctive characteristics,, much sought after by collectors, one noteable example being the Heron Island, volute, Cymbiolacca pulchra. Both this desirability and the lack of larval dispersal make them potentially vulnerable to depletion by overcollection.

Similar concern has been expressed for rarer, target species which have their distribution on accessible fringing reefs. A notable example is the small cowrie, Cypraea stolida brevidentata which, though dispersed throughout North Queensland, is most heavily collected on the fringing reefs of Dingo Beach, by specimen and semi-commercial collectors alike, resulting in local depletion. Other shells at the same locality would be subject to heavy collecting pressures simultaneously,

Further to the immediate effect of depleted populations of molluscs, the removal of a link in the food chain has been seen to cause imbalance in East African coral reefs (Kendall 1985). Removal of predatory gastropods has meant increases of echinoderms (Diadema, sp.) in plague proportions which,, in turn, feed on coral. Less well proven, but well advertised, in Australia, the current population explosions of the crown-of-thorns starfish, Acanthaster planci, have been attributed to overcollection of a major predator, the giant triton Charonia tritonis (Endean 1977).

MANAGEMENT

The recognition that shell collecting has had an impact on molluscan populations on several reefs emphasizes the need for local management of the limited resource on a sustainable yield basis, particularly in the light of increasing reef usage.

Management options practiced overseas are the imposition of controls and restrictions such as take limits, closed areas, export controls; the establishment of marine parks and reserves; education and small-scale mariculture (Wells 1986).

On the Great Barrier Reef recreational shell collecting, like most activities, is regulated in Sections of the Marine Park for which zoning plans have been developed, and is allowed in the General Use Zones "A" and "B", subject to possession of a permit obtainable from Queensland National Parks and Wildlife Service Maritime Estate Branch. Permits are issued for periods of up to 12 months and permit holders are required to submit a collection report with each application for renewal. Since 1981 274 permits have been issued to groups of one to 42 individuals, mostly shell club- members, for periods of one week to 12 months. Collection of Tridacnid clams, the helmet shell Cassis cornuta, the trumpet shell Charonia tritonis, and shells on egg **masses is** prohibited. The permits authorize only the taking of shells for the private collection of the permittee and for limited exchange. This represents a revision of the original bag-limit of two specimens of each species which was received by club collectors with considerable opposition.

The export of Australian native shells is regulated by the Australian National Parks and Wildlife Service'though no sound policy has yet been developed for the export of **molluscs** under the Wildlife Protection Act. As an interim measure authority has been granted to a number of shell clubs and dealers to export shells on condition that permission is obtained from ANPWS prior to the export of each consignment and a list of the shells supplied.

Though still in the early stages some inadequacies in these management measures are apparent. The original objectives of the permit system were:

1. to encourage responsible behaviour by reef users,
2. to separate potentially conflicting activities,
3. to impose limits on certain activities,
4. to collect data on the activity.

Preliminary assessment of the permit returns and discussions with collectors reveal that some of these objectives have not been realized. The majority of people applying for shell collecting permits already see themselves as responsible reef users. The casual collector is the one **least likely** to be in possession of a permit and may be unaware of the requirements. Estimates of permit non-compliance by two shell clubs , using a randomized response survey technique, indicated that, whilst people were willing to make the initial permit application, there was a high rate of non-compliance with permit conditions suggesting significant underestimation of the quantities of live shells removed (Chaloupka, 1985). The value as a monitoring tool is therefore questionable, with very low collection returns (10%) being recorded to date.

Policing in the field is seen by many to be inadequate. Only approximately 2% of the shell club members **(100-plus)** questioned on this subject have been approached in the field to date.

Shell collectors are **further** confused by the status of the coastal fringing reefs on which they collect, several of which, at present, fall outside the Marine Park and are therefore covered by State jurisdiction, as yet undeveloped.

The export controls also lack credibility. The data accruing to ANPWS contains obvious misidentifications and taxonomic **confusion. Recommendations made** by **Willan (1986) in a review of** the shell trade in Australia emphasize that this legislation be rescinded.

ALTERNATIVE MANAGEMENT OPTIONS

It is clear that localized regulatory measures, directed towards, all collector groups, are necessary, and must concentrate on the high-impact fringing reefs, unless they are to be regarded as "sacrificial sites".' Club members themselves, in their representations to GBRMPA, have supported the principal of periodic closures of the Dingo Beach area, on a cyclical basis. 'Habitat management is more feasible than species management at this stage but if such measures are to be taken seriously, adequate policing should be ensured, albeit a problem with current, field staffing levels.'

Education, particularly of the casual collector group must be given a high priority. The detailing of some basic guidelines to reef behaviour and an introduction to the fauna of the fringing reefs, to be distributed to coastal and reef resorts and caravan parks, to campers with their permits, and to school groups, is recommended. It is acknowledged that some club members already play a significant part in school education 'by means of instruction and displays. Further afield, the East African' Wildlife Society has produced a series of posters for display in Kenyan hotels and resorts, illustrating the damage caused by shell and coral collecting (Wells and Alcala, 1986).

Whilst club members may be considered more enlightened than others they should be encouraged to reassess their collecting behaviour by means of supervised participation in monitoring programmes on a local scale. Such programmes should be seen as supplementary to, more detailed research on the biology of the major target species.

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REEF WALKING: A SHORT REVIEW

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INTRODUCTION

Whilst reef walking itself must have been an activity which extends into pre-history, it is only recently that reef walking has been offered as a holiday activity, especially in the island tourist resorts on the Great Barrier Reef and in the last 10 or 15 years there has been a major increase in our use of the reef resource in this manner. The effects of reef walking have been studied on the islands of the Great Barrier Reef but the information is likely to be applicable to fringing reefs, at least in a general sense. The reef walk is carried out on the inter-tidal flats of coral reefs at low tides, usually without any special physical skills or equipment, but often accompanied by a guide who has local knowledge of the area. These guided groups will usually follow a pre-determined route or visit an area on a regular basis and their pattern of movement is a fairly loose formation which periodically condenses to focal points when the guide finds something of particular interest. Visitors will also venture out singly or in small unguided groups and wonder freely over the different reef zones. Minor accidents, such as stepping through delicate live corals and thin reef surfaces (pie crust) are common and due to the visitors unfamiliarity with the terrain. Many reef resorts issue walking sticks and protective footwear so that their customers are damaged as little as possible. Most people will aim to walk on sand or smooth solid coral pavement and areas of fragile or luxurious coral growth are generally avoided, however in some circumstances visitors either accidentally tread on fragile areas, or find that their only way forward is by crossing one of these patches of luxurient growth. When this happens the amount of damage becomes very obvious.

As Kay and Liddle (1985) remarked, the tourist or holiday-maker undertakes reef walking for pleasure and satisfaction. Interaction with the environment and appreciation of the aesthetic beauty of the coral community and its inhabitants is most important and a big draw card for the tourist industry. The tourists may have a number of expectatations when visiting the reef. Firstly they hope to see a variety of exotic features that are associated with and characterise the coral reef environment. Some favourite items are brightly coloured sea stars and fish, big molluscs, and hermit crabs, and architecturally ornate and delicate corals. Secondly most wish to feel that they are experiencing natural and unspoiled environment. Any obvious signs of environmental degradation interfere to some degree with the aesthetic naturalness of the habitat and produce feelings of irritation or disappointment. It is thus in the interest of the tourist operator to maintain the reef resource in as pristine a condition as possible.

THE ENVIRONMENT IMPACT OF REEF WALKING

Three studies have been made of the environmental impact of reef walking. One was undertaken by Woodland and Hooper (1977) on Wistari Reef and the other two by Kay and Liddle (1984a and b) on Heron Island Reef and Hardy Reef respectively (Figure 1). the first two studies were experimental and clearly. demonstrated that trampling on reef flat corals can cause considerable damage. The third study was observational and dealt with the use patterns and damage associated with reef walking on a popular reef used for a variety of tourist activities.

Woodland and Hooper (1977)

The Wistari Reef work (Woodland and Hooper 1977) involved one short term trampling experiment which demonstrated that four people reduced the live coral cover on an area of reef flat 4 metres by 25 metres from 41% to 8% after walking back and forth along it 18 times. An average of 12 kg m^{-2} of live coral was broken off, but most of the robust massive coral colonies, Acanthastrea and Goniastrea, survived.'

Kay and Liddle (1984a) and Liddle and Kay (in press)

The Heron Island investigation consisted of several different experiments involving both long and short term trampling trials, growth and survival experiments with damaged coral colonies and fragments , and laboratory tests of branch strength.

The major findings of the trampl ing trials concerned the susceptibility of different types of coral communities to relative damage from reef walking. There is considerable variation in the composition of the biotic communities and physical surfaces found on reef flats. They range from a partial or complete cover of flattened and encrusting coral colonies on a solid pavement of dead coral to a highly intricate mixture of taller three dimensional coral colonies, solid and honeycombed remains of dead coral colonies, and sand pools. Zones which are exposed to wave action and water turbulence such as those on edges of reefs, typically have the low compact coral communities while those in more sheltered situations further within the reef platform have the more upright complex coral communities.

Trampling caused much more extensive damage in a sheltered site on the outer reef flat at Heron Island than it did on an exposed reef edge site. The low compact forms of coral on the reef crest were relatively resistant to mechanical disturbances and trampling had little effect on the hard level surface. The percentage cover of corals was not reduced along pathways through this site which were regularly traversed 80 times every three months (equivalent to six or seven times a week) for a year and one half. In comparison trampling broke up many of the upright branching corals and most of the honeycombed, dead coral skeletons at the sheltered site. Ditches partially filled with dead coral rubble were formed along pathways which were traversed as infrequently as five times every three months (equivalent to once every two to two and a half weeks) for a year and

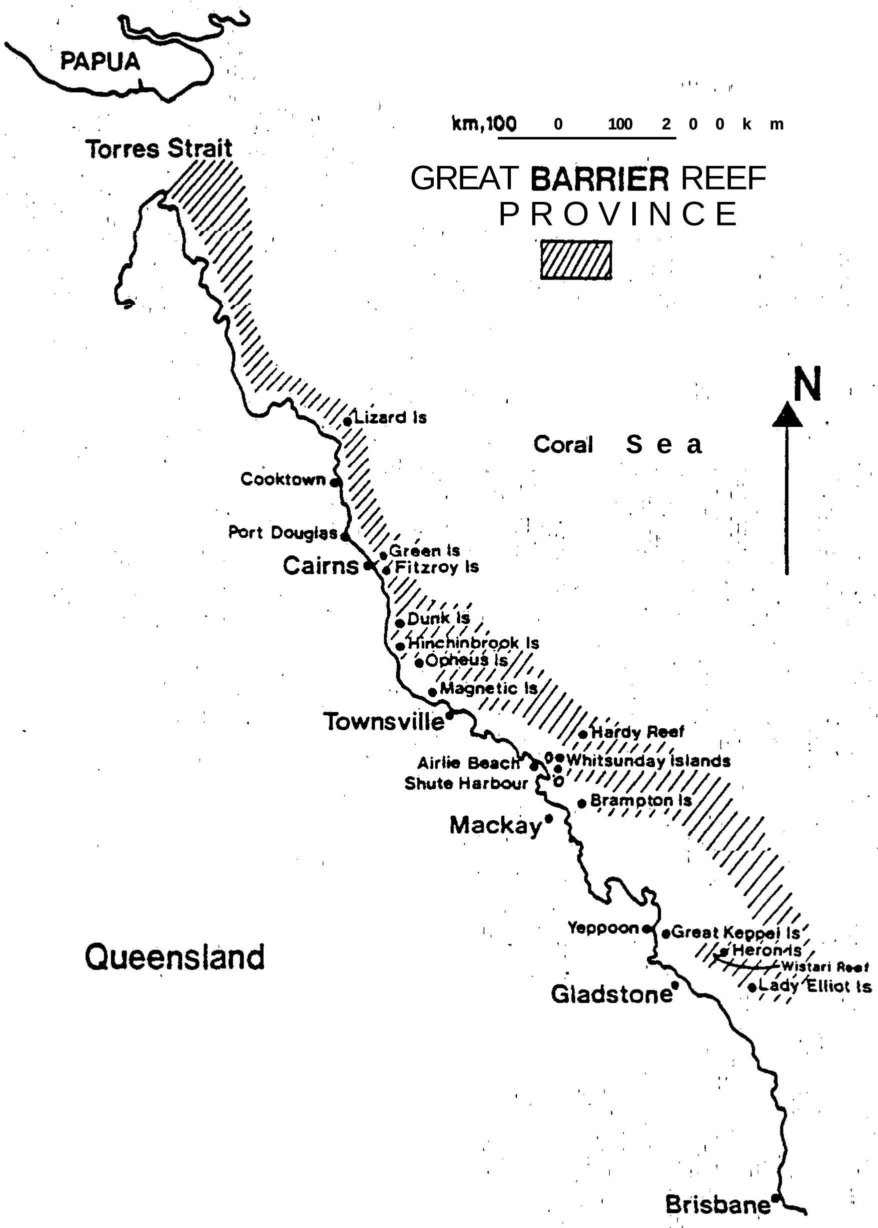

Figure 1 The Great Barrier Reef and major 'tourist centres

visitors are monitored on a regular basis to determine whether the management objectives are being met. If not the management objectives can be redefined and/or the methods used to implement them can be altered.

RBSOURCB BVALUATION

SURVEY OBJECTIVES

There are several basic questions which need to be asked when an area is considered for reef walking activities.

They are:

1. How accessible is the area?
2. How many people already use it?
3. How easy is it to walk around in it?
4. What attractions does it contain that will satisfy the reef walkers needs?
5. How vulnerable is the area to trampling damage?
6. What is its present level of damage?

The scope of this paper does not allow a detailed account of methodologies which may be utilised to answer these particular questions. A description of these methods is given in Kay and Liddle (1985) and they have provided techniques suitable to various levels of input of both tiae and money.

MANAGEMENT OBJBCTIVBS

ACCEPTIBLE ENVIRONMENTAL CHANGES

There are two main factors to consider when determining what will be acceptible environmental changes in a reef walking site. They are:

(a) The expectations and objectives of the users

As mentioned above tourists, and scientists, prefer to see an unspoilt natural environment. Additionally tourists expect to see a variety of exotic features such as brightly coloured fish and ornate corals which characterize the coral reef environment.

(b) The ability of an area to recover after damage.

The growth rates of different forms of coral vary enormously therefore reef [illegible] sites of different composition are unlikely to regenerate at the same rate after a given amount of reef walking damage.

These considerations suggest three general criteria for the determination of acceptible environmental change.'

i Visual evidence of physical damage should be minimal.

ii Reduction in the numbers and variety of the exotic features which attract tourists should be prevented or minimized.

iii Reduction in the cover of live coral should not be permitted to exceed that amount which could be regrown during an off peak season or reasonable period of closure.

IMPLEMENTATION OF OBJECTIVES

GENERAL APPROACH

Broadly speaking there are two approaches which can be. used in the formulation of management techniques.

They are:

(a) Control visitor numbers and/or guide or influence visitor behaviour

(b) Alter the environment so it is less susceptible to damage.

These two approaches are not mutually exclusive and often underlie the same management technique as shown in Table 1 which lists the management procedures we have described in this manual. Some of these techniques may also function as interpretive services where information is provided to enhance visitor enjoyment and safety (Table 1).

RESOURCE MONITORING

Ideally all monitoring schemes should begin before the site is opened to reef walking. One or more "before" surveys establish what the undisturbed or natural state of the site is like and provide a, standard to which the results of subsequent surveys can be compared.

The intervals between the surveys of a monitoring scheme will depend on the time and resources available, however, we suggest an optimum of six months until it has been confidently established that management objectives are being met. After this the intervals can be extended to a year or more unless use patterns change dramatically and more frequent monitoring is needed to detect rapid degradation before it goes too far.

The elements that may be recorded are: Mechanical change; coral composition; level of use. A full account of these techniques is also given in Kay and Liddle (1985), and they conclude with a comment on carrying capacity.

Table 1. Management techniques and their requirements

Technique	Visitor Control	Alter Environment	Interpretive Service
Guided tours	X		X
Information leaflets	X		X
Films and videos	X		X
Pathways	X	X	
Elevated walkways	X	X	
Transplantation of corals		X	
Limiting access	X		
Closed seasons and rotational use	X		

CONCLUSION

In presenting this paper the authors have in mind the sequence of attitudes that usually prevail with respect to any natural resource. Initially the resource is seen as unlimited and any change that may be made as a result of its use by man, tend to be regarded as beneficial. Then there is a phase of declining availablility and quality of the natural resource which provokes a reaction to conserve and finally to manage that resource both for the greatest advantage to its users, and its own intrinsic qualities. In the case of the tourists utilisation of fringing and barrier reefs, we have a situation where the resource has hardly been changed by use, except in one or two local instances, and our society has already moved to the position where the conservation of. that environment is in everybody'sminds and largely accepted by the community. The information that we have provided in our various reports will, we hope, aid in the final step of managing and preserving the resource for the greatest benefit of the tourists, the tourist operators, and the reef corals and its other inhabitants.

ACKNOWLEDGEMENT

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FRINGING REEFS: THE TOURIST'S VIEW?

David Colfelt

Fringing reefs, although they may not have the appeal of mid-shelf reefs, can nevertheless be a valuable asset as a tourist attraction.

Many tourists, particularly those from overseas, are frightened to actually get into tropical waters for fear of sharks or other tropical nasties. But they are happy enough to walk on top of a reef or to wade in water up to their knees as the tide starts to recede from a fringing reef.

All tourists have read about coral. Tourist promoters have sung hymns to the beauty of coral and the fact that their tourist facilities abound with 'coral opportunities'. Even the best books about the Barrier Reef - for example, the Reader's Digest book - marvel visually at the variety and beauty of coral, showing dazzingly colourful macrophotographic images that are rarely likely to be seen by the ordinary tourist.

It is human nature to try to put your best foot forward, and we all do it, whether we are courting a lover or applying for a job. How can the salesman be expected to do otherwise? Or the tourist operator? And we all tend to believe our own words after awhile, anyway.

Expectation has a great deal to do with perception. There are countless examples in life - 'from the notorious unreliability of 'eye witnesses' to crime, who often infer things they have not seen, to the example of the emperor's new clothes, to the story of the lady who had never seen an elephant before, and when one, which had escaped from the circus passing through town, appeared in her rose garden, she telephoned the police and explained that there was a strange creature picking her roses with its tail, "...and you can't imagine what he's doing with them!".

So our expectation colours our experience. If expectation is not in line with what actually happens, we often end up dissatisified even if the experience is not an unpleasent one.

The other point I want to make about fringing reefs is learning how to 'see'. If we don't know what to look for, we very often see nothing. Looking at a fringing reef for the first time is not unlike looking at a chest x-ray, or a weather map, or a voice print. We are assailed with unfamiliar information in a not immediately prepossessing format, and until we learn the code, we can't get very much satisfaction from what we see.

I've tried to illustrate these points with just a few slides. The message is that fringing reefs can provide hours of fascination and diversion if (a) the tourist has no previous misconception about them and (b) if he has been given the code to help unveil the reef's secrets. Operators can do much to help themselves and tourism by providing accurate interpretive information for the tourist.

As the tourist wings his way towards his Barrier Reef destination, his mind is filled with thoughts of 'Bali Hai', a subtle suggestion put there by tourist promotion which has spoken of tropic isles.

:10
He looks out the window of his plane and catches tempting glimpses of coral waters and sand beaches.

:25
The islands present a very pleasing aspect.

:33
He even finds some sand, as promised, in front of the resort, and there's also the odd palm tree. transported there.

:50
As he begins to explore his 'tropical island', he.finds nothing to complain about. It. has rugged beauty, and vibrant, turquoise waters lap at its shores.

:57
But the vegetation isn't exactly as he imagined it,

1:05
and some of the beaches are definitely not like those in,, the tales of Somerset Maugham.

1:13
On closer inspection: some of the 'sand' he saw from the air turns out to be coral shingle. He is beginning to experience a faint disappointment; that all in paradise is not quite as promised. This afternoon, the tide will be low, and he will have: his first look at coral - on a fringing coral reef.

1:36
But where is all the colour? Everything seems pretty lifeless and. grey.

2:10
At this point if the tourist resists the temptation'to turn around and go back to the resort bar, and particularly if someone has explained to him that the fringing reef does have a distinct, structure and zonation, and if he looks in the right places he will find all sorts of life going about its business.

3:00
After a while he will have a whole new series of questions and things to wonder about. It's like sitting down in a forest and just looking silently around.' When he stops and looks, the reef begins to reveal some of its secrets...

3:30
... corals that look' like Dr Who abandoned them there like spilt cans of slime...

3:45
...a wholee array of shapes, textures, colours; creatures that depend on each other for survival . ..life with its own reason and logic.. .

4:10
High up near the shore he encounters thousands of little balls of sand. He had made up some explanation to himself about them . ..which turned out to be quite inadequate when, walking along a bit further, he encountered the architects in action, marching along in phalanxes, pirouetting into the sand when he approached.

4.28
Hours can pass by quickly on a fringing reef once the code has been broken. New questions are raised to suggest the complexity of this reef - and all reefs. This insight is strangely humbling and gives rise to respect for something quite wonderful.

4:51
And as the tourist watches the sunset from the resort beach, he talks with satisfaction about the day's discoveries, and the new knowledge gained. He may even get out the book on the reef and read with newly opened eyes.

TOURIST OPERATORS DISCUSSION OF USE

David Hoffenstetz, Arcadia Holiday Resort, Magnetic Island

As Activities Officer, takes' clientele reef walking **6-8** times/month and snorkelling about the same amount;

fishing is not popular with guests; there is a local commercial enterprise that is available to take people fishing;

tends to have a passive clientele - uses reefwalking **as** an introduction to snorkelling;

he is getting together a marine library and slide. show, organises and posts a weekly schedule of activities, and puts an activities brochure in each room of the resort.

Rick Steen, Director, Marine Operations, **Hayman** Island Resort.

resort is now closed while reconstruction taking place, but previously:

had reefwalking, glass bottom boat trip on half tide;

found that having an Activities Officer functioned to help'protect the **reef;**

semi-subs were popular with tourists - the resort owns 3

half-day local fishing trip was popular - people enjoy a 20 minute boat trip - there was a full-day trip to **the** outer reef for keen fishermen;

once a week, on Wednesday night, they would have 'a marine slide show, and the following morning would be the best turn-out for reef,-walking;

a few times they took videos of guests snorkelling etc. on the reef and these turned out to be popular 'with guests, many asking for **their** own copy;

recommendations: good marine videos would be useful; staff training session (organised through their staff training officer).

Hike Mandbridge, Divemaster, H_2O Sportz, Hamilton Island.,'

most diving is done on the outer reef

once or twice/week they take a trip around fringing reef fringing reefs aren't easy to use - to enjoy a fringing reef, people need to be guided, with things being pointed out;

a reefwalking trip needs to be guided;

most of their staff stay around a while and are self-educated in marine matters;

need literature showing 'interrelationship of marine life;

need more information about specific areas.

Comments from Audience.

it seems that different levels of experience need to be communicated:

i) taxonomic - what is it?
ii) functioning and interrelationship of marine life (R. Kenchington)

is it practical for tourist resorts to have a biologist at $20,000/year? (C. Wilkinson)

would it be useful for Activities Officers, etc. to be able to present a certificate indicating completing of a TAFE-type of course? (D. Fish)

is it commercially feasible to buy this type of education? (D. Gartside)

it seems there would be some commercial advantage to tourist operators to do "educational" tours, which are popular in the U.S. (?)

providing a workshop in the field would be advantageous for tourist operators (R. Olsen).'

EFFECTS OF BUN-OFF, SILTATION AND SEWAGE

Donald W. Kinsey
'Great Barrier Reef Marine Park Authority, Townsville

Introduction

Run-off, siltation, and sewage are impacts which are all more pronounced on fringing reefs than they are on outer shelf or oceanic reefs; Based on my work with coral reefs over the last 25 years I believe that, contrary to some' popular opinion, reefs are quite tolerant to stress. However, there is a sharp threshold beyond which their collapse can be quite dramatic. In the case of fringing reefs, fresh water is 'probably the major "killer" in situations not. subjected to extreme anthropogenic stresses. It is likely that terrigenous sediment most usually constitutes a chronic stress though it may ultimately become a "killer" if the reef is subjected to actual burial. Sewage, also, most usually constitutes chronic stress but inevitably leads to a progressive degradation of the community, though not necessarily to its total destruction.

The example which I will discuss today is that of Kaneohe Bay, on Oahu, Hawaii. This is one of the most complete case histories available. The fringing reefs in Kaneohe Bay are very well developed., They 'have, in recent decades, been subjected to well developed and well defined stresses exhibiting convenient'gradients from one end of the bay to the other. The responses of the reefs have been well studied. Since 1978 there has also been a detailed study of the recovery of the fringing reef system since the diversion at that time' of a major domestic sewage outfall. The Bibliography lists a number of publications which summarise most of, the information available concerning those aspects of Kaneohe Bay considered: in this paper.

The setting and the stresses

Kaneohe Bay is one of the more spectacularly beautiful parts of the island of Oahu., It certainly has the best developed fringing reef structures in a low to moderate energy environment, and (at, least 'in the past) 'high , coral cover. This combination of a high aesthetic profile, well developed reefs, and a well-protected environment suitable forrecreational activity' has led to the bay assuming a very high importance in human values and to a great deal of attention being given to its fate. For a long period of time, and certainly pre-dating European occupation, some degree of agricultural activity has occurred in many parts of the bay. The greatest emphasis on agriculture has been, and still is, towards the northwestern end of the bay, and this has resulted in significantly increased terrigenous sediment run-off over extended time. There is no immediate suggestion of a cessation of this type of activity though hopefully somewhat greater control is now being exercised.

In more recent times there has been general residential development along the bay and an intensive suburban development in the Kaneohe City area. The population has increased from 5,000 in the 1920s to some 60,000 by 1980. This development has resulted in very large amounts of disruption to the land surfaces to facilitate building and road making, and this, in turn, has caused a very large degree of terrigenous sediment input particularly to the southeastern end of the bay.

Thus, northwest and southeast Kaneohe Bay have been subject to substantial sediment input; however, the central bay typically has been subject to very little in the past or in the present. The northwest bay also has been subject to some input from agricultural fertilisers and other materials associated with agricultural activity.

Fresh water run-off into the bay also is principally concentrated in the northwest and the southeast. The major run-off is from the Waikane and Waiahole streams in the northwest. The run-off into the southeast bay has been associated only with very small local streams. Recent urbanisation has led to substantial increases in run-off because of surface sealing and discontinuation of water conservation practices. Most of the sediment input is carried to the bay by the various stream systems.

Figure 1 indicates the approximate configuration of the bay, the location of the fresh water streams, the general tide/wind driven circulation, and the distribution of fringing reefs within the bay. The reefs in the central region have been consistently in quite good condition throughout history (except for occasional episodic kills as discussed below). Coral cover here is generally good.

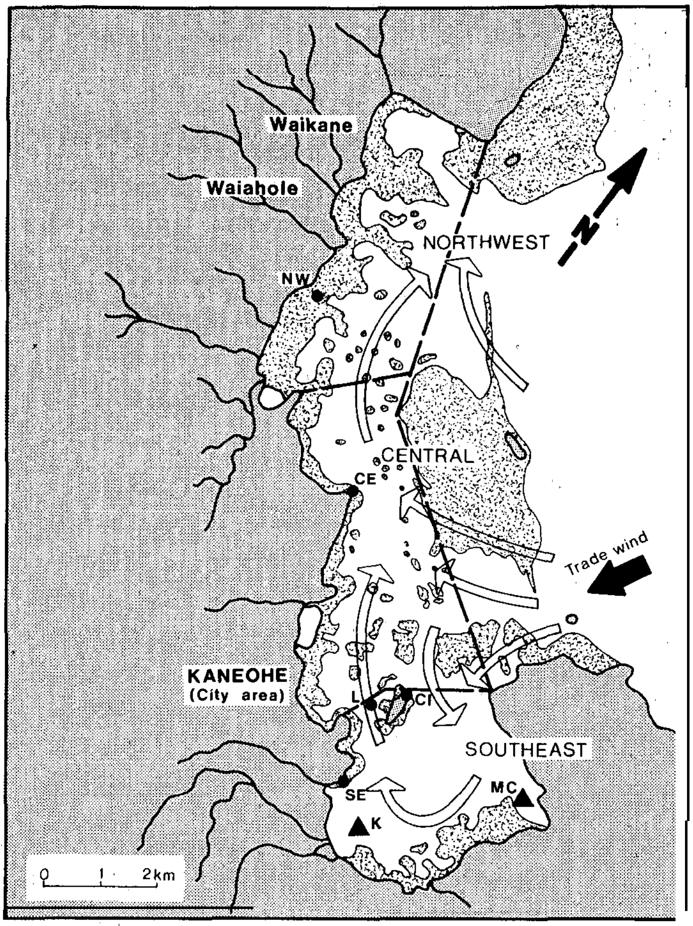

FIGURE 1. Kaneohe Bay on the island of Oahu, **Hawaii.** Principal watershed streams and all major patch-reefs and fringing **reefs are** shown. The bay is **semi-**enclosed by a substantial barrier-reef/sand-bar **struc-**ture and is considered functionally in **three** indicated zones: northwest, central, and southeast. The two sewage'outfalls, in use' to the end of 1977, are indicated A . K is the Kaneohe city outfall and MC is the smaller Marine Corps base outfall.' Reef-flat sites,, referred to **in** the **paper** are indicated • . General patterns of tide/' wind driven circulation are also indicated.

As far as we can tell from old records, kills of the fringing reefs in Kaneohe Bay have occurred periodically, and have been caused by major storm events. Reef-flat community destruction has been caused primarily by the build-up of fresh water in the upper levels of the water-column. Historically, sediment run-off associated with these heavy rainfall periods, while **obvious,** probably has not been sufficiently concentrated or persistent to be particularly destructive to the reef and, almost, certainly, recovery from these storm events by the corals and.other reef organisms has been quite good. The reefs have been able to survive this cycle, we assume, throughout much of the Holocene, though the **frequency of** severe run-off events is likely to have been increasedwith the effects of **urbanisation** discussed previously. Similar cycling of fringing 'reef environments has been reported from elsewhere in the world and almost certainly has been seen in various parts of the Great Barrier Reef Region.

Table 1 indicates some basic parameters of the Kaneohe Bay system and **also** indicates the potential impact of the watershed in discharging fresh water , into the bay. As can clearly be seen, even 20% of, the 'average annual rainfall occurring in one major storm could cause as much as one **metre** of overlying fresh water if most of the water ran-off into the bay, and if the storm were not accompanied by major wind turbulence or other mixing effects. In so far as the reef-flats in Kaneohe Bay rarely have more than a metre of water over them, because of the small tides, it can readily be seen that a single storm of this magnitude could subject all of the reef-flat surfaces to fresh water. This would cause nearly total destruction of hermatypic corals and many other fauna, and probably flora.

TABLE 1

General information relating to Kaneohe Bay

Kaneohe Bay		
	reef-flat area	$9 km^2$ at average depth 1m
	lagoon area	$19 km^2$ at average depth 15m
	total area	$28 km^2$
	water volume	$270 \times 10^6 m^3$
	flushing time	approx. 13 days
Water-shed		
	area	$90 km^2$
	average rainfall	$1.7 m.y^{-1}$
Freshwater input to bay		$6 m.y^{-1}$

During the years 1920-77, and particularly in the last two decades of that period, there has been appreciable input of domestic sewage to the southeastern end of Kaneohe Bay with the principle outfalls being those indicated in Figure 1. By 1977, $20000 m^3.d^{-1}$ of domestic sewage was discharged into the bay. This material contained 550 kg BOD. However, the more functionally important inputs associated with this sewage were dissolved nitrogen and phosphorous nutrients, and these were, effectively, from one major point source (Kaneohe outfall, $14000 m^3.d^{-1}$) and one minor point source (Marine Corps outfall, $5000 m^3.d^{-1}$) both in the southeast bay. The stream inputs also included significant dissolved nutrients but these were more diffuse.

Table 2 indicates the approximate nature and amounts of the nutrient inputs associated with both the sewage and the stream sources.

TABLE 2

Nutrient inputs **to Kaneohe Bay in 1977** (**mole** per day)

	Total dissolved nitrogen,	ammonium nitrogen	nitrate nitrogen	total dissolved **phosphorus**	**inorganic** phosphorus
Sewage	30000	16000		3300	3000
Streams	7000		5000	320	200

Note: Sewage inputs are oontinuous and point-source
Stream inputs are episodic and rather diffuse

The effects

The **priciple** effect associated **with** the sediment input to the'bay through, time has been the 'imposition of a chronic stress on the reef systems in' both the northwestern and southeastern ends of the bay. However, in more recent times, the stress on the inner northwestern reef-flats (site NW) has become critical, resulting in the complete destruction of any residual "normal" reef-flat communities.

The chronic stress condition is caused by a coating of much of the living surfaces by sediments, with sufficient frequency to cause physiological **disadvantage,** and, in the case of the autotrophs, a substantial reduction in light intensity.

'Actual killing of the inner reefs in the northwest has been caused by total burial of the reef surface. In this critical condition, **the** environment of the reef-flat shifted progressively from the normally balanced **trophic** state of a coral reef environment (community, photosynthesis being equal to community respiration) **towards** extreme autotrophy. The reason for this is simply that the bommunity shifted towards total algal dominance. A contributing factor was the eventual lack of availability of hard substrate **caused** again by the burial with sediment. This in turn resulted in the inability of most' reef-flat organisms to find any **appropriate** place to settle and develop.,

In the. southeastern end of the bay, I believe it is **true** to say that sediment has primarily been only a chronic stress.

The effects of sewage are quite different to those of sediment and probably quite different to those' most commonly assumed. When sewage is discharged, more or less continuously, from a point source, into a semi-enclosed, flowing body of water, phytoplankton will readily exhibit a chemostat-like response, resulting in the localiseh consumption of the point source nutrient input, and the formation of a plume of phytoplankton. Thus, the reefs do not have the opportunity to respond fully to the nutrient input as the bulk of the nutrients have been immediately assimilated. The overall result in Kaneohe Bay was a tidal and wind-driven plume of phytoplankton and associated zooplankton, with only moderately enhanced dissolved nutrient levels. This plume ran from the sewage discharge points in the southeast bay towards the central and northern parts of the bay where it swung out into the open ocean (see fig. 1). Plankton and residual nutrient levels fell with distance from the outfalls because of mixing, consumption, and some sedimentation. However, the residual dissolved nutrient levels were probably the. most significant factor by the time the plume reached the central bay reefs.

The plankton flow had two principal effects on the fringing reefs in the southeast bay (sites SE, L, CI). The first was to cause a substantial light reduction. The second was to subject the reefs to a significant organic loading of assimilable material. Thus, the overall reef response to both of these effects was to shift strongly towards heterotrophy. There was a decline in many algae, a serious decline in coral and coralline algae cover, and a favouring of the development of organisms which utilise filter feeding such as sponges, barnacles, zooanthids, etc. Because many filter feeding organisms are also infaunal, another effect of the sewage was to lead to very extensive substrate boring and eventually, in the main outfall areas (site SE), to total substrate collapse. Thus, unlike sediment input, which merely causes passive prevention of the maintenance and calcification of the substrate, sewage input leads to positive destruction of the substrate.

It was apparent that much of the observed degradation of the southeastern reef-flats was not caused by the sewage or sediment stress alone. The mechanism, rather, seemed to involve episodic kills by fresh water followed by a failure of the normal community to reoover under the influence of the chronic stress imposed by the effects of sewage (and sedimentation in some cases). This was dramatically demonstrated by the reef slopes in many areas of the southeast bay. Here, the corals and other coral reef biota were quite persistent below the immediate influence of 'the surface. These organisms were surviving notwithstanding very low light levels and being subjected to substantial plankton input. The adjacent reef-flat communities were totally modified. Similar persistence of "normal"communities below surface layers is dramatically evident on many reefs in highly polluted Jakarta Bay in Indonesia.

The central site (CE) was subjected to marginally elevated,plankton and nutrient levels. At this level of enrichment, the community was not grossly modified. However, it is interesting to note the effect here was 'to encourage heavy development of an autotroph, the bubble alga Dictyosphaeria. Only limited increases in filter feeders (hetrotrophs) were noticeable. As the sewage effects became more extreme through time, Dictyosphaeria moved further north in the central bay, It 'clearly represented the major initial (or marginal) response to sewage input. It should be noted, however, that even though the conspicuous effect in the, centraal bay was the development of an "invading autotroph, the area nevertheless exhibitted a heterotrophic balance.

In summary, the southeast outfall site has been subjected to both sediment and sewage stresses. By 1977, it no longer had any remaining hard substrate, largely because of infaunal boring together with some' sediment burial. The site, therefore, had reduced standing stocks of even, the favoured heterotrophic filter feeders, The other southeast bay sites were subjected primarily. to sewage related stresses, but' still had. hard substrate overgrown with filter feeders. Normal reef organisms were at' low, or nil, standing stocks. The central site was subjected to marginal 'enrichment of sewage origin. It exhibited general enhancement' of all aspects of community function while retaining a reasonably normal reef community, somewhat overgrown, in patches, with both an invading alga and some, filter feeders. The northwest site was subjected to heavy sedimentation, had all hard substrate buried, and was dominated by algae. There was essentially no normal reef organisms. All 'of the sites are likely to have been subjected to increased, frequency of the episodic, critical stress associated with fresswater run-off.

The recovery

Over the period November 1977 to May 1978, all of the major sewage input from Kaneohe City and the Marine Corps base was diverted from the bay outfalls. The effects of this diversion, as might be expected, were quite dramatic. The most immediate effect was the clearing of the water column due to the virtually total cessation of the plankton production previously associated with the outfalls. This was followed quite rapidly, within the following six months, by a decline in' most of the more conspicuous filter feeders in the southeastern areas of the bay. Thus the sponges, zooanthids and barnacles largely ceased to be a feature of these reef-flats. Following these immediate effects, subsequent changes were much slower.

By 1982, most of the southeastern reef-flats, previously dominated by an overgrowth of filter feeding organisms, now showed the underlying hard substrate of earlier reef surfaces. Needless to say, this was not true in the outfall area where the reef-flat substrate had literally been destroyed by boring. All of these southeast reef-flats were also exhibiting a significant bloom of macro-algae (mostly reds). This phenomenon probably was the compound effect of increased light penetration and a continuing availability of non-point-source higher-than-normal nutrient levels. The latter resulted from remineralisation of the enriched lagoon floor sediments accumulated over the decades of sewage input. Little conspicuous recovery of any coral communities had occurred by this time.

By 1985, macro-algal blooms appeared to have declined, probably reflecting a general further decrease in the nutrient concentrations in the bay as a result of exhaustion of nutrient input from remineralisation of sediments. Also, by this time, there was evidence of good coral recovery over all of the hard reef substrate areas in the southeast bay and perhaps, suprisingly, even over much of the unconsolidated rubble of the degraded reef-flats near the outfall. Throughout all of this recovery period, the central bay exhibited no dramatic changes, though there was some decrease in the amount of Dictyosphaeria.

It now seems clear that something approaching total recovery of the central and southeast reefs of Kaneohe Bay will occur. In the case of the outfall site it seems likely that, notwithstanding some degree of continuing chronic sediment stress caused by the urbanisation 'of the area (local regulations are now minimising this effect), that there will be a reconsolidation 'of the" reef 'surface and a redevelopment of coral fauna and coralline algal cementation.

It is, however, equally clear that the inner reef-flats in the northwestern end of the bay, already largely destroyed by sediment burial, will continue in their present state as none of the degradation of these reefs was associated with the sewage input., and nothing is occurring which is likely to cause a removal of the heavy sediment overload already existing. In fact, it seems probable that even a total cessation of agriculture would not be likely to result in the recovery of these reef-flats.

Conclusion

In conclusion, fringing reefs typically are quite tolerant of stresses. They may, however, reach a certain threshold beyond which their degradation is very rapid. I believe it is true that fresh water is the major killer of shallow fringing reefs in a short time frame. Sediment is usually a chronic stress but may at times kill by burial. Sewage is almost always likely to be a chronic stress and will result in progressive, slow environmental and community degradation. Chronic stresses ensure that recovery from a freshwater kill or other episodic catastrophe will not occur. However, it seems clear that recovery from an, almost totally degraded condition is possible in fringing reefs' once existing chronic stresses are removed.

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MAINTAINING WATER QUALITY ON FRINGING REEFS WITH EMPHASIS ON TOURIST DEVELOPMENT

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Abstract

It is in the interest of tourist operators and government bodies to maintain water quality 'on fringing reefs and management practices which will maintain water quality should'be implimented. Collecting and interpreting data on fringing reef hydrodynamics and sedimentation to enable appropriate management decisions to be made is generally beyond the capability of individual operators, and very expensive.

Modelling water circulation in Pioneer Bay, Orpheus Island shows circulation to be tidal, with bay flushing rates generally greater than 90%. The effect of secondary circulation in the lee of headlands is shown to be important in establishing the nature of the circulation. The model is then applied to a number of other bays in which resorts are situated. Methods are presented which may enable water quality deterioration to be avoided in resort bays if basic hydrodynamic data are collected, and appropriate management practices adopted.

Introduction

The management of a natural resource such as the Great Barrier Reef involves the manipulation of that resource so as to optimise its long term value to man (Burton, 1983). The process of resource management usually involves the development of an informal or formal management plan.

Being in'the zone of influence of land based activity and runoff, problems associated with freshwater runoff (with associated pollutants) and sedimentation may be important. Tourist development on continental islands may lead to a number of potentially damaging situations requiring management.

The legislative framework

Any attempt to apply scientific findings to management situations must consider the institutional and legislative framework which covers the region of interest. In the Great Barrier Reef region the responsibilities of the authorities involved in management are not always clear.

The Great Barrier Reef Marine Park Act 1975 provides for the establishment, control, care and development of a marine park in the Great Barrier Reef region (Bates, 1983; Australian Environment Council, 1984). The system of federal government in Australia has complicated the administrative arrangements in relation to the Marine Park (Kelleher and Kenchington, 1982). The Great Barrier Reef Marine Park Act applies up to low water mark. The mainland and islands are controlled by state legislation, except where owned by the Commonwealth and this control is extended by the Coastal Waters (State Title) Act 1980 which vests title to the seabed over the three mile territorial sea in the State, but is subject to the continuing operation of the Great Barrier Marine Park Act (Brazil, 1981).

This situation results in an area of uncertainty around islands (including cays) and the mainland coast, which is of particular importance to the control and management of fringing reefs. Around each island is a 3 mile belt of territorial sea to which State legislation may apply although the Great Barrier Reef Marine Park Act applies to low water mark, even on the mainland (Brazil, 1981). The management of fringing reefs and island resorts (which are frequently established by lease within a Queensland National Park (Ogilvie, 1981)), situated on high islands within the Marine Park is, therefore, complicated by this legal uncertainty. A functional approach (Brazil, 1981) based on consultation and co-operation which ignores artificial jurisdictional lines is needed. To this end, the Queensland Government enacted the Marine Parks Act (1982) which largely mirrors the Great Barrier Reef

Marine Park Act (1975) providing for the setting apart of tidal lands and tidal waters as Marine Parks (Australian Environment Council, 1984). Although the jurisdictional uncertainty remains, the, cooperative approach adopted by both State and. Federal governments appears to provide some solution to the legislative complications.

The provisions of the Clean Waters Act 1971-1982 which prohibits the indiscriminate, uncontrolled dumping or discharge of waste water and other polluting matter, cover GBR waters under state jurisdiction. The Great Barrier Reef Marine Park Act covers similar situations in areas under its jurisdiction.

Both the Commonwealth and Queensland have accepted the' desirability of having environmental impact assessment procedures to review any developments which may affect the environment., It is unclear whether environmental impact assessment in the Great Barrier Reef Marine Park comes under the jurisdiction of the Environment Protection (Impact of Proposals) Act 1974, or provisions of the Great Barrier Reef Marine Park Act. It is clear, however, that significant developments within the Marine Park will be subject to review, and that it is likely that any proposal will be reviewed by the Great Barrier Reef Marine Park Authority. Queensland, however, has adopted a decentralised system of administrative responsibility for environmental impact assessment, with no specific legislation, and oversight by no one department. Each department is required to assume responsibility for environmental impact assessment with respect to its area of activities and responsibilities (Australian Environment Council,' 1984). Environmental impact assessment on islands within the Marine Park is within the control of the State. A potential area of conflict, however, may come from developments on islands which cause no significant damage to the island environment, but which transfer damage to the marine environment. The management of fringing reef environments with particular reference to resort development must involve the cooperation of federal and state institutions, and resort operators.

The modelling process for management

There are many different approaches to modelling, but all have the overall objective to describe the system accurately, while simplifying it so that the model is substantially less complex than the system itself. The most basic approach is the development of a conceptual model which may be based on logic alone or on empirical evidence. The conceptual model is an essential prerequisite for further study, being merely an extension of the scientific method.

Model development for both research and management should be based on the most relevant attributes (or variables) for the particular problem being examined with "irrelevant, distracting or unknown attributes" (Bell, 1983) being excluded. Various parts of the system should be modelled separately, so that as many variables as possible can be eliminated where they are not relevant. The real world is too complex for practical treatments of complete systems (Bell, 1983). This approach means that the models developed can be used to answer specific problems with relative ease. Complete system models, although useful to and useable by the specialist are not generally useful to the environmental manager. It is recognised that models which are easy to conceptualise, treating few variables at a time, are likely to be less complete than larger models which do not need to approximate as many variables but the techniques may be used in more situations, being easier to use and less costly.

The object of all hydrodynamic models is to be able to predict the concentration of a substance at all points and at all times, this being governed by the way the substance disperses. Solution of the equation

$$C=C(x,y,z,t),$$

where x,y and z are space coordinates and t is instantaneous time is therefore the ideal, but no available model can achieve this. However, most management considerations only need approximations, which can be achieved by simplification, with the reduction in the number of dimensions that must be considered. This is usually achieved using spatial and temporal averaging techniques. A coastal embayment, which normally does not have unidirectional water flow, has many advection axes and different rates of dispersion caused by the combination of all forcing mechanisms (such as wind, tide, freshwater flow). Consideration of all sites within the bay at once is unnecessarily complex, and not needed for most management applications. Consideration of subsections of the bay system (both temporal and spatial) separately enables the development of models based on consideration of simple problems rather than on one three dimensional problem, which is very difficult to solve. The result is a cluster of models which identify individual mechanisms but which may be used in any combination.

The first step in the development of the model' cluster is the identification of all forcing mechanisms, and the resulting water movements. Simplification of the conceptual model follows with the removal of all mechanisms which have minimal effect. The models may be developed from theorywhen it is available, but where systems are poorly understood an empirical approach is necessary. Small scale experiments are then undertaken to study the effect of each forcing mechanism, at a number of sites in the bay, and at a number of times. Specific questions, such as bay flushing, which necessarily involve the entire bay, are also studied by means of separate experiments.

Models are developed within either a Eulerian or Lagrangian reference frame. The Eulerian approach is most common, with the spatial grid being fixed. The Lagrangian approach has a spatial grid which is fixed to the water, and therefore contracts and expands to follow the water movement. Field studies can be similarly classified, with data collection either being Eulerian with data being collected at specified locations; or Lagrangian, with a parcel of water being labelled and followed as it disperses. Field studies can use both approaches concurrently.

The development of models, the direct examination of water movement and the determination of the behaviour of pollutants often involves the labelling of a parcel or parcels of water (either naturally or artificially) and following the dispersing parcel through time, either by sampling the labelled parcel or by measuring concentration at various points on a known grid. A great number of artificial tracers are available but fluorescent dyes (particularly Rhodamine WT) are generally the most appropriate for management studies. Analysis of concentration is achieved using a filter fluorometer or spectrofluorometer. Reviews of the technique can be found elsewhere (Wilson, 1968; Smart and Laidlaw, 1977; Parnell, 1982, 1984).

The density of fluorescent dye solutions are higher than sea water. The density can be adjusted using methanol or fresh water to reduce the density to that of seawater, freshwater or to a value required to simulate an injection of a contaminant, and using glycerine to increase density. The ability to simulate an injection of a solution of a particular density is particularly useful in the modelling of contaminant behaviour. The release of dye with a density less than that of seawater enables the surface circulation to be modelled.

The study location

The islands studied all lie in the Central Section of the Great Barrier Reef Marine Park, from Dunk Island in the north to the Whitsunday Islands in the South. All study sites have extensive fringing reef development, and are subject to broadly similar climatic and tidal influences. Pioneer Bay, Orpheus Island (Figure 1) was chosen as the site for model development as it was representative of many of the bays in which resorts are, or potentially may be, located. It demonstrates a number of features desirable for resort development such as flat land suitable for building, a sandy beach, a potential water supply, a sheltered anchorage, reasonable access to outer reefs and hills suitable for walking tracks. Its lee side location, the nature of the reef flat, the offshore depths and the defining headlands are also characteristic of bays in which resorts have located. Other situations examined were Hazard Bay on Orpheus Island, and the resort bays of Hamilton, Long, South Molle and Dunk Islands.

Pioneer Bay is one of a number of bays on the highly indented western side of Orpheus Island, with a 400m wide reef flat which is completely exposed during spring low tides. The outer band of living

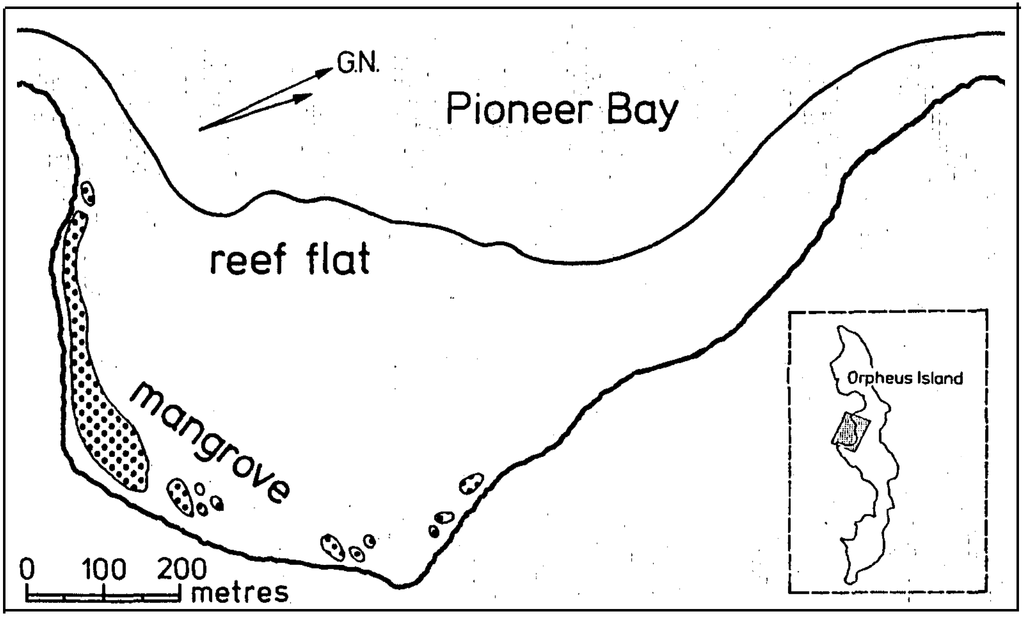

Figure 1 Pioneer Bay, Orpheus Island

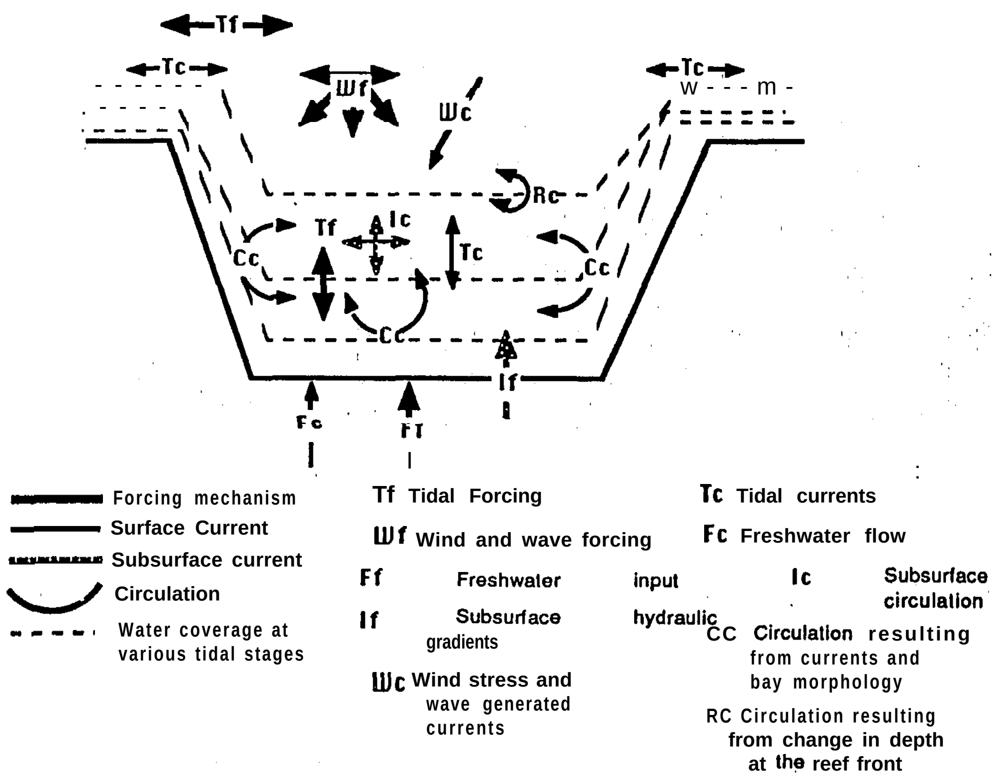

Figure 2 Conceptual model of water circulation in Pioneer Bay

coral is flanked by 100m of rubble with some living colonies. The inner reef flat consists of fine to very fine sand and coral debris with some dead microatolls. An area of mangrove is situated on the southern inner reef flat, with isolated specimens elsewhere. The beach in the centre of the bay rises steeply from the reef flat into a dissected vegetated beach ridge sequence about 100m wide. The northern and southern shores of the Bay are predominantly composed of small boulders (10 to 20 cm in diameter), with considerable accumulations of coral clasts above high tide mark. The catchment of Pioneer Bay rises steeply to 156m with six small ephemeral streams flowing into a depression behind the bay at each end of the ridge. During periods of heavy rainfall water percolates through the ridge sequence discharging onto the beach and into the reef flat framework.

The reef front is highly indented, with the base at 5m below Chart Datum (CD). The sea floor slopes gently to 15-25 m well offshore. Pioneer Bay is sheltered from the predominant southeast and easterly winds. Only for a short period during the summer months when winds have a westerly component is the bay exposed. Even during such periods, waves are small as the fetch is short due to the proximity to the mainland. At most times of the year the bay is calm, even during very windy periods.

Pioneer Bav - Modelling

The generating forces which operate and may cause water movement within Pioneer Bay are illustrated in Figure 2. The most important generating forces which must be considered are wind, waves and tides. Additionally, freshwater inflow and hydraulic gradients within the reef framework must be considered.

The principal tidal currents stream across the bay, north on the ebb tide and south on the flood. Velocities are usually highest off the southern bayhead. Additionallv, tidal currents are required to move water into and out of the bay. The combination of these currents is the most dominant influence on bay circulation. Representative current diagrams for one site near the mouth of the bay are in

Figure 3. It is apparent that tidal streaming is out of phase with the tide. With a similar tidal range velocities are lower on the ebb tide than on the flood.

A number of tracer studies using fluoroescent dyes were undertaken in order to determine the circulation pattern which results from the interaction of forcing mechanisms. The experiments were carefully designed to give data on velocity and direction of water movement at sites of interest under a' variety of tidal conditions, and to indicate where 'olcl'water may accumulate. For much of the work, Eulerian type data would have been impractical to collect as water velocities are often near the lower limit of measurement of commonly used current meters, and in order to study circulation at the small scale, the number of instruments needed would have been prohibitive. Dye data can, however, be used to estimate velocity. A generalised circulation,, based on these experiments is illustrated in Figure 4. Experiments indicated that. there was a zone of accumulation of 'old water near the northern beach.

The particular feature which makes the bay with a fringing reef different from other coastal embayments is the dramatic change in water depth at the reef front. There is a general upwelling at the reef front indicated at all stages 'of tide. There is preferential upwelling in small crevices in the reef front, but there is no evidence of preferential movement into larger embayments. Water coming off the reef flat remains near the surface for a considerable distance.

Estimates of flushing are generally made using volume exchange models. The term "flushing time" and its counterpart "residence time", are used in many ways, but, normally describes either average residence time of a particle in the system, or the amount of time it takes to'remove a proportion of the water or tracer, and are usually measured in tidal cycles: To determine flushing time for management the bay extent is defined, and the bay partitioned. Detailed bathymetric analysis enables volume to be calculated. Tidal measurements must be made 'or estimated. An approximation to an even distribution of dye over the bay'is achieved by dividing the bay into segments and injecting'dye as a slug at the centre of, each segment, the amount of which is proportional to the segment volume.

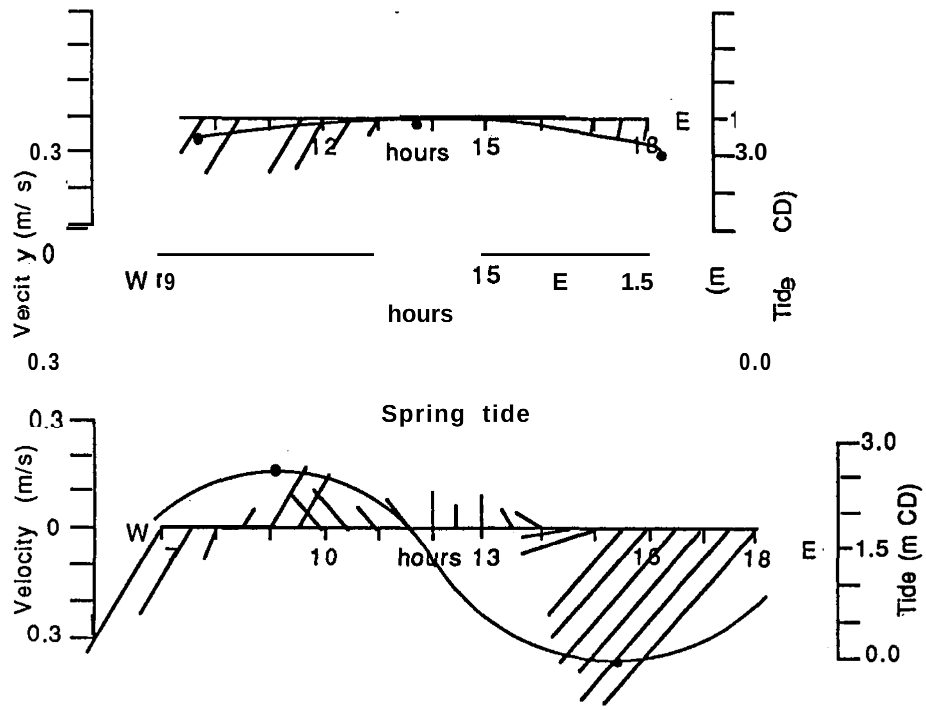

Figure 3 Water velocities and tidal data at the bay mouth on spring and neap tides

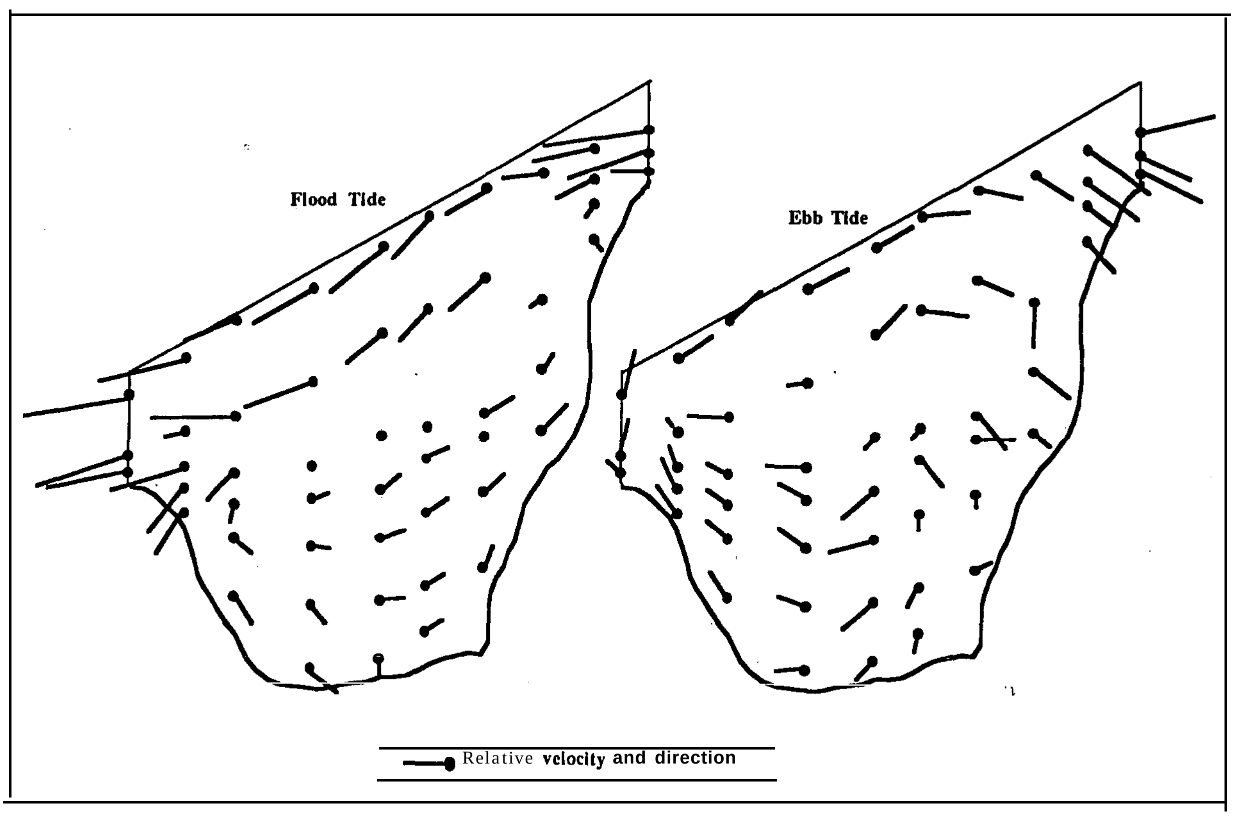

Figure 4 Generalised circulation, Pioneer Bay

Alternately, for the answer to a more specific' problem, dye' can be injected at a' point, or as a line source. The results of experiments in Pioneer Bay indicated that 92% of the water in the bay at one high tide was removed on the average tide, with most of the water remaining being concentrated along the northern shore. The total proportion of dye removed over two tidal cycles was 99.5%. This indicated that the exponential model of decay (which is generally applied to estuary situations) may apply to the bay situation.

As a comparison bay volume was modelled to determine flushing time Over the period of the bay flushing experiment, using an average value for high and low water volumes, T (residence time)= 4.12 tidal cycles. This compares with T= 1.08 established using fluorescent dye. Although the bay flushing experiment using dye may slightly underestimate T because some dye will be present below the minimum detectable limit, it is clearly much less than T predicted using the standard volume exchange model. This is because bay circulation is superimposed on the volume exchange required by the vertical tidal movement. Because much of the water within a bay is stored seaward of the reef front if the bay did not have well developed circulation it would have a long residence time approaching 4.12 tidal cycles for the average tide.

The circulation in Pioneer' Bay is a result of many forcing mechanisms and residual currents associated with them. Circulation is predominantly tidal, with the combined effect of eddying in the lee of the headlands, and diverging flow caused by tidal streaming against the opposing shore causing flow within the bay to be opposite in direction to flow across the bay. The southern shore is at a higher incident angle to the tidal stream than the northern shore,' and this combined with the requirement to move water into and out of the bay, ensure higher velocities along the southern shore than along the northern shore. At a smaller scale, freshwater inflow, boundary effects and the effects of topography (particularly at the reef front) cause local modification to the overall pattern, and cause differing velocities in the vertical. The effect, of wind for most of the year is minimal, but the effect' for the small period of the year when the bay is exposed is unknown.

The movement and distribution of sediment over the reef flat and offshore can be explained in terms of source and the predominant bay circulation. Most of the sediment on the reef flat has a local origin, with sediment from the catchment, and coral and shell fragments from the reef flat and slope contributing to the offshore sediment facies. The importance of bioturbation to the movement of sediment through the system was noted.

Modelling investigations - other bays

Circulation in bays in which resorts are located (Brammo Bay Dunk Island, Happy Bay Long Island, Bauer Bay South Molle Island, Catseye Bay Hamilton Island and Hazard Bay Orpheus Island) was studied (Figure 5). It was found that the most important factor in determining the nature of the small scale hydrodynamics and bay flushing was the nature of secondary circulation established as a result of the relationship between the ebb and flood tidal streaming and the bay shape.

Happy Bay Long Island has a similar aspect and tidal streaming to Pioneer Bay. On the ebb tide strong eddy circulation is developed in the lee of the southern bayhead, but because of the long northern shore it is not reinforced by water being deflected into the bay at the northern bayhead. On the flood tide, water moves into the bay from the north, and leaves the bay around the southern bayhead with only slight eddy circulation along the northern shore. Similar patterns exist in Brammo Bay, and in Catseye Bay (except that the tidal streaming is east-west). The extent of eddy circulation is directly related to the angle the bayheads form with the prevailing tidal stream. The circulation in Bauer Bay is complicated by the presence of Mid Molle and North Molle Islands, which has the effect of lengthening the bay on its western side. Again, an eddy circulation is evident, but the primary mechanism is the diversion of water against the opposing headland, as opposed to the eddying effect in the lee of a headland. Hazard bay is much less indented than the other bays and the circulation within the bay is dominated by the tidal streaming, illustrating the importance of bay shape on circulation.

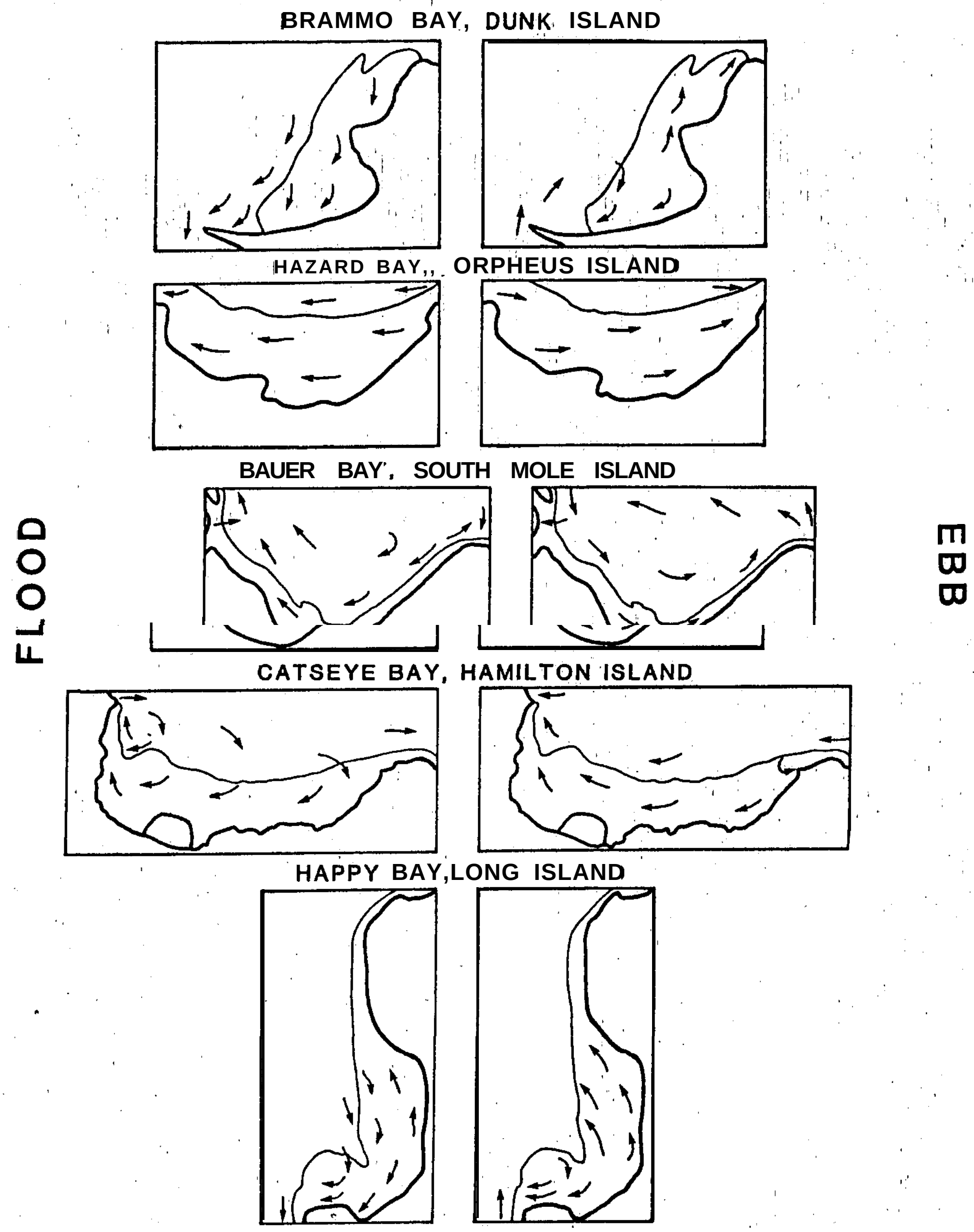

Figure 5 Generalised **circulation** in five resort bays

Water quality management problems

The two principal causes of water quality deterioration in the vicinity of resorts are caused by the impact of wastewater (including freshwater) discharge and associated increases in sediment discharge onto the reef, and by changes in the hydrodynamics and sediment movement due to engineering works.

The study bays illustrate a number of these problems. Evidence from Hazard Bay, shows that a channel across the reef flat, perpendicular to the dominant water flow is trapping sediment moving along the coast in both directions. The direction and velocity of flow in the channel is altered, and there is potential during periods of high winds for- the removal of substantial quantities of beach sediment into the channel and off the reef flat. The long term effect of the construction of a watersport enclosure in Catseye Bay is as yet uncertain, but there were indications of a change in sedimentation along the beach and accross the reef flat. The problem of retaining sand on the beach is illustrated in Bauer Bay, where beach sand is continually being removed and deposited off the reef flat. In two resort bays substantial quantities of silt was observed to be flowing onto the reef flat during periods of heavy rainfall. This is likely to be a problem in all bays with resort development and is potentially damaging to reef communities. It was found that reef flat sediment in resort bays contained substantially more terrigenous material than sediment in similar undeveloped bays.

A summary of management techniques

There are a number of techniques which can be used by the non-specialist to assist in the interpretation of bay hydrodynamics and assist is management decisions. Ideally information should be gathered before wastewater discharge or engineering works begin, but the methods described may assist in minimising the impact of present situations.

Well designed small scale tracer studies can lead to the understanding of where individual parcels of water move. If a number of these experiments are conducted, a model of bay circulation can be derived using the data and basic equations. This can then be used to predict circulation at other sites and times.

There are a number of techniques which are available to examine the movement and flushing of introduced pollutants. The characteristics of a tracer can be made to resemble that of a pollutant and injected at the site of a potential outfall as a slug; or continuously over a period of time. The effect of a single injection can then be measured using concentration data, or by integrating the concentration curve with respect to time at any site of interest, the ultimate or equilibrium concentration at the site of a continuously injected contaminant can be estimated (the superimposition principle). At a larger scale bay flushing can be estimated using a volume exchange model (which is likely to give'a very conservative estimate of total flushing), or by introducing a tracer at a number of points within the bay in proportion to water volume, and monitoring its removal. If the flushing of a particular segment of the bay is required, the experiment can be confined to the area of interest.

Sedimentation patterns can be monitored by examining the potential sources of sediment, and relating this to bay circulation. Velocities and directions established using tracer data (or model data) can then be used to predict sediment distributions, with rates established using sediment transport equations. The possible effects of increased sediment input or of engineering works can then be examined.

Conclusions

The study of bay hydrodynamics involves a cluster of models (Figure 6). Models of water volume and flushing, and studies of boundary effects, the effect of the change in 'topography at the reef front on circulation, and the study of other small scale factors such as water movement within the reef framework, are used to further refine the circulation model which is derived from a number of well designed Lagrangian tracer experiments.

Data from a number of lee side fringing reef bays indicates that the nature of bay circulation is

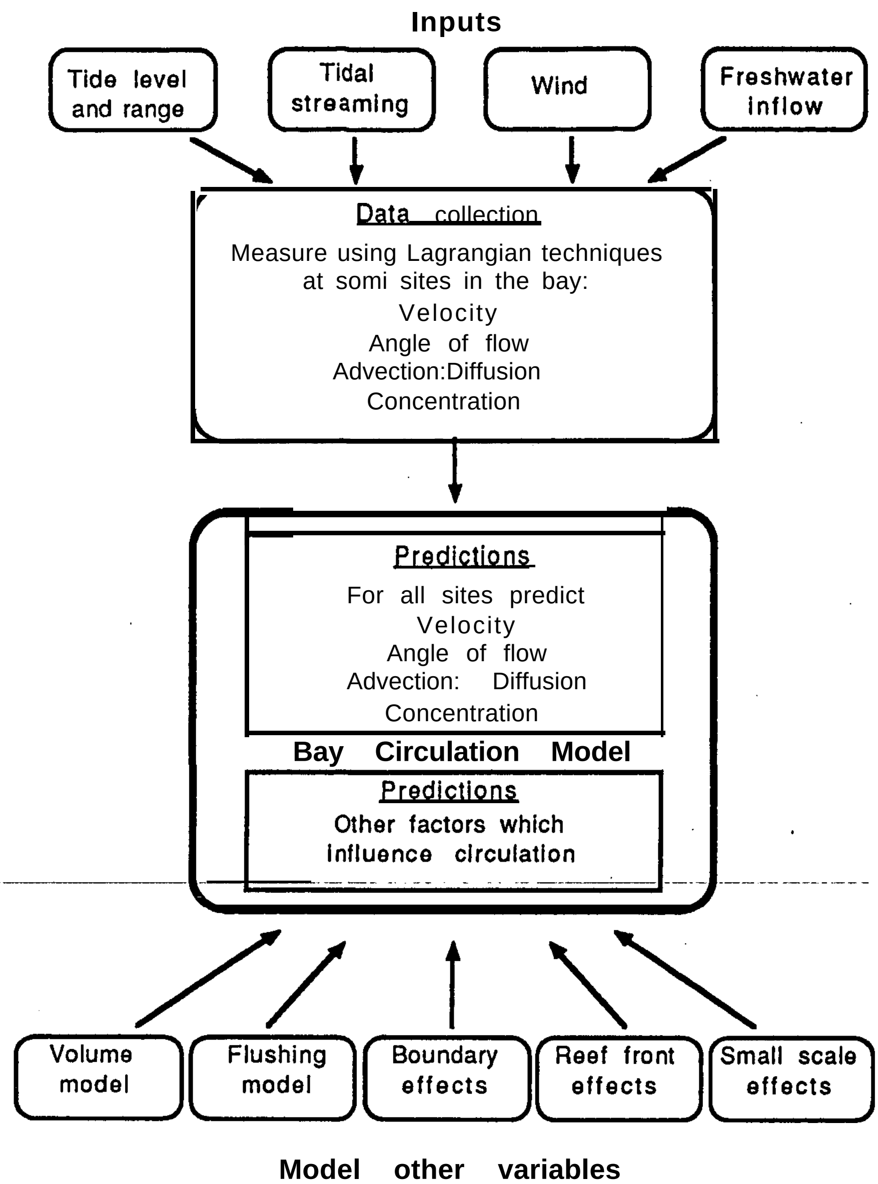

Figure 6 Bayhead fringing reef modelling, model cluster

determined by &relationship between **tidal streaming** and bay **morphology**. The' extent of eddy circulation is related to **the** extent of bay indentation. "Where eddy circulation is established bay flushing (and hence removal of pollutants) is high. Velocities within bays are variable and must be, considered when changes in sediment supply are envisaged. Once a hydrodynamic model for the whole **or part** of a bay is obtained, the likely impacts of wastewater discharge or engineering work can be determined.

Although the legislative framework within which management decisions must be made is unclear, it is to the benefit of government, resort operators and visitors that water quality be maintained. 'Major studies are expensive and generally need to be undertaken by specialist personnel. **Although such** studies are both useful and necessary, reasonable quality information which can be used in many management situations can be obtained inexpensively by non-specialists using, Lagrangian tracer techniques.

Acknowledgements

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POLLUTION AND SPONGES OF GREAT BARRIER REEF AND CARIBBEAN NEARSHORE REEFS

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The biomass of sponges was determined for nearshore coral reefs of the Great Barrier Reef (GBR) and the Caribbean/West Atlantic region. The techniques employed were similar to those employed previously to examine sponge distribution (Wilkinson and Trott, 1985). The data reported here represent wet sponge biomass per, square metre based on three, 40 m2 transects at constant depths of 20 m (or 15 m when deeper areas were not available).

Sponge biomass was considerably larger on Caribbean nearshore reefs than on comparable reefs of the GBR. Table 1 represents a subjective classification of reefs by the degree of land influence on the areas surveyed. In each region the reefs are listed from lowest influence to the highest perceived, which usually equates to human induced pollution. For instance, Clack Reef is approximately 35 km from land in an areas remote from settlements, whereas Pandora and Phillips Reefs are 19 and 17 km from land, within a shallow embayment, near large towns. All the Caribbean reefs are within 10 km of land, but in most circumstances the land masses are small. Barbados East coast and the Exuma Cay sites are in clear water, under predominantly Atlantic Ocean influence. By contrast, the Key Largo and Barbados West coast sites are adjacent to areas of extensive tourist developments.

The data in Table 1 show clearly that sponge biomass is clearly related to the degree of land influence. This was shown in a previous study of sponges across the continental shelf of the GBR (Wilkinson and Trott, 1985). The most likely causative factor is increased organic nutrient concentration through either increased productivity, via raised levels of land derived inorganic nutrients, or additional organic matter from the land e.g. pollution from sewage. In areas where there is extensive human based development and agriculture, both sources would be applicable.

Differences in sponge populations in the Caribbean were directly related to the degree of land influence. The lowest biomass was recorded on Barbados East coast and Exuma Cay sites where land influence is minimized because the predominant currents sweep in from the Atlantic Ocean. The highest biomass was recorded on the two sites adjacent to tourist developments. Untreated sewage is discharged directly adjacent to the reefs on the West coast of Barbados with the result that sponge biomass is almost 7 times greater than on, the East coast. In parallel with increased sponge growth, there has been a decrease in the viability of corals on these reefs because of increased loading or organic matter and reduced light penetration (Tomascik and Sander, 1985). The reefs off Key Largo in Florida are under the direct influence of extensive developmerits in the Florida Keys and the city of Miami.

Any reduction in coral coves will have deleterious effects for tourist development, as the, visitor usually wishes to view flourishing corals rather than sponges. This is more accentuated on the GBR, where sponges are. generally smaller and less spectacular than. on Caribbean reefs. In' addition, increased' nutrient loadings will accentuate the growth of bioeroding organisms, especially sponges with the result that the reef framework will be gradually destroyed. In order to maintain fringing reefs, it is essential that organic pollution be controlled and that only well treated sewage effluents be discharged in the vicinity of fringing reefs.

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Table 1. Biomass of sponges on fringing reefs of the Great Barrier Reef and the Caribbean. The reef sites are listed in descending order from low to high incidence of land influence.

REEF SITE	BIOMASS g m-2
Great Barrier Reef	
Clack Reef' Northern GBR	1 9 7
Pandora Reef Central GBR	570
Phillips Reef Central GBR	399
Caribbean/West Atlantic	
Barbados East Coast	368
Exuma Cay East Side	399
St. Croix,Buck Island	654
Puerto Rico South Coast	792
St. Croix Salt River Canyon	1354
Key Largo French Reef	1259
Barbados West Coast	2458

SOME POTENTIAL PROBLEMS ASSOCIATED WITH BOAT HARBOURS AND MARINE STRUCTURES ON CORAL REEFS

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INTRODUCTION

Expansion of tourism in the Great Barrier Reef region has resulted in the development of many new tourist resorts as well as the upgrading and expansion of existing resorts. Virtually all such resorts provide for holiday experiences which emphasise the idyllic tropical island paradise or the unique natural environment of the Great Barrier Reef. Essential to both concepts is the marine environment as both a recreation area and a spectacle to be observed and enjoyed.

For these. reasons, as well as the need to provide access to the resort, most island resorts require various marine facilities, including jetties, boat harbours and marinas, beaches and lagoons for water activities. Furthermore, space for marine service areas, helipads and even airstrips, often can only be provided by reclamation of portions of the foreshore.

When there is a coral reef, either as a fringing reef adjoining a continental island or the mainland or a platform reef on which the coral cay is situated, the provision of these marine facilities and structures usually involves construction on or in the coral reef. This paper discusses some of the problems associated with such projects.

FRINGING REEF ENVIRONMENTS

The principal factors that all fringing reefs have in common are that they adjoin the shoreline of a continental island or section of mainland and that coral and biogenic sediments constitute a significant proportion of their surface and upper substrate (1). In other aspects they can be very different. Three examples are given to indicate this diversity.

1. Norfolk Island (Figure la)

   This island lies in the Pacific Ocean between New Zealand and New Caledonia. On its southern shore it has a short, narrow, exposed reef located about 50m offshore from a sandy beach. There are several narrow gaps in the reef which connect to a narrow lagoon and to a small bay at one end of the reef. This reef is subjected to heavy breakers from the continuous swell as well as storm waves from several directions. Wave-induced currents are well developed with strong current outflows through the various gaps in the reef The wave-induced circulations dominate over tidal circulations (2).

2. Hayman Island (Figure lb)

The northernmost island of the Whitsunday group,. lying within the Great Barrier Reef lagoon, Hayman Island has a wide comparatively, sheltered reef. on its southern shore. Tidal and wind induced circulations dominate. Local "wind waves' are small except during occasional cyclones. The reef is predominately 'formed, of coral and biogenic sediments, overlying an earlier'reef of Pleistocene age (3).

3. Nellie Bay, Magnetic Island' (Figure lc)

Another comparatively sheltered reef subjected to local wind waves and some' low ocean swell, again with occasional cyclones. Significant input of terrigenous sediments from a creek at one end dilutes the biogenic reef-derived sediments (4). The nature, of the reeef substrate is not known but could be largely terrigenous sediments with corals and reef derived materials confined to the surface layers. Several fringing reefs in North Queensland have this type of structure (1).

BOAT HARBOURS AND MARINAS

Basic Requirements

Boat harbours or marinas form an essential part of many island resorts particularly in sheltered waters such as in the Whitsunday area. These facilities are required where it is desired to anchor vessels for considerable periods of, time. Where only a short stay is required, for. instance for commuter traffic, day trips or inter-island transfer, an open unprotected jetty may be adequate, although even in this case some dredging of the reef surface may be necessary.

The basic requirements of a boat harbour,. are a navigable entrance, a sheltered mooring area, suitable landing structures, such as pontoons or jetties, and adequate space for services and storage. Provision of the entrance may involve dredging an access channel from the edge of the reef, while the mooring'area may also have to be dredged out of the reef. Breakwaters or submersible bund walls may be required to provide'the necessary shelter at all stages of the tide. Jetties will involve driving piles into the reef surface and reclamation of part of the reef flat may be required to provide service areas. Navigational aids such 'as lights and beacons will of necessity be located on the reef in most areas.

Environmental Effects,

The're are 'many potential environmental effects which can result from a major disturbance to the reef flat such as dredging a boat harbour.. Some of the more obvious ones are given here as examples, of what can happen. It is not intended to be a discussion of all possibilities.

Firstly, the dredging of the boat harbour and its access channel may alter current and wave patterns. Moreover the consequences of these alterations will be modified if the dredged basin is surrounded by a breakwater or bund wall. An unprotected basin may fill up with sediments from the adjoining reef flat or from a stream discharging into or close to it (Figure 2a and b). Some of the sediments may be carried out through the entrance channel and completely removed from the reef surface*. A basin protected by a breakwater or bund wall should not fill with sediment but the wall may deflect the current seawards and still cause removal of sediment from the reef surface (Figure 2c). Moreover, the breakwater may change wave directions on the reef flat and shelter portions of the beach, causing changes to the beach alignment.

Secondly, during dredging a surface layer of reef rock may be broken through and underlying loose material exposed. This material may slump into the basin, effectively causing sedimentation additional to that described above. Continued removal of this material may weaken reef surface areas surrounding the dredged area and cause foundation problems.

Thirdly, disposal of dredge spoil may be a problem if it is not required or is unsuitable for reclamation purposes.

ARTIFICIAL LAGOONS AND RECLAMATIONS

Some resorts may need a shallow protected lagoon for water activities, such as swimming, wind surfing, paddle boats, etc. Such an area could be provided by enclosing a portion of the reef flat with a low flat bund wall (Figure 3a). The effect of the bund wall is to raise the low tide level over the reef flat while still allowing some tidal movements at high tide (Figure 3b). Such a project will require extensive investigation to ensure that problems such as pollution, changed ecology and sedimentation are minimised. For instance, pollution can be minimised by the continual tidal inflow over the top of the wall at the higher tide levels and discharge through sluice at low tide from time to time as required. However, tidal inflow creates the possibility of reef sediments being carried over the bund wall into the lagoon during periods when waves are stirring up sediments on the reef flat outside.

Design of the enclosing bund poses various problems associated with its appearance and safety for visitors walking on it, as well as the basic engineering problems of location, stability and water-tightness. The nature of the reef surface and its substrate is again important with regard to both their ability to support the bund wall and drainage structures and also their permeability which determines the amount of subsurface leakage from the lagoon.

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*This situation exists at Heron Island in the Capricornia region of the Great Barrier Reef. There, a dredged boat harbour and access channel provide a channel for tidal outflow to remove sediments from the reef and cay into deep water (5,6). A satisfactory and economical solution to this problem has yet to be devised.

Reclamations on reef flats may have settlement problems as the reef substrate consolidates. Moreover, the location and extent of the reclamation may cause changes to the current,circulations and beach.,, alignments similar to those caused by breakwaters. 'When "the reclaimed area is close to the reef edge, for example,' the end of an airport runway, special protection structures may. be required to dissipate wave energy (Figure 3c).

STRUCTURES ON REEFS

Foundations

Coral reefs generally do not make good foundations for structures (7) . Certainly structures should not be founded on sand cay or sand banks unless the foundation is taken down onto a firm substrate at or below reef surface level.

The variable nature of the reef structure makes design of foundations difficult (Figure 4). Bearing capacity and pile skin friction for calcareous sands are lower than for quartz sands and settlements tend to be greater (8,9). Piles have a habit of disappearing into unconsolidated sediments'which often underlie a 'thin hard surface of reef rock. In these cases raft foundations are preferable but more expensive (10).

Design Water Levels

Normal water levels are determined by the tides. Even if these are not known at a specific location, they can usually be estimated by interpolation from predictions for nearby locations*. If necessary, their measurement is simply a matter of installing a suitable recorder and operating it for a suitable time period.

Storm tide levels are another matter altogether. Cyclonic storm surges may result in substantial water'level increases offshore from the reef depending upon the intensity and direction of 'approach of the cyclone. Coastal topography can also significantly affect the storm surge height. At Townsville numerical modelling predictions indicate that the storm surge from the 1 in 50 year cyclone would be about 3.m above predicted tide, whereas' the 1 in 500 year cyclone would produce a surge of, almost 4 m (11). The height of these surges could be further increased as they travelled over the shallow reef flat, On the' other hand the probability of the occurrence of very high storm tide levels is reduced because this depends upon the surge arriving at or near the predicted astronomical high tide.

Selection of design water levels clearly must be made taking account of both the probability of occurrence of a given storm tide level and the expected consequences in terms of loss of life and damage to faciltities.

Wave Impacts

Structures located on reefs are subjected to wave action. Under normal conditions the waves are not very large and create few problems. During cyclones large waves may break on the edge of the reef. Intense plunging breakers may cause destruction of coral at the reef edge as well as the formation of ramparts or berms of coral rubble and shingle some short distance shoreward of the reef edge. The breaking waves are transformed into turbulent bores which travel, for several wave lengths across the reef before the waves reform into smaller oscillatory waves which continue to move landwards (Figure 5a). At low tide virtually all wave energy is dissipated at the reef edge although water levels on the reef flat may be increased (Figure 5b).

The'zone of intense disturbance and aeration varies in width with the. size of the waves and the depth of water over the reef. For typical conditions in the Great Barrier Reef lagoon, say waves of 3 m height and 6 s period in 3 m water depth, this zone is about 100 m wide (12). For extreme waves, it might be 200 m wide. Clearly wave impacts on structures will be much lower if the structures are located away from the reef edge. Furthermore, while the largest waves reaching a structure, such as a bund wall located well back of the reef flat, will occur at the highest water level, these largest waves will not be caused by the largest waves offshore. The largest waves that actually reach the structure are those which just cross the reef edge without breaking and hence, with minimal previous energy loss, break directly upon the structure itself (Figure 5c).

Knowledge of wave action on reef platforms is not very extensive. However, the following points should be considered by designers:

(i) Structures should be located back from the edge of the reef outside the initial breaker zone to minimise wave impacts.

(ii) The largest waves to'reach a structure on the reef will be those which just pass over the reef edge at high tide level without breaking.

(iii) The height of reformed waves on a horizontal or very flat reef platform does not normally exceed 0.55 times the water depth (13,14).

(iv) Waves breaking at the edge of the reef will increase the water level on the reef flat by an amount of the order of 10% of the offshore wave height. The wave set-up decreases with increasing tide level.

(v) The prediction of cyclonic wind waves have been improved in recent years and a numerical model, which has been tested in northern Australian environments, has been developed (15,16).

Construction Materials

Stability of breakwaters, and bund walls may be difficult to achieve with available methods and materials., Coral rubble may be too small or unavailable; in sufficient quantities, nor may there be a convenient, economical and environmentally acceptable source of rock on the island or adjoining mainland. New alternative construction methods need to be developed to cope with such situations. such methods might involve the electrodeposition of calcuim and magnesium salts from seawater (17), or biological approaches involving the cultivation of corals or algae to bind material together, or controlled formation of beach rock in specified locations.

BEACHES BEHIND REEFS

Beaches behind fringing reefs tend to be formed of a relatively steep upper beach at the shoreline, the base of which is between mean tide level and low tide level. A lower beach of much flatter slope may exist on the landward side of the reef flat with exposed coral shingle. and living coral further offshore (Figure 6a). The upper beach will normally be formed of medium to coarse sand of either biogenic or terrigenuous origin, generally with a mixture of both types of sand., The lower beach will tend to be finer in size.

Generally waves reach the beach only at tide levels above mean tide level, the largest waves occurring at high water as explained previously. The general alignment of the beach is determined by the dominant wave direction with sand movement along the beach in either direction as wave directions fluctuate about the dominant one. In some cases ocean swell from outside the outer reef may have a different effect to local wind waves (Figure 6b). Significant changes to the beach only occur during cyclonic conditions when beach recession of 10 m or more can occur. The timing of the cyclonic waves and surge with the tide is crucial,.

> If the cyclone occurs at low tide there is little effect on the beach.
> If the cyclone occurs at high tide there is significant erosion and recession of the shoreline.
> If the cyclone occurs at high tide plus storm surge there is a disaster.

Where the beach is inadequate or has been badly eroded, beach replenishment may be contemplated. In some cases this may be achieved by mechanical or hydraulic movement of sand from accreted areas back to eroded areas. Where sand has been permanently lost from the beach-reef system or where it is desired to improve an existing beach, it will be necessary to bring sand from a source outside the immediate beach-reef system. Such material should be selected with care and should have properties as close as possible to those of the existing stable beach; The evironmental effects of its removal from the source area will also have to be considered.

SUMMARY AND CONCLUSIONS

1. The characteristics of a given fringing reef system depend upon a combination of geological, climatological, oceanographical and ecological factors. Every reef is different from its neighbour and an understanding of the particular characteristics of a given reef is essential if substantial engineering works are to be constructed on it with minimal environmental disturbance.

2. Substrate conditions of reefs are very variable and can present significant problems when either firm foundations or water-tightness are required.

3. Normal wave climate on the fringing reefs of the Great Barrier Reef is relatively mild but tidal effects are significant in most areas.

4. Extreme wind and wave conditions are infrequent but the possible effects of cyclonic waves and surges can be catastropic.

5. Ecological considerations will almost certainly be more significant than in normal mainland beach environments.

6. Very little specific data is available concerning water circulations and, more particularly, wave action on the reefs of the Great Barrier Reef. Furthermore, some concepts. and design formulae commonly used by engineers in other coastal environments may not be applicable.

7. As a consequence of the above facts the investigation and construction costs for projects located on fringing reefs are likely to be greater than for an equivalent project on a reasonably accessible mainland beach but may not be as great as for a coral cay environment in exposed water.

AN IDEA FOR RESEARCH

There is a need for interaction between reef scientists and engineers in defining useful applied research projects. For example,, the design of breakwaters and bund walls might be improved if new methods for stabilising their materials could be developed. Perhaps marine biologists could determine how to cultivate corals or algae from the reef rim to provide a natural binding of an artificial mound. Geochemists could develop a means of rapidly producing beach rock. The latter would be particularly, helpful in stablising breakwaters and bund walls on reef flats in relatively sheltered areas which are only occassionally subjected to strong wave action.

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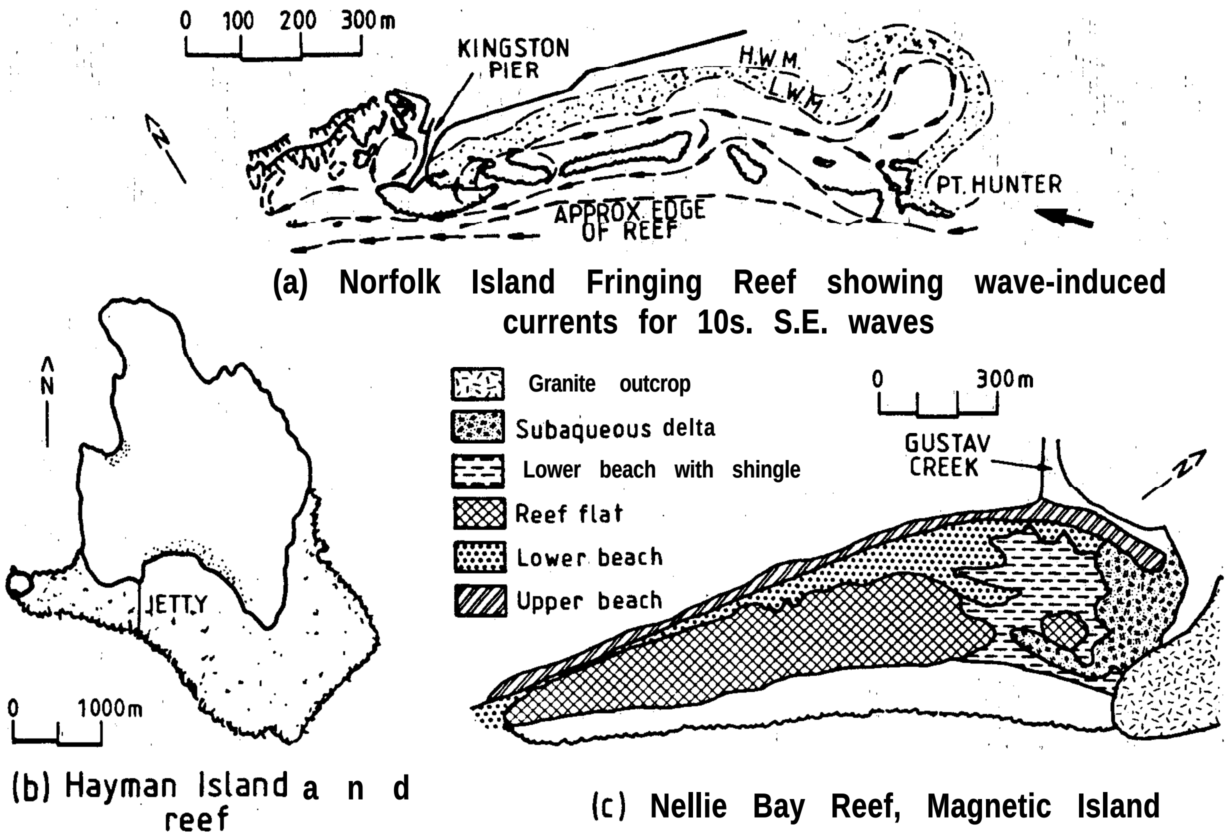


(a) Norfolk Island Fringing Reef showing wave-induced currents for 10s. S.E. waves

(b) Hayman Island and reef

(c) Nellie Bay Reef, Magnetic Island

Figure 1. EXAMPLES OF FRINGING REEFS

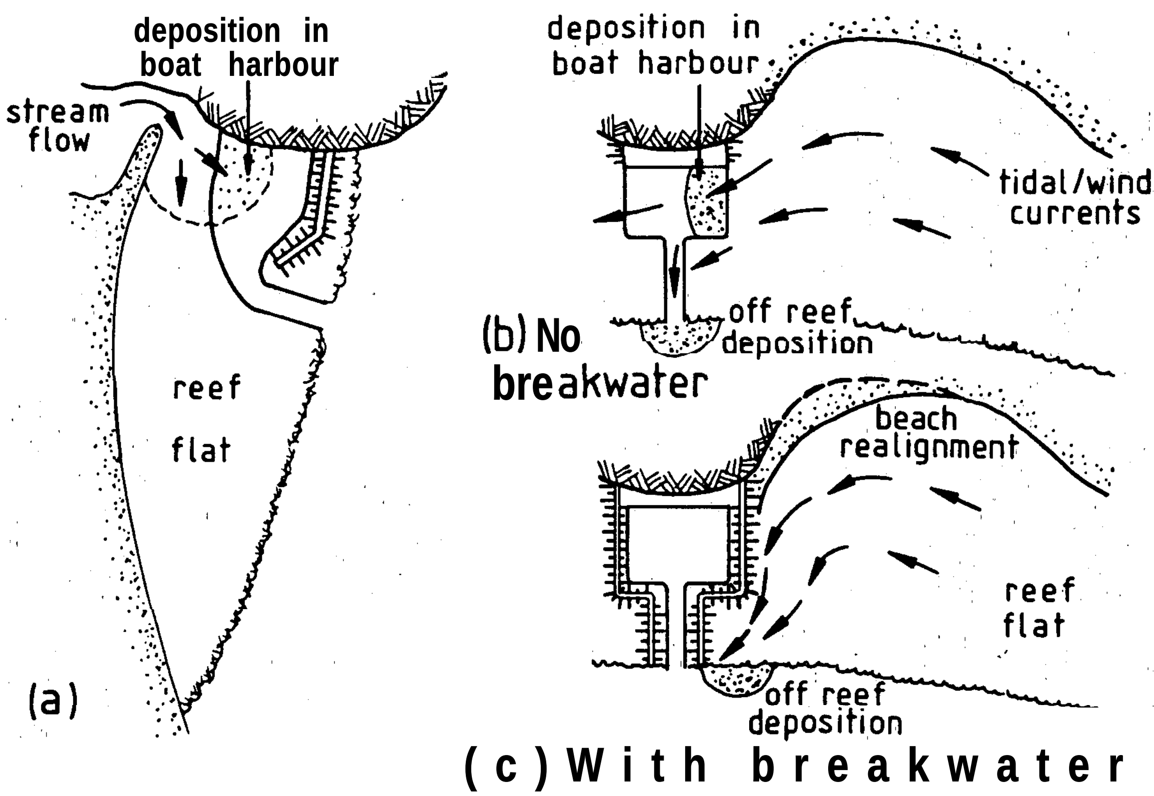


Figure 2. SEDIMENTATION IN BOAT HARBOURS

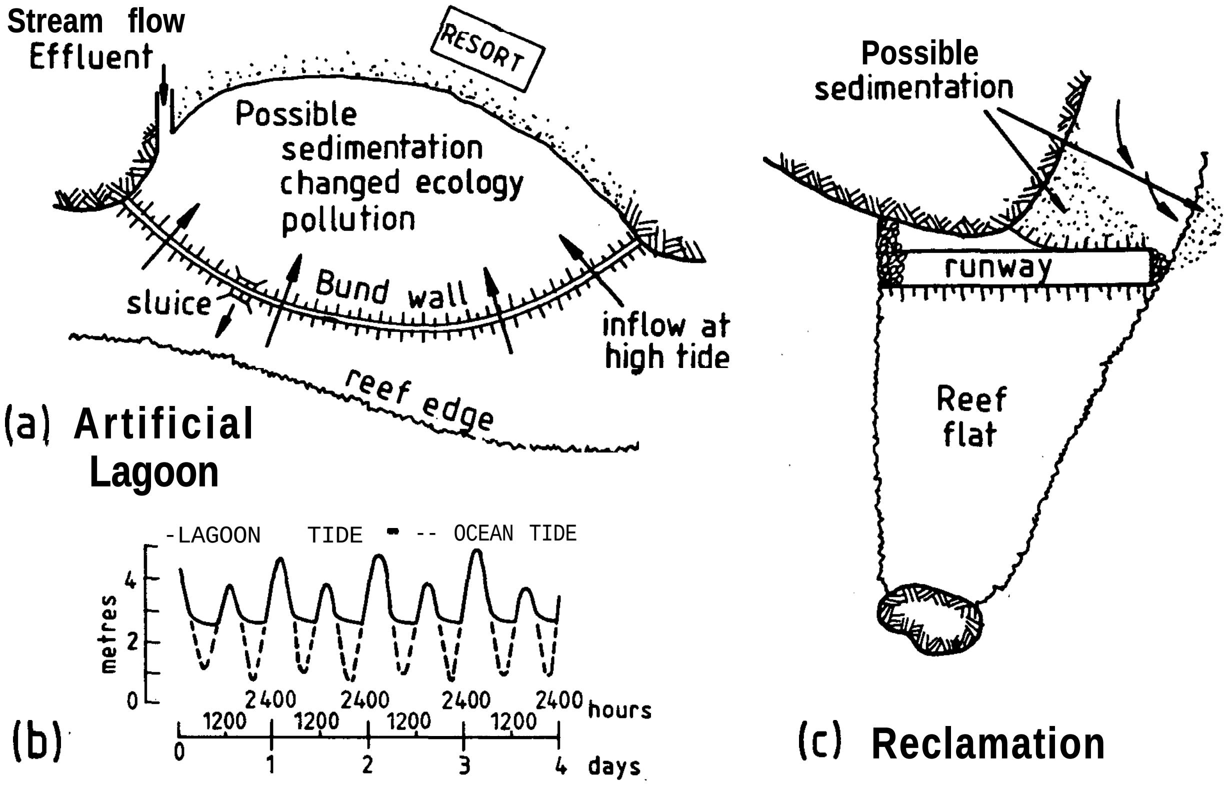


Figure 3. ARTIFICIAL LAGOONS AND RECLAMATION

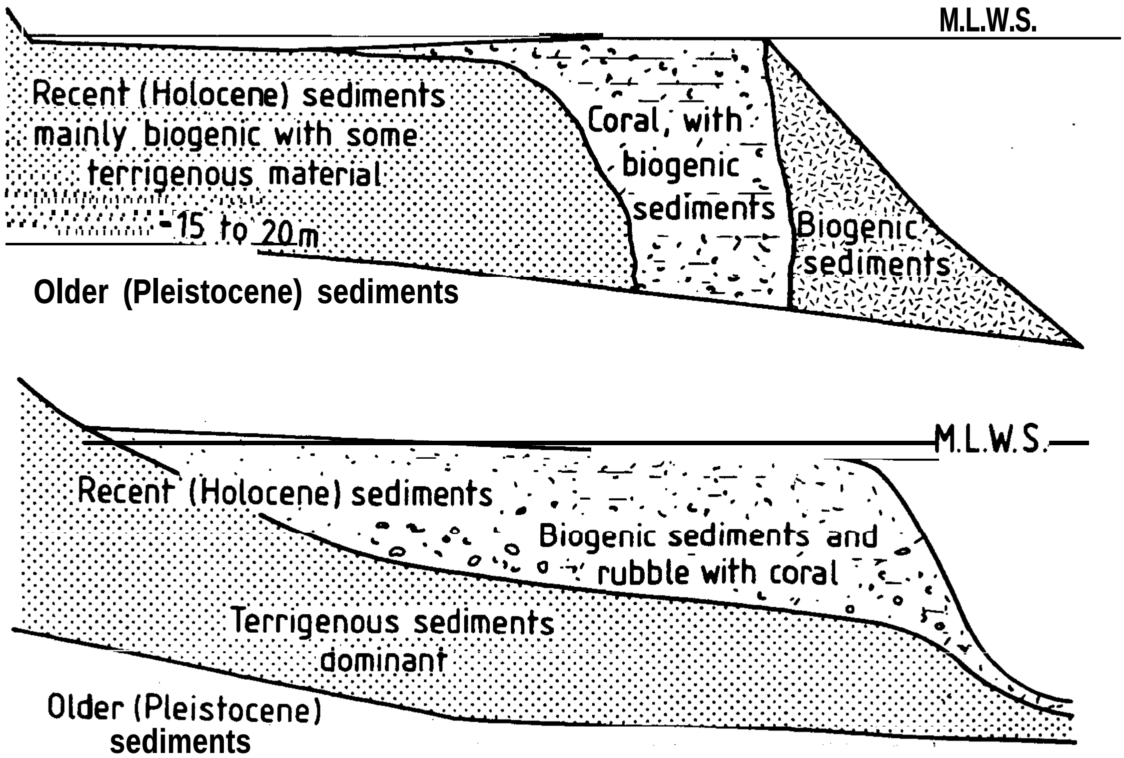
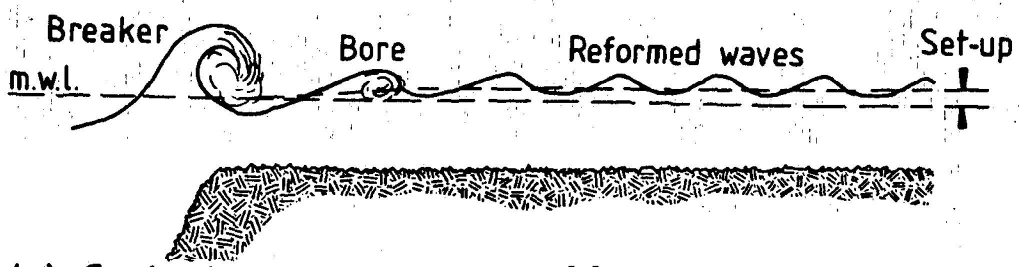
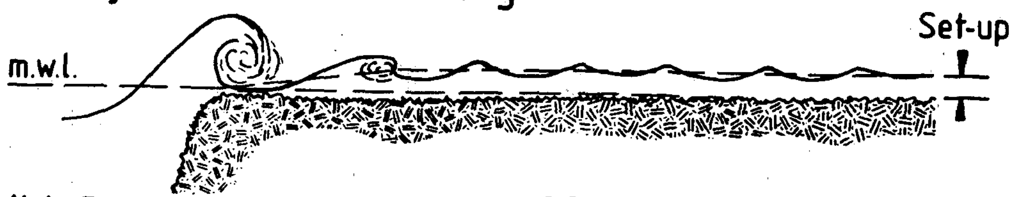


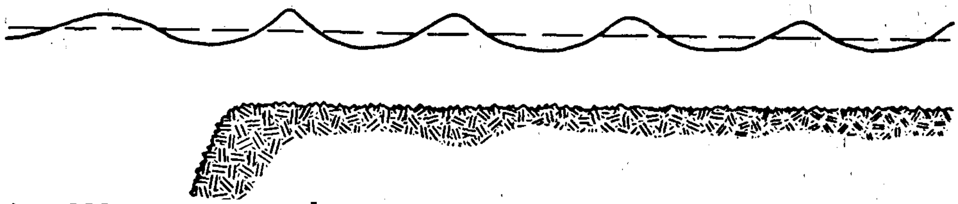
Figure 4. TWO TYPES OF REEF STRUCTURE



(a) Cyclonic waves at high tide

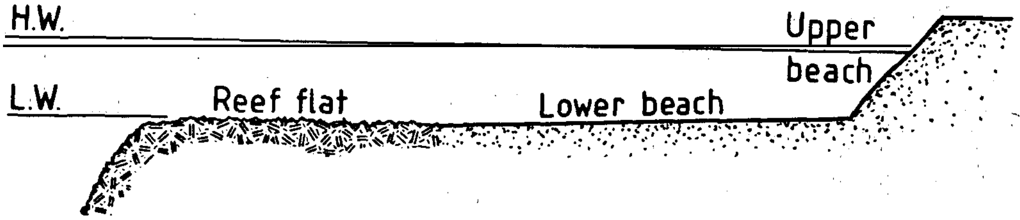


(b) Cyclonic waves at low tide

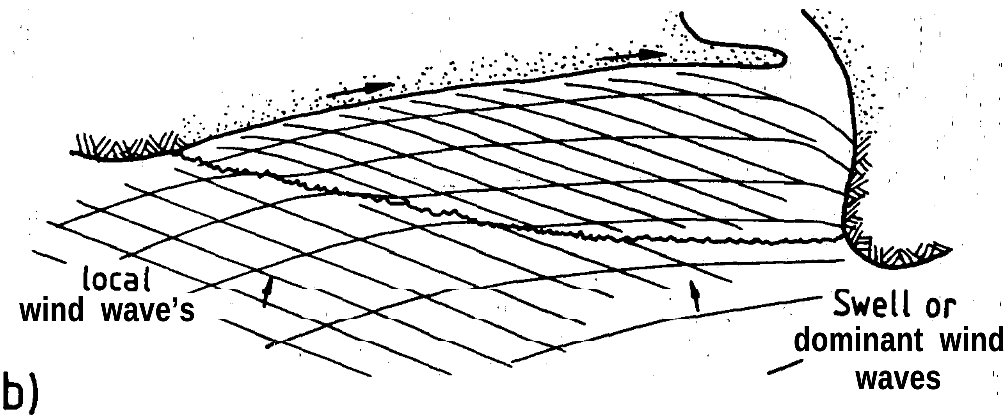


(c) Waves passing over reef 'at high tide without breaking

Figure 5. WAVES ON CORAL REEFS



(a) Typical beach profile



(b)

Figure 6. BEACHES ON FRINGING REEFS

KEY ISSUES FOR DAY-TO-DAY MANAGEMENT OF FRINGING REEF AREAS IN THE CENTRAL SECTION OF THE GREAT BARRIER REEF MARINE PARK

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BACKGROUND

The Queensland National Parks and Wildlife Service (Q.NPWS) is responsible for the day-to-day management of the Great Barrier Reef Marine Park, on behalf of the Great Barrier Reef Marine Park Authority (GBRMPA) under a joint agreement between the Australian Commonwealth Government and the government of the State of Queensland. Under this arrangement, the Commonwealth Government provides initial capital and 50% of operating expenses, and the balance of costs is met by the State.; Day-to-day management responsibilities may be broadly divided into several categories including surveillance and patrols, law enforcement, research and monitoring, with a particular emphasis on education and contact with park users. The Q.NPWS also undertakes the daily management of Queensland Marine Parks within the Great Barrier Reef region. These Marine Parks have been established over tidal lands and tidal waters of Queensland, and responsibility for their declaration and zoning has resided with the Premier's Department. In addition, the Service is responsible for all aspects of management ~~of the State's national~~ and ~~environmental parks~~. On the mainland adjacent to the Central Section are several such parks, while some sixty continental islands within the Section are included in the national park estate. Although the legislation applicable to these various national park and marine park areas does differ, complementary management of these island/coastal, tidal and subtidal park areas is considerably enhanced through the delegation of daily management responsibilities to a single management agency.

INTRODUCTION

The title of this presentation deliberately refers to fringing reef areas, as fringing reefs can rarely be considered as clearly delineated entities. Ecologically, fringing reefs are not isolated communities. They are continuous with terrestrial environments via rocky shores or beaches which abut them higher up in the littoral zone; and with the seawater, and the soft bottom areas adjacent to them underwater. Similarly,'human usage is not limited to fringing reefs, but involves also the adjacent terrestrial and marine environments. Moreover, the impacts of human activities are unlikely to originate in or impinge upon only one type of environment, and those affecting fringing reefs may well arise in a neighbouring area. Management of fringing reefs clearly needs to take these inter-relationships into consideration.

Fringing coral reefs are well represented in the Central Section of, the Great Barrier Reef Marine Park, but in terms' of reefs surrounding continental islands,, rather than those bordering the mainland coastline. The Section's principal areas of fringing. reefs are located (from north to,south) around the Family Group, the Brook Islands, the Palm Islands, Magnetic Island, islands off Bowen such as Holbourne Island, and the numerous islands of the Whitsunday region. Most of these islands are located rather close to the mainland relative to the width of' the continental shelf, and it is noteworthy that there are very few coral cays anywhere in this Section of the Great Barrier Reef Marine Park. Substantial fringing reef development and diversity of coral species have been noted in locations such as the Palm Islands and Magnetic Island, and more detailed studies in the Whitsundays would probably confirm a comparable diversity in the southern part of Central Section.

Access to mid shelf and outer shelf reefs has greatly, increased during the past decade. Nevertheless, with the exception of commercial fishing' activities which are probably more evenly spread, human usage of offshore areas focuses on a very few reefs of particular recreational or' tourist interest. Most human activity within the Central Section is concentrated in the nearshore areas, to which access is possible using a greater variety of craft or even directly from the land, and is generally easier, quicker, cheaper and less weather'-de,pendent. With the continuing growth of Northern. Queensland cities such as Townsville and the rapid expansion of the 'tourist industry especially in the Whitsunday region, usage of the Central Section can only be expected to increase. Al though remarkably few figures are available on current usage patterns of the Central Section (and even fewer referring specifically to fringing reefs), it is likely that inshore environments will'continue to receive relatively much greater use overall than offshore areas. Furthermore, the area covered by fringing reefs in this (and other) Sections of the Great Barrier Reef Marine Park is much less than that occupied by non-fringing coral reefs. Thus human usage and impact, direct or indirect, are much greater inshore, and are generally concentrated on or near a far smaller area of coral reef.

KEY MANAGEMENT ISSUES

The Zoning Plan proposed for the Central Section is expected to go before the Australian Parliament early in 1987, and details of the recommended Zoning Plan are at present still confidential. However , in the light of previously zoned Sections and the Draft Zoning Plan issued for Central Section, it is expected that zoning of inshore areas will be comparatively complex to accommodate the range and intensity of established uses.' An important part of day-to-day management is to ensure that park users are informed of details of the Zoning Plan and Regulations which may affect their activities, and wherever p'ossible to gain public support and co-operation for the zoning. This task will be all the more challenging in the case of the heavily used, nearshore waters of the Central Section and correspondingly complex zoning.

A further problem for day-to-day managers lies in the fact that the management regimes in different parts of the Maritime Estate are not necessarily identical. Although both the Great Barrier Reef Marine Park and Queensland Marine Parks are multi-use marine parks and have been zoned as far as possible to provide complementarity, the legislation is not identical and occasional differences or discrepancies might lead to problems with interpretation and management. Perhaps more significantly, the island, and coastal national and environmental parks are, in contrast, not multi-use parks in the sense of their marine counterparts. They are afforded a much higher degree of protection than generally applies below high water mark, roughly equivalent to Marine National Park 'B' Zone. Where this degree of protection does not extend into the marine park (which may often be the case), management difficulties may be encountered where usage frequently extends above and below the high water mark. For example, it is not always easy for a ranger to explain to park visitors that they may not collect even dead shells or driftwood from above high water mark, but that that may do so further down on the beach, and may even go fishing and collecting on the adjacent fringing coral reef!

This Workshop indicates an increasing awareness of the importance of fringing reefs in the Great Barrier Reef Region. However, the significance of fringing reefs has tended to be underestimated, in terms of their scientific, recreational, and tourist and commercial values. Day-to-day management staff will be seeking to promote a greater awareness amoung marine park users of the resources offered by fringing reefs. For example, many tourist operators and even private recreationalusers seem to be under the misconception that nearshore reefs are somehow not 'proper' reefs, and that 'outer barrier' reefs are the only 'real' coral reefs. A better appreciation is required of the recreational potential of fringing reef areas, along with a recognition that these are proper reefs, and may (as other types of coral reefs) be vulnerable to misuse. In addition to using interpretive approaches such as displays, slide talks, and written materials, the Service expects to be involved in specific impact-reducing and educational projects in fringing reef areas, such as establishment of self-guiding reef walking/underwater trails (eg. at Magnetic Island), and positioning of moorings in popular anchorages (especially in the Whitsundays).

Al though our knowledge of coral reef communities has increased substantially in the last ten or fifteen years, our understanding of those complex ecosystems is still very incomplete; and this is of course as much the case with fringing reefs as with other types of coral reef. Simply because species found in fringing reef areas closer to the mainland,tend to be more tolerant of certain environmental stresses (such as turbidity and sedimentation) than species more typical of clearer offshore waters does not indicate that these inshore species have an unlimited ability to cope with such stresses. The presence of a handful of coral species on the breakwater in Townsville Harbour does not constitute a coral reef either in structure or diversity! And while coral reef communities may indeed show recovery following moderate siltation events or after sources of pollution such as domestic sewage have been eradicated, the rate of change or 'recovery' of a fringing coral reef community may not necessarily occur within the short time scale that environmental managers might wish, as, the work of Done (this Workshop Proceedings) indicates. Much more information' is needed about fringing coral reefs and their ability to tolerate various short- and long-term stresses (including likely synergistic effects), and about their potential for recovery. Studies of mainland fringing reefs in the Cairns Section discussed elsewhere in this workshop, illustrates the difficulty of establishing causal relationships and verifying the effects' of certain environmental factors on reefs, especially when quite unrelated events (such as a strong gale) may unexpectedly disrupt field experiments or destroy part of a study area.

Long-term monitoring programs need to be established to assess the present condition of fringing'reef areas in the Great Barrier, Reef Region, and to monitor their'well-being, particularly in relation to known or potential human impacts. Design of such monitoring programs will require careful planning to ensure that data collected are relevant to precisely - formulated monitoring objectives and can supply the appropriate management Information. While research and monitoring of fringing reef areas are expected to be carried out by a range of agencies, there is clearly an important role for the Q.NPWS, as most day-to-day management staff are frequently working in the field and are operating from a number of locations, along the coast.

More information on humanusage of the Central Section is also essential for planning and implementation of effective day-to-day management.. Some very relevant questions have already been addressed by Driml (this Workshop Proceedings) in her presentation on tourist developments on continental islands. Again, the Service has a'valuable role to play in obtaining much' needed data on current and predicted trends in 'usage of fringing reef areas.

In conclusion, during the next few years the Central' Section is likely to experience a rapid1 y accelerating level of usage which has not hitherto been experienced in the Great Barrier Reef Region. A, key ingredient for successful day-to-day management\ especially of the most heavily used nearshore areas, will be a balanced combination of planning to take into account this increased usage, and flexibility to adapt to unforeseen and emergent management challenges.'

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PERMIT REQUIREMENTS FOR OFFSHORE DEVELOPMENTS

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The control of offshore development proposals is an increasing responsibility of the Great Barrier Reef Marine Park Authority. A number of these are on or could affect fringing reefs eg. Shelburne Bay silica sand project and Magnetic Keys project. This paper is an outline of the processes, legal and administrative which the Authority follows to assess and control these developments.

The goal of the Great Barrier Reef Marine Park Authority is to "provide for the protection, wise use, appreciation and enjoyment of the Great Barrier Reef in perpetuity through the development and care of the Great Barrier Reef Marine Park". The Authority has also adopted aims, several of which are directly relevant to tourist operators involving offshore developments. These are:

(a) "to provide for the protection of the natural resources of the Reef, whilst providing for multiple use of the Reef's resources"

(b) "to minimise regulation of, and interference in, human activities, consistent with meeting the goal and other aims of the Authority"

(c) "to provide for development compatible with the conservation of the Reef's natural resources"

(d) "to minimise inhibitions on economic activities consistent with meeting the goal and other aims of the Authority".

Zoning of the Marine Park is directed towards achieving the object of the Great Barrier Reef Marine Park Act and provides for 'as of right uses' (eg. trawling in General Use 'A' Zones) and also for uses which require permission of the Authority.

Permits are a flexible discretionary management tool which allows the Authority to control offshore developments of widely differing size, complexity, purpose and location.

In assessing applications for permission to place and operate an offshore development in a zoned Section of the Marine Park, the Authority has to have regard to certain criteria (Attachment A).

Offshore development proposals usually involve substantial hardware and/or construction. For example those along the coast and which may affect fringing reefs can involve proposals for construction of loading facilities, marinas, breakwaters, and boat harbours, for beach replenishment and for dredging of lagoons. Waste discharge is an important issue. The potential impact of large numbers of visitors on one site is another factor needing consideration. Typically, therefore, the assessment of a major proposal for tourist purposes will require the provision of detailed information (example at Attachment B). In seeking this information every effort is made to keep requests to a minimum and to avoid as far as possible duplication between different regulatory agencies.

The assessment of permits for offshore developments is an evolving discipline. The Authority has had to contend with proposals which were not envisaged when the Act was first passed. Each new proposal tends to throw up new issues, of a technical, policy and legal nature for resolution.

Some common elements are emerging in this process and are usually reflected in permit conditions. For example:

- permits are limited in time - to date 12 months has been the maximum period before renewal. This gives the Authority flexibility to monitor the operation and adjust the conditions if necessary., This adjustment can work to the benefit of the operator i.e. removal of unnecessary restrictions.

- permits are not transferable. This avoids difficulties associated with permits acquiring an economic value and allows reassessment of a new owner .

- where a proposal is judged to be environmentally significant, there is an obligation on the Authority to invoke the provisions of the Environment Protection (Impact of Proposals) Act. This does not automatically, mean that an environmental impact assessment is to be undertaken; howeverfor projects of high environmental significance it could involve substantial work and public review.

- the need for co-operation with other Government agencies. The Authority tries to ensure as, far as, possible that the requirements placed on the proponent are minimised and that, where there are other Government agencies with similar regulatory powers, any permit or licence conditions are mutually compatible. There is a high degree of co-ordination and cooperation between agencies. For example, areas for co-operation are

  - waste discharge
  - works (harbours,breakwaters, marinas, etc.)
  - leases
  - mariculture
  - collecting
  - research
  - moorings

- a financial bond. or bank guarantee is required to ensure that there is some redress where removal of hardware from the Marine Park is required through default by the owner. For major developments we also, require financial surety to cover possible, environmental damage.

- a need for monitoring programs to assess impacts in both the short and long term.

Like all managers we have to make. the best decisions possible with whatever information is available or can be obtained by the time the decision needs to be made. Our present approach is to be as comprehensive as possible in assessment of the project to minimise impacts; to build into the permit protective devices such as time limits and financial bonds.and finally to monitor for feedback, review and adjustment, if necessary.

ATTACHMENT A

APPLICATIONS FOR PERMISSION - CRITERIA FOR ASSESSMENT

In considering an 'application for permission the Authority shall have regard to:

(i) the objectives of the zone;
(ii) the orderly and proper management of the zone;
(iii) the conservation of the natural resources of" the Marine Park;
(iv) the existing use and amenity, and the future or desirable use and amenity, of the area and of adjacent areas;
(v) the size, extent and location of any proposed use in relation to any nearby use;
(vi) the likely effects of any proposed use on adjoining and adjacent areas and any possible effects of the proposed use on the environment; and
(vii) the proposed means of access to and egress from any use and the adequacy of provisions for aircraft or vessel mooring, landing, parking, loading and unloading.

ATTACHMENT B

INFORHATION REQUIRED TO ASSESS APPLICATIONS FOR TOURIST PROGRAM AND ASSOCIATED FACILITIES

This information is necessary for the assessment of an application for permission to conduct activities of the type with which you are involved. Provision of this information **and** subsequent assessment may obviate the need for an Environmental Impact Study.

(a) date the facilities are proposed to be placed at the various locations;

(b) date tourist program operations are proposed to commence;

(c) number of visitors per day expected to use the facilities or to participate in associated tourist programs;

(d) activities that are proposed to be conducted in, on or associated with the facilities;

(e) means of access by clients to the facilities, and details of this. If helicopters or floatplanes are proposed to be used, or to be provided for, this should be indicated;

(f) number of staff involved in the operation, including number of staff who will be present at any one time;

(g) map of reef locations showing all facilities including positions of units, moorings, cyclone moorings, navigation markers and proximity of coral bommies to those.facilities and any swing moored facilities;

(h) detailed drawings of the facilities themselves;

(i) proposed servicing and maintenance procedures including method and place of removal of marine growth, whether antifouling will be used and what type;

(j) whether there will be any accommodation on any structure, and, if so, the number of persons to be accommodated;

(k) where a structure such as a pontoon is to **be** installed, an engineer's assessment of the suitability of the structure for the purpose for which it is to be used in the conditions which **may** occur at the site;

(l) if there will be accommodation, the contingency plans for evacuation of the structure, including decision criteria for evacuation, and the type and availability of evacuation craft;

(m) details of any effluent/waste which will result from the activities proposed, and proposed procedures for disposal or removal;

(n) nature of the moorings including any fixing to the bottom and the nature of the bottom both below units and where moorings will be placed;

(o) proposed action regarding units in the event of imminent, cyclone, eg planned sinking, removal from the area, use of additional moorings;

(p) your' estimated cost of removal, of mooring's from the Marine Park;

(q) your estimated cost of 'removal of each unit from the Marine Park:

(i) if in good condition; and
(ii) if totally wrecked and either stranded on reef or sunk;

(r) details of existing uses of the area(s) where you propose to operate, including effects of your operation on the, general public's use of the area, and on other users eg commercial, scientific, etc;

(s) the likely environmental impact of all aspects of your operations, including effects on other users;

(t) proposed monitoring programs and procedures for environmental impacts, changes etc;

(u) details of any services to be provided by other operators to participants in your tourist program while they are at your nominated location(s);

(v) details of any proposed future developmentor expansion;

(w) whether any other operators will use your facilities, the purpose for which they will be used, and the number of persons involved.

Great Barrier Reef Marine Park Authority

Fringing Reef Workshop : Science, Industry and Management

Management Issues Identified from Assessment of State Proposals for Marine Park Declaration

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Cameron McNamara Pty. Ltd.

Abstract:

A study undertaken on behalf of the Queensland Government to identify areas suitable for declaration as Marine Park under the Queensland Marine Parks Act 1982 has revealed several significant management issues. Key amongst these is the apparent conflict between fishing, both commercial and recreational, conservation and preservation. In seeking conservation, the overriding management factor has been found to be accessibility to the fringing reef areas.

Introduction:

The comments made in this paper are based on the experience gained in a current study for the Queensland Premier's Department. The study is entitled: "Investigation of Tidal Lands and Tidal Waters of Queensland within and adjacent to the Great Barrier Reef Marine Park - Cairns Section for Declaration as a Marine Park". Similar studies in various stages of completion are underway on other sections of the Great Barrier Reef Marine Park.

The aims of the investigation are to define areas suitable for declaration as State Marine Parks under the Queensland Marine Parks Act 1982, and to prepare zoning 'plans and management plans for these areas:

The Study:

The study team for.this investigation has involved the authors of this paper as environmental planners and Dr. T. Ayling as the marine biologist.

The requirements of the M'arine Parks Act are that public submissions be called for to indicate areas considered suitable for declaration and issues relevant to the management of the areas. A'total of 18 submissions were'received (see Table 1).

The points raised in these submissions have been discussed with most of their authors and there has been further contact with the Local Authorities, Aboriginal Communities, commercial fishermen and some tourist operators.

The study is being administered by an inter-departmental, working group 'convened by the Premier's Department. Representation is' indicated in Table 2. Representatives of these departments and authorities have attended meetings reviewing proposals and draft reports.

The study has been rather drawn out as similar investigations on other sections of the reef/coast are underway and some interaction on approach and wording of text has been warranted.. The final areas recommended for declaration are apparently now agreed upon for the Cairns Section and most of the management issues have been identified.

Management Issues:

The key management issues relate to the apparent conflict between fishing, both commercial and recreational (amateur), conservation and preservation. These are considered legitimate uses of foreshore fringing reefs. There is, however, most support and interest for conservation of reef areas.

This is certainly seen as a primary objective of the State Marine Parks Act which states that in preparing proposals regard shall be given "to the needs of conservation of, research in and reasonable use and enjoyment by persons of the area to which the proposal relates" (Section 14(2)).

In defining areas and proposed zones (which are desired to be totally complementary with the GBRMP zonings), the major issue has been fishing versus conservation. It is acknowledged that fishing is a legitimate commercial activity, for benefit to the whole community, and that recreational fishing is very popular. However, the case invariably put is that if a fisherman is disadvantaged in any way, the proposal should be dropped.

The Accessibility Factor:

In seeking conservation, the overriding management factor has been found to be accessibility to the fringing reef. The general experience is that tourists do not wish to travel for more than 2 hours in a boat/-craft to get to a day-trip destination. This clearly defines destinations within about 70 km of boarding points as being regularly visited using present craft types.'

Though this observation applies particularly to reefs and cays in the off-shore areas in the Cairns Section, a similar accessibility factor applies to foreshore fringing reefs. For example, Murray Reefs between Cape Flattery and Cape Bedford are rarely visited, other than by members of the Hopevale Community, because they are not generally accessible from the land and are too distant by boat. However, the fringing 'reefs north of Cape Tribulation are now more frequently visited as access has improved.

Similarly, visitation to the Rocky Ledges reefs north of the Starcke River has increased recently because of a change in access permission through the adjoining cattle station.

These factors are considered to have implications which require attention in defining management of areas of fringing reef.

Acknowledgement:

We wish to acknowledge the permission of the Queensland' Premier's Department for reference to the, current study in preparing this paper.

Table 1

Summary of Public Submissions

No.	Type of Respondent
2	Private Individuals
3	Individuals with Commercial Interests
4	Associations and Societies
	Wildlife Preservation Society of Qld.
	Australian Littoral Society
	Trinity Bay and Inlet Society
	Australian Coral Reef Society
3	Local Authorities
	Cook Shire Council
	Cairns City Council
	Mulgrave Shire Council
1	Government Authority
	Cairns Port Authority
5	Government Departments
	Department of Forestry
	Department of Mines
	Department of Local Government
	National Parks & Wildlife Service
	Department of Primary Industries

Table 2

Inter-Departmental Working Group

Premier's Department
Queensland Fish Management Authority
Department of Primary Industries
National Parks & Wildlife Service
Department of Harbours & Marine
Department of Community Affairs
Department of Survey & Mapping
Queensland Boating & Fisheries Patrol
Great Barrier Reef Marine Park Authority

ZONING FRINGING REEFS IN THE GREAT BARRIER REEF MARINE PARR

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THE ZONING PROCESS

Zoning is the management planning approach which forms the basis for establishment, control and development of the Great Barrier Reef Marine Park. Section 32 of the Great Barrier Reef Marine Park Act 1975 makes detailed provision for the development of zoning plans. Their function is to make provision with respect to the purposes for which zones may be used or entered. Section 32 (7) of the Act specifies that regard shall be had, to the following objects in the preparation of a zoning plan:

. the conservation of the Great Barrier Reef;,

. the' regulation of the use of the Marine Park so as to protect the Great Barrier Reef while allowing the reasonable use 'of the Great Barrier Reef Region;

. the regulation of activities that exploit the resources of the Great Barrier Reef Region so as to minimize the effect of those activities on the Great Barrier Reef;

. the reservation of some areas of the Great Barrier Reef for its appreciation and enjoyment by the public; and

. the preservation of some areas of the Great Barrier Reef in its natural state undisturbed by man except for the purposes of scientific research.

The Great Barrier Reef Marine Park Authority (GBRMPA) has developed zoning plans for the Capricornia, Cairns, Cormorant Pass and Far Northern Sections of the Marine Park and is finaliiing the zoning plan for the Central Section. The Far Northern, Cairns and Central Sections. all contain fringing, reefs on the mainland coast and on continental islands. The zones, provide a gradation of restrictions on activities which is illustrated in Table 1.

Zoning plans are developed by a process which involves two phases of public participation during which principal users and groups which have an interest in the area being planned are contacted. The process has been described in more detail (Kelleher and Kenchington (1982), Kenchington (1984), Kenchington (1985)). Briefly, the object of the first phase of public participation is to add to the information held by GBRMPA as a description and definition of the resources of the area being planned and to seek suggestions regarding the content of the plan and approach to management. The second phase consists of review by the public of a draft plan developed by GBRMPA on the basis of a wide range of information including results of the first phase of public participation.

In socio-economic terms there are four reasonably coherent, but not necessarily mutually exclusive, lines of direct interest in management and availability of reef resources in any Section of the Marine Park:

- Commercial fishing - which encompasses activities ranging from trawling, through line fishing and trolling for pelagic species to collection fisheries for aquarium fish, corals and shells such as trochus;

- Amateur fishing - which is a socially important and growing activity ranging from the occasional non-expert fishing session in which the taking of fish is a secondary objective to highly organised and efficient programs whose principal objective is the sale of fish for cost recovery and profit;

- Tourism and recreation - the fastest growing' area which encompasses the provision of transport, accommodation and the means for individuals and groups to experience the reef for extractive or non-extractive activities; and

- the environment observer, fish watcher, reef watcher or researcher who observes and enjoys the reef directly.

To these may be added the category of the vicarious user and philosophical supporter who experiences the reef indirectly through print, film or photograph. Such a user may never visit the Great Barrier Reef but sees its protection for present and future generations as an important national responsibility.

CHARACTERISTICS OF FRINGING REEFS RELEVANT TO ZONING

The allocation of reefs to particular zones depends upon a number of physical and usage factors which may be considered here in relation to fringing, reefs:

- accessibility - fringing reefs which are accessible, to coastal roads, tracks, harbours, boat ramps or safe anchorages are likely to:

  - be heavily used for a wide range of uses;
  - be the site of friction between incompatible uses;
  - be the site of user stress;
  - be more difficult to manage than more remote reefs

. shelter - fringing reefs which have a high degree of shelter are likely to have large coral colonies and to be attractive to small boat'. users.

..exposure - fringing reefs which are exposed to waves generated by prevailing winds and storms are likely to have a high, biological diversity but to suffer quite frequent physical, impacts which may have major effects on biological communities.

. turbidity - some species thrive in turbid conditions,' benefitting from high nutrient levels associated with coastal. runoff and possibly from reduced competition with species which cannot tolerate high silt levels. Other species which are found deep on open water reefs can occur in shallow water 'on fringing reefs in turbid areas. Mainland fringing reefs and those of nearshore islands occur in areas which are likely to be turbid for much of the year. They may thus have rich and distinctive biological communities. The fringing reefs of offshore islands are often remote from turbid waters and little different in biological communities from free standing reefs.

. salinity - most corals and many other reef species are adversely affected by low salinity. Species which are able to tolerate or survive low salinity are more likely to be found on inshore fringing reefs.

Fringing reefs, particularly those on the mainland or islands close to the mouths of major rivers, are a distinctive reef habitat. They are specialised and often marginal environments. They are likely to have biological communities dominated by species which can cope with or thrive in periods of adverse conditions such as depressed salinity following cyclonic rains..

On populated coasts fringing reefs are often the most accessible reef sites for recreational boating, fishing, reef walking, fossicking and, when turbidity permits, underwater. reef viewing. In planning terms they 'are a scarce resource .' This makes the task of developing a zoning plan more difficult because of the lack of alternative sites for activities which may be displaced by zoning decisions. Accessibility, particularly where'a road comes close to a fringing reef, makes surveillance and management' of use more difficult. Managers can take advantage of the accessibility but they have to be prepared to react rapidly and at shorter notice than may be the case in more remote areas.

JURISDICTIONAL ISSUES

For' their greater part fringing reefs of the Great Barrier Reef are subtidal although their upper levels extend into the intertidal zone to the extent that their corals and algae are able to tolerate exposure to the atmosphere at low water. Much of the biological activity, such as fish feeding, occurs at or below the low water mark as does much of the human use of fringing reefs. Fringing reefs thus occur on a jurisdictional interface. Below low water they are within the Great Barrier Reef Region and as such, with few exceptions, they have been included within declared sections of the' Great Barrier Reef Marine Park. Intertidally they come under the maritime jurisdiction of the state of Queensland and may be declared Marine Parks under the Queensland Marine Parks Act 1982. They occur within the three mile territorial sea of the State of Queensland unless they are on the shore of an island owned by the Commonwealth. The jurisdictional complexity is compounded by the multitude of interpretations of the meaning of the term low water and further by the physical difficulty of determining a precise location of low water even if there is an agreed interpretation.

A further constitutional issue may arise where regulation under the Great Barrier Reef Marine Park Act could deny access to parts of Queensland.

In practical terms, whatever the definition of low water, the boundary is difficult to determine, particularly with a degree of precision necessary to convince a court of law considering an offence alleged to have taken place at or about low water. Therefore effective management of fringing reefs and their adjacent sub-tidal and supratidal areas needs complementary plans and regulations applying either side of the low water mark. The policy of the Commonwealth and Queensland governments, co-ordinated through the Great Barrier Reef Ministerial Council, provides for such complementary action. Planning under the Great Barrier Reef Marine Park Act,1975 (Commonwealth) and under the Marine Parks Act, 1982 (Queensland) is being undertaken in parallel for the Southern Sections of the Great Barrier Reef Marine Park and for adjacent waters under Queensland jurisdiction. Plans are being developed under the Marine Parks Act (Queensland) which are complementary to zoning plans for other sections of the.Great Barrier Reef Marine Park.

CONCLUSION

Fringing reefs are generally-more accessible than offshore reefs.. Inshore, they often have distinctive and well developed communities of particular interest to scientists. On the mainland coast and nearby islands their accessibility and the shelter provided by the islands make fringing reefs attractive sites for a range of human activities ranging from shell collecting and fishing to scientific research although frequently high turbidity precludes or severely limits reef viewing activities such as snorkelling. Offshore, in clear waters, the fringing reefs of continental islands present opportunities for a wide range of reef activities. Fringing reefs are a scarce resource which present a number of problems in planning, resource allocation and management.

REFERENCES

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Kenchington, R.A. 1984. The concept of marine parks and its implementation. In Symposium proceedings: The Capricornia Section of the Great Barrier Reef, Past, Present and Future. The Royal Society of Queensland and the Australian Coral Reef Society. Brisbane: 153 - 159.

Kenchington, R.A. 1985. Planning for multiple use of marine resources: the Great Barrier Reef Marine Park approach. Maritime Studies 25: 11-14.

Table 1. Simplified guide to the major activities by zones for the Cairns and Cormorant Pass Sections

Zones	Boating Diving	Collecting	Line Fishing	Bait Netting	Trolling	Spear-fishing	Pole & Line Tuna Fishing	Trawling	Cruise Ships	General Shipping
General Use 'A'	YES	PERMIT	YES	YES	YES	YES	PERMIT	YES	YES'	YES
General Use 'B'	YES	PERMIT	YES	YES	YES	YES	PERMIT	NO	PERMIT	NO
Marine National Park 'A'	YES	NO	YES	YES	YES	NO	NO	NO	PERMIT	'NO
Marine National Park Buffer	YES	NO	NO	NO	YES	NO	NO	NO	PERMIT	NO
Marine National Park 'B'	YES	.NO	NO	NO	NO	NO	NO	'NO	PERMIT	NO
Scientific Research	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Preservation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

The proportional coverage of zone types is'illustrated in Table 2.

Table 2. Extent of zone types in the zoning plans for the Capricornia, Cairns, Cormorant Pass and Far Northern Section final zoning plans and the Central Section draft zoning plan

Zone type	Area (km^2)	No. of reefs/shoals	% of Marine Park	% of reefs/shoals
General Use A	153603	234	74.4	14.9
General Use B	37758	1014	18.3	64.8
Marine National Park A & Buffer.	1615	45	0.8	2.9
Marine National Park B	12836	243	6.2	15.5
Preservation/ Scientific research	572	29	.3	1.8
TOTAL	206384	1565	100	99.9

In addition to zones, the zoning plans make provision' for a system of permits which covers activities for which it is considered that more detailed consideration or information is required in order to determine appropriate conditions of use and entry.

MONITORING OF FRINGING REEFS

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The Great Barrier Reef Marine Park Authority is responsible for the care and development of a Marine Park in the Great Barrier Reef Region. As others in this workshop eg. Kenchington, Woodley and Dineson have outlined this involves the development of zoning plans for each Section of Marine, Park, the establishment of management in each zoned section and day to day responses to specific issues through permit assessment and field operations.

As far as fringing reefs are concerned, the development of zoning plans requires information on their locations, and the types of uses of fringing reefs, the extent of those uses,potential impacts and conflicts. Management may require similar information on a finer scale or additional information to establish management guidelines.

The provision of educational and informational material to users and the public is fadilitated by information on the history and development of fringing reefs and an appreciation of their role in the terrestrial/marine interface. Table 1 gives a listing of projects funded by GBRMPA related to fringing reefs . A number of these relate to greater understanding of fringing reef systems, but it is also evident that many projects relate to the development of techniques to describe and evaluate such systems spatially and temporally and in comparison with other reef types. These evaluative projects are part of the monitoring program which the Great Barrier Reef Marine Park Authority with the assistance of its day-to-day management agency, the Queensland National Parks and Wildlife Service, is establishing for the Marine Park.

The monitoring program has four objectives. These are to:

1. Determine whether the objectives of the zoning plan and regulations are being met,

2. Evaluate the uses and their impacts on the Marine Park,

3. Test the well being of the biological component and the state of the physical components of the Marine Park, and

4. Assess the socio-economic impact of the zoning plan and day to day management on Marine Park users and others outside the Park.

The monitoring program is designed to provide both "baseline" measurements to give an insight into workings of the environment and human activity, and to provide measurements which will give an indication of critical change.

The program is being developed and implemented slowly,, for a number of reasons, including uncertainty about the natural qariability of the reef system and the difficulties of establishing 'projects which will distinguish zoning effects or human impacts from the natural variability of the system.

A systematic 'approach, ba'sed on a series of matrices for each monitoring objective, is being used. This matrix series.has the following steps for monitoring objective 1(to determine whether the objectives of the zoning plan and regulations are being met):

Monitoring objective

Activities related to objective

Attributes of activity

Measurement method of attributes

An example of the matrix approach to monitoring the effectiveness,' of the zoning plan and regulations is shown in Figure 1.

This procedure enables us to identify techniques'which range from being in existence and implemented to those which are desirable but need considerable development', or those which are unl'ikely to be, developed for some, years. Additionally, each technique can be related to the objectives it is addressing.

Similar series of matrices. are being developed for the remaining three monitoring program objectives.

For more details of the development of GBRMPA's overall monitoring program see Craik (1986).

The monitoring of fringing reefs (both biological and socio-economic) can be encompassed within all four of the overall objectives of the monitoring program. As other speakers have identified, fringing reefs are particularly important because, of their accessibility and thus may be subject to impacts from both direct activities eg. shell collecting, reef walking or indirect impacts such as adjacent land use eg. urban development., Fringing reefs may thus be subject to particularly intensive' uses. The' establishment of monitoring regimes at particular fringing reefs is, and will be, based on the capacity of the monitoring 'exercises to address the overall monitoring program objectives.

It is only with regard to monitoring objective 3 that fringing reefs will be monitored specifically for their fringing. reef characteristics', i.e. as a specific "biological component" of, the Marine Park. Although there is not always a clear separation, in addressing the other monitoring objectives, the decision to monitor fringing reefs will be. based largely on considerations of use and impact. In this respect, the considerations applied to site selection regarding fringing reefs will be similar to those for mid and outer shelf reefs.

In one significant respect, however, fringing reefs have presented a unique set of problems,' and that is in the **area** of appropriate techniques. The majority of reef survey techniques which GBRMPA and others have developed have been developed at the mid and outer shelf reefs of the Great Barrier Reef where the water is clear, visibility is reasonable and topography reasonably regular. Such techniques include manta towing, for broad scale reconnaisance and coral survey, straight line life form transects, straight line and timed-swim fish transects and stereophotography.

However wave and wind activity in the shallow waters surrounding fringing reefs and the proximity of such reefs to run off from rivers and adjacent land, means that visibility is frequently reduced to almost zero. This has meant that the assessment of reef "health", uses and impacts have required some fairly extensive reconsideration and evaluation of techniques. This evaluation has been hampered by the relative patchiness of information on fringing reef fauna and dynamics.

The major difference in techniques is the relative failure of broad scale reconnaissance techniques such as manta tow to be useful on fringing reefs. Techniques which involve greater proximity to the resource, a reduction in area covered and a reduction in speed of coverage are all favoured in fringing reef monitoring studies.

Monitoring techniques can be scaled from broad reconnaissance techniques to fine detailed techniques as shown below. From field experience, it is evident that finer scale techniques are more appropriate to fringing reef studies. However due to the size and scale of the Great Barrier Reef Region, GBRMPA is currently investigating development of remote sensing monitoring techniques which should offer considerable potential in the longer term. It is believed that an increase in the use of remotely sensed data and a decrease in field work would be cost effective.

Scale	Monitoring technique
Broad	satellite sensing
	aerial photography
	manta tow
	site description
	line transects
Fine	stereophotography

As has been outlined, the monitoring of the status of condition of (fringing) reefs currently requires, a considerable field commitment. Tourist operators, because of the nature of their business are in many cases, daily or several-times-weekly visitors to the same location on the Great Barrier Reef. Given this frequency of contact, such operators are in an ideal position to observe their local reef surroundings on a more regular basis than most research grants permit. One tourist operation, working out of Port Douglas, has established a. monitoring program in which line transects and other monitoring sites have been established.

Should other operations be interested in and prepared to establish similar monitoring programs GBRMPA would be pleased to assist.

REFERENCE

Craik. Wendy. 1986. Monitoring in the Great. Barrier Reef Maxine Park in Oceans 86 Conference Record: Monitoring Strategies Symposium. Vol. 3.:785-790.

Figure 1 Use of matrices to investigate monitoring objective. 1: To determine whether the objectives of the Zoning Plan and regulations have been met.

Matrix A

Attributes of activities related to objectives of Zoning Plan

Objectives of Zoning Plan	Vessel traffic greater than 500 tonnes in GUA or within GUB	Vessel traffic less than 500 tonnes in GUA or within GUB	Trawling in GUA or within GUB	Changes in bottom community	Length frequency of fish populations	Catch per unit effort (fish)	Species occurrence	Fish community structure	Occurrence of people in seasonal closure areas	Bird nesting success	Turtle nesting success	Diving, snorkelling etc. in GUA, GUB, MNPA, MNPB, or SRZ, PZ.
GENERAL USE 'A' ZONE (a) To provide opportunities for reasonable use consistent *with the conservation of the Great Barrier Reef;*	●	●	●	●	●	●	●	●	●	●	●	●
(b) To provide areas for trawling;			●	●			●					
(c) To provide for Replenishment Areas where fishing and collecting are prohibited for limited periods to enable resource stocks to regenerate.					●	●	●	●				
GENERAL USE 'B' ZONE (a) To provide opportunities for reasonable use consistent with the conservation of the Great Barrier Reef;	●	●	●	●	●	●	●	●	●	●	●	●
(b) To protect reefs from the potential effects of trawling and commercial shipping;	●	●	●	●								
(c) To provide for Replenishment Areas where fishing and collecting are prohibited for limited periods to enable resource stocks to regenerate; and					●	●	●	●				
(d) To provide for Seasonal Closure Areas to protect from human intrusion some important bird and turtle nesting sites.									●	●	●	

Matrix B

Measurement method

Attributes of activities related to objectives of Zoning Plan	Aerial Surveillance (Coastwatch)	Aerial Surveillance (Charter)	Harbour Reports	Management Officer Reports	User Reports	Benthic Survey	Log Books	Coral Trout Survey	Fish Community Survey	Creel Census	Permits Register	Seabird Survey Technique	Turtle Survey Technique	Coral Community Survey	Diving Impact Survey Method	Charter Boat Survey	Resort Survey
Vessel traffic greater than 500 tonnes in GUA or within GUB	●	●	●	●	●						●			●			
Vessel traffic less than 500 tonnes in GUA or within GUB	●	●	●	●	●						●			●			
Trawling in GUA or within GUB	●	●		●	●	●	●			●							
Changes in bottom community						●											
Length frequency of fish poulations							●	●		●							
Catch per unit effort							●	●		●							
Species occurrence						●		●	●					●			
Fish community structure																	
Occurrence of people in seasonal closure areas	●	●		●	●						●						
Bird nesting success												●					
Turtle nesting success													●				
Diving, snorkelling etc. in GUA, GUB, MNPA, MNPB, or SRZ, PZ.	●	●	●		[illegible]										●	●	●

TABLE 1

GBRMPA FUNDED RESEARCH AND MONITORING RELATED TO FRINGING REEFS

Survey			
Reef and Island classification Map and Gazetteer	J Oliver (JCU)	$20,454	1982-83
GBR aerial photography	GBRMPA JCU AIMS	$1,000	1977
Maps of Cairns Reef and Islands at 1:300,000 scale	N. Harvey (JCU)	$1,500~	1978
Oceanography and Geosciences			
Past present and future changes in the Cairns and Townsville urban Coastlines.	J Spriggs (JCU)	$1,700	1985-86
Sediment Field of the North Queensland Coast.	A Pringle (JCU)	$4,332	1985-86
Modern Sediment Dispersal at the Burdekin River Mouth.	R M Carter (JCU)	$3,330	1984
Sedimentation between the Herbert River Delta and Orpheus Island.	D Johnson (JCU)	$5,150	1981-82
Study of the fringing'reef at Orpheus Island.	A Slocombe (JCU)	$ 640	1981
Radiocarbon dating of Fantome Island Fringing Reef Corals.	D Johnson (JCU)	$4,000	1982
Paleo-environmental interpretion. of Holocene corals on the Central Great Barrier Reef.	F Muir (JCU)	$2,700	1983
Circulation and sediment movement on and around North Qld. bayhead fringing reefs.	K Parnell (JCU)	$10,452	1983-85,

Geomorphological information on continental shelf coral reefs.	T Graham (JCU)	$900	1983
Comparative structure and growth of windward and leeward fringing reefs on Orpheus Island, North Qld.	R. Barnes (JCU)	$700	1984

Marine Biology

Endo-cryptolithic fauna of Lizard Island.	P Hutchings (AMUS)	$ 600	1976
Pop'n biology of Montipora ramosa.	A Heyward (JCU)	$ 225	1981
Lipids in sediments and holothurian grazing	M. Peters (Melb U)	$ 757	1982
The interactive biology of Montipora ramosa.	J Robertson (JCU)	$ 225	1981
The ecologial distribution of hermatypic corals and crustose coralline algae on the fringing reefs in the Great Barrier Reef	Mr K. Fujiwhara (JCU)	$ 484	1982
Scientific advice on three areas of the Great Barrier Reef	GBRCC	$10,000	1978
Monitoring juvenile crown of thorns starfish on Great Barrier Reef (Pilot Study) - Pelorus Is.	R Bell (JCU)	$ 5,000	1986
Study of development and refinement of coral baseline and monitoring methodology	T Done (JCU)	$32,200	1978-80
Stereo-photographic coral monitoring of Lizard Island area sites.	A Ayling (Sea Research)	$ 3,345	1984
Manta tow survey of benthos and crown of thorns starfish at reefs in the proposed Cairns Section of the Marine Park.	W Nash (JCU)	$40,000	1980-82

Coral trout and coral survey of the Far Northern Section.	A Ayling (Sea Research)	$47,000	1984
'Coral trout and coral survey of the Central Section.	A Ayling (Sea Research)	$48,800	1984-85
Coral trout and, coral survey of the Capricornia Section.	A Ayling (Sea Research)	$46,950	1985-86
Assessment of juvenile coral 'trout survey methods.	A Ayling (Sea Research)	$ 650	1982
Visual censusing of coral trout in Cairns Section.	A Ayling (Sea Research)	$43,750	1983
Coral trout survey Whitsunday and Townsville areas.	A Ayling (Sea Research)	$12,000	1983
Coral trout monitoring at, Lizard Island Reef.	H Sweatman (Maq Uni)	$ 2,340	1981
The establishment of a data base for fringing high island coral reefs in the Southern Sections of the Great Barrier Reef Marine Park.	R Van Woesik (JCU)	$14,850	1986-87
Survey of several islands and fringing reefs in the Southern Sections of the Great Barrier Reef Marine Park.	Q.NPWS	$ 8,500	1986-87
A survey of the fish fauna of fringing high island coral reefs in the Southern Sections of Great' Barrier Reef Marine Park.	A Steven (JCU)	$ 1,500	1986
Biology and management of trochus	W. Nash	$40,000	1982-86

Cape 'Tribulation

Initial site survey of Cape Tribulation coast fringing reef.	A Ayling (Sea Research)	$ 2,200	1985
Sedimentary setting of fringing reef at Donovan Point.	D Johnson (JCU)	$ 5,470	1985-86

Coral recruitment on fringing reefs near Cape Tribulation.	V Harriott (JCU)	$15,300	1985-88.
Monitoring of Cape Tribulation fringing reefs.	A Ayling (Sea Research)	$88,500	1985-88
Effect of disturbed rainforest catchments on adjacent fringing reefs at Cape Tribulation.	D Hopley (JCU)	$38,460	1985-88

Impacts and Analysis of Use

Review of selected recreational activities in the Great Barrier Reef.	A Domm	$6,500	1976-77
Social and economic elements of a strategic plan for Whitsunday area.	P McGinnity (GU)	$ 600	1981
Far Northern Section Workshop	GBRMPA	$ 8,025	1978
Tourism Workshop - Mackay	GBRMPA	$ 9,825	1979
~~Reef tourism data base review~~	~~ATIA~~	$ 9,000	1980-83
Resource Inventory, Far Southern Area, Great Barrier Reef.	E. Hegerl D. Tarte (AIMS)	$ 7,550	1984
Information facilities on the GBR	Cameron McNamara	$17,600	1980
A study of the decision - making behavior of day visitors to the Great Barrier Reef Marine Park	N Whittem (UNE)	$ 720	1983
Economic impact study of the Great Barrier Reef Marine Park	S Driml T Hundloe (GU)	$ 9,930	1982
Waste Water Disposal - Hamilton and Hayman Islands.	R V Woesik and A Steven (JCU)	$ 1,000	1986-87
Guidelines for management of waste discharge to the Marine Park.	P Greenfield (Uni Qld)	$15,000	1986-87

Evaluation of economic and biological characteristics of coral collecting in the Great Barrier Reef Marine Park.	J Oliver (JCU)	$79,000	1983-86
Biological and.economic characteristics of shell collecting in the Great Barrier Reef Marine Park	B. Barnett	$30,000	1985-87
Fringing Reefs Workshop	GBRMPA	$ 2,000	1986

Management of Anchorages in Marine Parks

Peter Hunnam
Queensland National Parks & Wildlife Service

Summary

Anchorages, are the aquatic equivalent to car parks, showing problems associated with the concentration of activities - conflict between users, overcrowding, pollution, habitat destruction and wildlife disturbance - yet at the same time providing managers with positive opportunities for contacting users, monitoring and regulating impacts, and supplying facilities and services to enhance the site's use and enjoyment.

A preliminary analysis is given of anchoring and mooring within the Cairns Section of the Great Barrier Reef Marine Park. The concluding sections outline a strategy for the management of anchorages in the Marine Park, including the active promotion of CARE, a Code for Anchoring on the Reef, and propose a set of guidelines for Low Impact Moorings.

Introduction

The key to the management of most parks is access - where people go 'and, are allowed'to carry,out different activities.

In terrestrial parks the.science and art of controlling access and movement of people and vehicles are highly developed. Considerable attention is given to the planning and design of parking areas, ticket booths, and barriers, and to the alignment and grading of 'roads and walking tracks. These constraints facilitate cbst-effective management by concentrating aid segregating visitors' activities; they provide "bottlenecks." at which to educate, regulate and monitor.

In Marine Parks, it is more difficult physically to control access : boat access channels are definable in some areas, but barriers to movement are generally impractical; "off-road driving" is the norm., However, 'there are two areas which are particularly relevant to management - one is the boat launching ramp or jetty from which the park user leaves the land for the maritie park, and to which he returns, and at which he can be assailed by managers plying information or questions; the'second is the anchorage - the safe haven for the user's boat while in the park.

Anchorages are the aquatic equivalent to car parks. As with car parks, anchorages need to be planned and managed properly, if attendant problems are to be avoided. This paper is concerned with Marine Park anchorages, and how they are important to management.

Anchorage, Anchoring and Mooring

In'this discussion, use of the terms anchorage, anchoring and mooring is as follows : an **anchorage is** an area where vessels can anchor or moor with some degree of safety, as a result of the area's topography providing shelter from wind, wave action and 'tidal currents. **Anchoring** is the action of using an anchor to hold a vessel at a spot; all the gear is taken with the boat when it moves. A **mooring** is the tackle placed at a site to provide a more-or-less permanent *facility.

Impacts at Anchorages 3

Boats and **boaties** have various effects upon the areas they frequent. These may include physical damage by anchoring; pollution by spillage of fuel or littering; and direct effects on the marine life such as fishing or fish feeding. So-me of these impacts are listed in Table 1.

These impacts become concentrated at anchorage sites, so that there is a danger that the sites most frequently seen by visitors become degraded. Some effects may be exacerbated by the sheltered nature of anchorages, pollution for example, because of reduced water flushing rates, or physical bottom disturbance because the substrate tends to be finer silts, more easily disturbed and transported before settling out again.

Management Opportunities

Anchorages provide managers with some positive opportunities as well as problems. The Concentration of user activity - the "bottleneck effect"- makes **it more** cost-effective to provide facilities and services, such as vessel moorings, ranger presence, informative or regulatory signs, interpretive trails, swimming pontoons, garbage collection, etc., and to monitor and **regulate** activities and -impacts.

Anchoring and Mooring in the GBRMP Cairns Section

Boat skippers seek anchoring sites which are suitable for their diverse purposes - sleeping, fishing, diving, etc - and are reasonably sure to provide safety and comfort for the duration of the stay, allowing for tidal changes of current and depth, and for possible changes in wind direction and strength. Obviously, a dive site anchorage need not be so secure or comfortable as an overnight anchorage or where a vessel is to be left untended for a time.

Examination of one of the most heavily-used areas of the Marine Park - off Cairns- Port Douglas - indicates that, even in the extensive, relatively-shallow and sheltered waters of the Great Barrier Beef, good anchorages are scarce. In an area of over 4600 square kilometres which contains 90 reefs, there are only 40 anchorages suitable for overnight stays, 26 in southerlies and 14 in northerly wind conditions. This results in a great deal of activity being concentrated at these sites.

An estimate has been made of the "anchoring pressure" in the Cairns Section by calculating the numbers of anchors set and weighed in a year (see Table 2.). The preliminary survey of various categories of boat operations in the area indicated that private pleasure craft and commercial fishing boats generate the greatest anchoring pressures, followed by charter boats 'for diving and recreational and, game fishjng. This is with allowance made for the.percentage frequency with.which fixed moorings are used instead of anchors and for the relative size of the anchor gear. The total number of anchor drops and retrievals without moorings is estimated at roughly 183,000 a year in the Cairns Section. The 'survey indicated also that 117 reef sit'es are used frequently (3 times per month'or more) by particular operations and that at present only 30 moorings are installed at these sites.

Management of Marine Park Anchorages

Within any area of the Marine Park used regularly by boat operations, attention must be paid to the rational management of anchorages.

Preliminary, work to be done includes identifying all current and potential anchorage sites and assessing the current boat operations in the area. From this dual base it is possible to identify the anchorage siteswhich are used by large numbers of boats on an occasional or once-only basis, and the boat operations which are frequent users of particular sites.

It is important to know also the sites which are most vulnerable to boat-associated impacts, by surveying for. such components as physically fragile stands of coral, fine sediment areas and sea-grass beds; marine biota sensitive to pollutants; sites which are prone to congestion, or where there are conflicts between' activities.

Four complementary areas of management action are proposed :

- promotion of CARE - the Code for Anchoring on the Reef;
- prohibition of anchoring at certain, vulnerable sites;
- encouragement. or re'quirement for site-faithful operators to install or upgrade their own moorings; under management supervision to meet the guidelines for Low Impact Moorings;

. active management of the most heavily used anchorages, including, as appropriate, agency-installed moorings, separation of activities, user information, higher routine presence, and site condition monitoring.

Low Impact Moorings

Moorings are permanent facilities; used instead of anchoring for convenience or security, for vessels to return to exactly the same site, to provide a permanent mark, or to avoid anchoring damage. A mooring's hardware comprises ground tackle, cable to the surface, and floats.

There are three main types of ground tackle used in mooring installations :

1. cable fastened round rock or massive coral outcrops;

2. cable fastened to large weights in such a way that there is some movement of cable against the seabed; the loose cable is the shock absorber between vessel and ground weight.

3. large weights with cable to the surface in such a way that there is no moveable ground tackle.

4. an auger or bolt embedded into the substrate.

At present, approximately half of the 30 moorings in the GBRMP Cairns Section are type 1 and half are type 2. In addition, there are some type 4 auger anchors installed on trial by Queensland National Parks & Wildlife. Both type 1 and 2 can cause substantial damage : the ground chains or wires are heavy-duty and, with the movement of the moored vessel or pontoon, 'can saw continually against the seabed, wearing away rock, crushing coral and raising clouds of sediment into suspension.

At present, most mooring sites are selected for operational convenience, safety and comfort; most mooring system designs and hardware are chosen for security, economy and durability. For moorings in the Marine Park, **low environmental impact** must be added to this list of criteria.

It is 'suggested that adherence to the following guidelines when installing and using a mooring would ensure that the environmental impacts are reduced. The guidelines relate to the mooring's location, placement, operation, maintenance and materials.

Guidelines for Lov Impact Moorings

Location and placement

1. The mooring's location and placement must not detract from the use of the area by others, with particular reference to existing operations and on-site facilities.

2. The mooring site must be located carefully in relation to sites to be accessed from the mooring; and to any ecologically-sensitive sites in the area.

3. The mooring should be placed so that no coral reef" will be-shaded by any pontoon or similar facility'.

Installation and operation

4. The ground tackle design and fastening should be such that there is no movement of any cable (chain, wire or rope) or any other component, on or close to any part of the seabed.

5. No part of the mooring system should be within 5 metres of any outcrop of coral or rock.

6. The iater depth at low tide must be sufficient'to ensure no impact on any part of the seabed or reef from the moored vessel's hull or propellor thrust.

7. There should be no cables within 3 metres of the, water surface at low tide, other than those directly beneath the surface flotation device.

8. The surface flotation device must be clearly visible to other users of the area; light- and RADAR-reflective surfaces should be used where practicable.

9. No toxic or noxious materials should, be, used; in particular, certain paints, anti-fouling and metal components should not be used.

Maintenance

10. A routine visual check of all components should be carried out each day the mooring is used; a thorough service and re-fit should be carried out annually.

11. During installation and annual overhaul operations, great care must be taken to ensure that no damage is done to the site by service vessels, tools or underwater work.

CARE for Marine Parks

Code of Anchoring on the Reef

- use moorings where provided; check condition before use
- do not anchor at fragile sites
- use a suitable anchor and chain length to prevent dragging
- anchor in sand or silt away from coral
- ensure that anchor chain and rope do not foul coral
- **allow for** a good depth of water beneath the boat through a full 360 swing
- **if coral anchoring is unavoidable, for short periods use a** lightweight pick or a sand-bag, with no chain; protect the rope with plastic tube

/TABLE 1 Summary of Possible Impacts at Anchorages

Loss of amenity

"overcrowding"

spoilt seascape due to, moorings, pontoons, boats, signs, etc

conflict between incompatible activities, such as

- snorkelling - water-skiing
- anchoring - reef appreciation
- large boat mooring - small boat anchoring
- boat mooring - boat access channel
- fishing - fish watching;

Physical effects

impacts associated with anchoring :

sedimentation; bottom disturbance; coral breakage

impacts associated with moorings :

bottom, disturbance; artificial reef; fish attractant

propellor or hull damage to substrates

diver damage to substrates

Biological impacts

fishing

collecting marine specimens

dispersal of hull fouling organisms

feeding of fish, gulls and other scavengers

scaring away of marine animals

fish aggregation

bird roosting

Pollution

littering - biodegradable, degradable, durable

waste and sewage disposal

fuel oil spillage - accidental and deliberate

anti-fouling chemical concentration

TABLE 2 Boat Operations in the GBRMP Cairns Section

	TYPES OF BOAT OPERATION (see Note 2)							
	A	B	C	D	E	F	G	TOTALS
No.boat operations in area	12 2	5	21	22	27'	80	6000	6187
Av.no. reef trip-days/year	300	150	150	350	150	200	10	
Av.no. stops/trip-day	1.5	1.5	3	5	2	1	3	
% stops not on moorings	1	98	70	5	100	loo	98	
No. anchorings/year	54	5500	6600	2000	8100	16000	145000	183000
Anchor gear size factor	x3	xl	x0.5	x0.1	x0.5	xl	x0.2	
Annual "anchoring pressure"	162	5500	3300	200	4050	16000	29000	58000
No. stopping sites used frequently by particular boats (Note 1)	8	38	48	21	0	0	2	117
No. sites with moorings	8	1	10	9	0	0	2	30
No. permitted moorings	8	15		9	0	0	0	23

Note 1 "Frequently" = 3 times per month or more

Note 2 A = large regular tourist ferries;
B = charter, extended tour operators, (diving);
C = day-dive tour operators;'
D = glass-bottomed boats, semi-subs, etc..;
E = recreation and game fishing charter boats;
F = commercial fishing vessels;
G = private pleasure boats (sail and motor);

PROVIDING A BETTER REEF EXPERIENCE"

Ray Neale

Assistant Executive Officer
Education/Information Section
Great Barrier Reef Marine Park Authority

One of the real challenges to come from any workshop, this one in particular, is to go away from it and translate the information provided into action. We hope to help you in that task.

This segment, although aimed mainly at members of the tourism industry, is also applicable to the data providers because it demonstrates some of the applications and the need for good information.

The industry and the GBRMPA desire certain outcomes: These can be illustrated as

- Good cash return;
- Bouquets and positive feedback;
- Satisfied visitors;, and
- A happy reef.

The four elements apply to the tourism industry such that if good cash return is anticipated then there must be: happy visitors, who will return to a respected operator, who works on a well cared for reef.

The GBRMPA is pledged to provide for wise use by people,, and for conservation of the resource, so, it also is interested in the same four elements.

The market now is increasingly being recognised as more educated, more discerning, and more demanding. They are a more educated clientele. Schools and educational institutions now teach sophisticated sciences, environmental studies, marine sciences and consumer education.

The products of this approach to new subjects, new methods, and broader experience are already today's tourists and visitors. Their more educated children will demand even more in five years' time.

To satisfy this market requirement an <u>educated provider</u> is now essential. An educated provider will <u>either provide</u> a better reef experience themselves or get an educated assistant to do it for or with them.

It. makes good economic sense to do <u>much more</u> than dump tourists at a reef and collect them <u>three hours later</u> and think that they will again provide dollars, thank you for the trip, be satisfied, or respect the Reef:

If I may use the BIOSEARCH/QUICKSILVER operation as an example:

> Wendy Richards said <u>"We have entered the age'of the educated tourist"</u>; and "m<u>any people want **more than a** sightseeing trip</u>".

She is aware of what a rich reef experience can be and has set about providing a detailed, rich experience for her 'clients.. Concurrently she is researching the reef area and providing both herself and the GBRMPA with data that will lead to better management.

This seminar has provided some tools in the form of information, namely:-

- value of fringing reefs as a resource;
- biological detail;
- ecological data; and
- management issues.

Our job is to show you some of the method resources or helpful suggestions that are produced by the GBRMPA.

I would hope also that the workshops have provided the stimulus to seek new ways of providing the educated trip, the richer experience.

I would also urge tourism principals to accept the challenge and seek assistants to provide that richer experience. Perhaps, it would be appropriate for the industry itself to develop operator training and/or trained personnel who can be directly recruited for the task. There is entrepreneurial opportunity in this field.

There are unemployed marine biologists. Why do they think their only future lies in research or teaching? Why not be a marine biologist working in the hospitality industry providing this richer experience for tourists? Why don't resorts employ marine biologists (with flair for people relationships) as expert operators? Probably because we have not expected such a thing'to happen.

Surely, there is the potential for say regional groups to prompt an expert into training educators who can conduct better tours, or to travel from centre-to-centre conducting operator training courses. Wendy has taken the path of recruiting university graduates but as each operationis different so also will be the' staff training requirements.

In 1979 at the Tourism and the Great Barrier Reef Workshop in Mackay, Mr. John Richardson (Assistant General Manager of the Australian Tourist Commission) commented that "the attention to detail." is essential. Wendy Richards spoke of great efforts to attend to biological detail and to customer comfort detail. She said "I put on a slide show on the way out and once there, supply all the equipment, providing them with only the best".

John Richardson went on to comment that training was needed - it cannot be left to natural instincts. "When properly trained, Australians are very good." he said. I believe they are second to none but many are untrained and the experience they provide reflects it.

What to train operators at is only a matter of analysing needs, marshalling resources, then to go to it. What is more difficult is to tap into the imagination, flair, and foresight that people (including operators) have so that there will be something with which to train operators or to use to provide the rich experience.

Areas such as art experience tours, poetry and literary activities, reef-based drama and 'creative 'movement activities are virtually unheard of. Reefs are not just for looking at! and swimming on,' or fishing near. They can be enriching in the (aesthetic and cultural, fields as well.

Tom, Offord conducts art instruction - cum-tourism trips from Woolgoolga to the Flinders Ranges that are rich experiences for the terrestrial artist. There is scope for the occasional trip to reefs and islands for the brush-lover but I don't know of anyone who does it. Certainly this market would not be as large as the "swim, dive and look" market but' who knows? Who has, 'tried it before?

The tranquility of early morning on a reef is inspiring and, 'in the hands of a good operator, many people could 'have a very enriched trip dabbling at a canvas, creating poetry, engaging in tai-chi, dreaming up creative movement, or putting their imagjnation to work in the words of a story.

The key here is "in the hands of an expert". Providing for the educated tourist is not a job for the amateur.

We, at 'the Marine Park Authority,, have been assisted' by other experts in developing two ambitious projects. Both are aimed at giving operators some ideas and some expert methods and training',, so that better 'information will result in a better experience for the tourist and visitor.

Calvin Tilley will detail these two products.

PROJECT REEF-ED & REEF ACTIVITIES MANUAL

Calvin Tilley
Education/Information Section
Great Barrier Reef Marine Park Authority

PROJECT REEF-ED

"Project Reef-Ed" was produced by the Authority to encourage study of the Reef and help schools to organise student visits to the reef.

The project provides teachers with a wide range of resource materials and programs from which they can select, according to their own needs. Suggestions are also made as to how various kinds of programs might be constructed.

The Reef-Ed material is aimed at students in the 15 to 17 year old age bracket which means it could be easily adapted to the general market i.e. tourist.

The project has taken four years to develop and is considered to be one of the most comprehensive marine education programs yet developed. As you can see it occupies these eight rather large volumes.

Volume A - Introduces Reef Education and suggests a rationale for education and in particular reef fieldwork. It also discusses the learning experiences for a Reef Education program - Encountering, Enquiring, Evaluating, and Expressing.

Volume B - Covers the logistics of reef field trips
Sites and travel arrangements
Permit procedures
General considerations relating to camping, accommodation and catering
Safety, health and First-Aid
Useful equipment
Guidelines for aquatic activities - reef walking, snorkelling and boating.

Volume C - Outlines a number of student activities in a form that allows them to be duplicated for immediate use. The activities are considered in two main groups: The Natural World; and The Human Dimension.

Volume D - Covers background information on the Reef as a whole. Biological, Geological, Geomorphological and Oceanographic data is given and various aspects of the relationship between people and the reef are treated.

Companion Guides

1. Heron Island and Reef
2. Northwest Island and Ree'f
3. Lady Elliott Island and Reef
4. Lady Musgrave Island and Reef
5. Green Island, and Reef
6. Reef Trips - Cairns to Port' Douglas
7. Reef Trips - Townsville to Ingham
8. Reef 'Trips - Whitsunday Area

The companion, guides 'provide more detailed information on the specific area as titled. Only'the first four guides have been drafted to date.

The current status of "Project Reef Ed" is that the draft has been produced and is currently'being reviewed. We are currently negotiating with the printers.. However because of the complex nat'ure of the task this is not proving easy or inexpensive (estimations are around $100,000). All donations will be gratefully accepted.

REEF ACTIVITIES MANUAL

The Reef Activities Manual was the result of a workshop held 'on Green Island in November 1982.

The purpose of the manual is to be an introductory handbook for those people conducting interpretive activities which focus on the Great Barrier Reef,. It is designed to be of use to tourist operators as a training and working aid for their activities staff, so that activities can be provided which are enjoyable and recreational for tourists and which contribute to the conservation of the Great Barrier Reef.

One of the guiding themes used in the construction'of the activities was the kind of emotional experience available during that activity. This approach is consistent with the point of view which argues that tourism is centrally concerned with providing a rich and diverse range of experiences to people; in short that the product sold by the tourist industry is a set of emotional experiences. The activities in the manual are designed to stimulate positive emotional experiences.

The main contents of the manual are divided into three sections: Reef Activities, Reef Information and Island Activities.

1. "Reef Activities", includes:

   Introduction to coral reefs
   Glass bottom boats .
   Reef walking
   Beginning snorkelling
   Advanced snorkelling
   Scuba' diving
   and a number of other activities.

2. "Reef Information" covers some aspects of the Biology, Geomorphology, Geology and Oceanography of Reefs.

3. "Island Activities" include:

Beach walk
Green trail quiz
Examination of a coral cay
Bird identikit etc.

Currently the Reef Activities Manual is out of print and is in the process of being reviewed and updated. It is also intended to produce a document that is Reef-wide in its application. The current manual needs updating to include additional reef activities such as fishing, use of semi-submersibles, high speed catamarans, reef walking, and snorkelling trails.

REPORT FROM WORKING GROUPS

Four working groups were formed with a cross-section of interest areas in each group. Each. group was asked the same set of questions:

1. What are' the 'needs of tourist operators re fringing reefs?
2. What 'are needs for research 'and management?
3. Recommendations of the workshop?

The following is a brief report of each working group. The recommendations are summarized in the Executive 'Summary.

GROUP 1 - Chairman - Clive Wilkinson, Scribe - Leon Zann

Neids of tourist operators.

Why the workshop has not been attractive to tourist operators:

1. Location;
2. 'Timing;
3. 'Communication problems;
4. Programme did not appear interesting;
5. Operators may feel their use of outer reefs is more significant.

Research and management

1. Effects of siltation on coral species: dumping silt on a batch of corals; evidence of different species reactions are anecdotal.
2. Long 'term work on specific sites - as by Done & Collins
3. Temporal variation
4. What sort of changes are "normal" and possible
5. Understand the nature of people's experiences,
6. Understand expectations

Recommendations

1. Encourage resorts to engage scientifically trained people
2. Demonstrate that this may generate income;
3. GBRMPA consider providing an attractive training programme to operators;
4. Encourage better liaison between resort' and research stations, on Orpheus, Lizard and 'Heron, that will result, in other resorts doing the same.

GROUP 2 - Chairman - Peter Hunnam
'Scribe - Ian Dutton

Needs of tourist opirators

1. Fringing reefs have potential for use - how can their best use be facilitated?
   - Assist operators with promotion (Expert facilitation)
   - Instill sense of husbandry and responsibility
   - Enhance awareness and value of fringing reefs
   - Encourage developers to assess alternatives to maximise opportunities (e.g. structural vs non-structural approaches)

Research and management

1. Research Needs

- Definition of fringing reefs - i.e. an incipient fringing reef vs a community on a reef vs fringing reef
- What is the distribution/composition of fringing reefs in the GBR Region? More surveys are needed e.g. Cumberland Group.
- What is, present "health" of fringing reefs - need for baseline data especially from hot spots.
- An improved basis for integrating remote sensing and ground truth techniques.
- To define the value of fringing reefs (e.g. fishing, recreation, coastal stabilisation).
- How do indicator species work - do processes differ between reefs. Should they be treated differently?,
- A better understanding of response to disturbance - modelling.
- Effect of siltation/run off - freshwater, herbicides.
- Comparison with S.E. Asian reefs.

2. Management

- A need for better strategic control of tourism development. Zoning is not allocated according to "best possible use" of fringing reefs.
- What are limits of acceptable change.
- Strategic planning at sub-zoning level.

Recommendation

1. That there be no more workshops until more is known.

GROUP 3 - Chairman - Wendy Craik
Scribe - Kevin Parnell

Needs of tourist operators

1. Tourist resorts need resources to be made available to:
   - assess the value of fringing reefs;
   - develop activities/education packages and training courses.
2. Tourist operators need a clearing house for management and scientific advice

Recommendations

1. Conduct further' workshops which are taken to operators and are precisely targetted.
2. Workshops to include:
   environmental impact statements
   monitoring systems
   explanation of legislation.

GROUP 4 Chairman - David Steen
Scribe - Zena Dinesen

Needs of tourist operators

- To take care of these reefs as 'a useful asset.
- To use them to the fullest advantage.
- To make resort visitors aware of fringing reefs using interpretation-and guides.
- To consider visitors' expectations and prepare them for a fringing reef experience.

Needs for research and management

- To determine what levels of stress (i.e. from sewage and siltation) can be tolerated by fringing reefs.
- To gain a better understanding of usage patterns..
- To acquire more basic knowledge of fringing reefs.
- To require more information on shell collecting and on natural and collected populations of collected mollusc species.
- To acquire more information about the substrates upon which fringing reefs grow.
- To determine what systems can be used to effectively manage easily accessible reef areas.
- To determine whether the public or tourist operators can be effectively used as reef "guardians".

Recommendations

- That steps be taken towards fulfilling all of the above requirements/acquiring all of the above information.
- That the essentials of this Workshop be repeated in locations and at times more convenient for tourist operators.

Donald W. Kinsey, Conference Chairman:

Following on the report of the last working group, it seems worthwhile to make the comment that there have been quite a number of studies in various parts of the world to consider the direct effects of sediment load on corals and coral reefs. Specific experiments certainly were done in both St. Croix and Malaysia and I seem to recall that there have been several others. A literature. search on this subject would be well worthwhile.'

SUMMARY OF WORKSHOP

Don Kinsey
Conference Chairman

My comments may be somewhat out of sequence in 'that I will be summarising the formal workshop presentations and not attempting to summarise, the activities of all the individual discussion groups which have already reported to you on the results of their deliberations this afternoon. It clearly is not necessary for me to suinmarise again what they have just told you.

One significantly disappointing aspect of the workshop has 'been that we failed in our original objective to get a high involvement from the tourist industry. This means clearly that those matters which we have identified as being in the industry's interest were presented mostly from the perspective of non-industry representatives and therefore are mentioned here in full recognition of that. Nevertheless, I believe that ' we have brought forward some, major information on fringing reefs,together with many matters which will be useful to us, and to others, in the future management and sensible exploitation of this very accessible resource.

The Conference has considered the basic, setting and description of fringing reefs. We have have considered many aspects of the human use of fringing reefs. We have had very successful discussion with, the few tourist industry representatives that we did have. We have considered a number of very important specific issues that affect fringing reefs in a negative way. We have considered the management of fringing reef environments and we have considered several matters relating to the education of, the public in relation to fringing.reefs.

I will try to summarise some of my general impressions of the matters presented and discussed, but clearly cannot hope to address all matters which have been raised in the last two days.

. Perhaps one of the most significant points to emerge on Thursday was a contradiction on the instability yet resilience of fringing reef systems. We have heard today of the very great "survivability" of fringing reefs but we have also heard of their tendency to exhibit very abrupt declines.

I don't believe these are in fact in any sense, contradictory. I think what we are seeing is that fringing reefs have a very "on-again/off-again" type of history. It really just depends on which point 'in their development one happens to look at, as to whether they are seen to be unstable or surviving well and/or declining or recovering.

It is, therefore, very important that we' recognise this somewhat, erratic behaviour. for what it frequently' is;' namely, a natural feature of' fringing reefs. We should not always blame our own actions for the apparenteffects which we see. It is, of course, equally important that we do not blame nature for what we have ourselves done to these systems.

- On Thursday we heard about many aspects of the uniformity of fringing reefs in both the biological and ecological sense. Today we have heard quite a bit about their considerable variability in physical parameters.

- Yesterday I developed a sneaking feeling about the beauty of fringing reefs. It seemed that perhaps we were trying too hard to convince ourselves of their beauty when, in reality, there seems to be generally a rather low level of interest, at least in the surface levels of fringing reefs, by the average visitor and that this perception is probably substantially enhanced by the generally dirty water.

  Sally Driml indicated that she believed people generally wished to see pretty things and it seems rather clear that the common perception of fringing reefs is that they are not very pretty and that may be, in a superficial sense, true.

  Zena Dineson generally supported this perception but indicated that any individual's understanding of a system varied very much as a function of their real familiarity with it.

  David Colfelt explained that it is not particularly difficult, if one is dedicated to the task, to demonstrate the subtle beauty of such systems to the average person whose initial perception has been that the system is unattractive.

- It seems there is still a need for a convincing case to be made for promoting biological excellence in the personnel used in the commercial exploitation of fringing reefs for tourist activities. We clearly recognise the desirability of such excellence but its cost-effectiveness has been queried by a number of people.

  Perhaps the most relevant opinion I can make is that people with biological training are available in considerable excess at present and they do not cost significantly more, if at all, than other people who might be used for general interactive tasks in association with these tourist activities.

- Ross Woods has indicated a general tendency amongst tourists these days to be looking for "experiential" enjoyment in their holidays and there is a tendency in these trends towards a "do it yourself" emphasis. There is, however, an emphasis on doing this in relative luxury. It seems to me that these tendencies could be very compatible with fringing reefs because of their easy and comfortable accessibility. This is likely to lead to tourists having the time and the interest to appreciate the subtleties of these systems. I hope that we may be able to take advantage of the trends.

- We have heard some stimulating ideas on fisheries' management. I think it is perhaps unproductive for' me to comment further on this.

- We have discussed many specific'uses of reefs for both fun and profit and we finished Thursday with an extremely good discussion with the industry representatives which made it clear that' they do make use of fringing reefs but that the potential for considerably more use certainly still exists.

- In the area of 'management, it is clear that there are difficulties in the resolution of highly'polarised' issues, and that there is perceived to be difficulties in the application of management strategies.

  There also seems to be a recognition of some aspects of duplication in requirements among the various agencies.

  It is clear that a great deal of management emphasis has been placed on the perceived greater problems of fringing reefs and their monitoring.

  It is also clear that there is a need for better output from managers to the user and for substantially increased feedback from the user.

We certainly will make use of the information which has come out in this workshop and clearly recognise the need for a different. form of workshop if we wish to address more directly the tourist industry representatives whom we regretably had here in such small numbers.

I hope that you have all benefited from the experience of being here and I thank you all for coming.

Finally I would like to thank particularly Claudia Baldwin for her efforts in organising this workshop, and her helpers, Scotty Miller-Smith, Christine Dalliston and Felicity Gray.' I would also like to thank the Arcadia Resort for their substantial help and 'in fact Hayles generally for assisting in the arrangements for smooth running of this workshop.

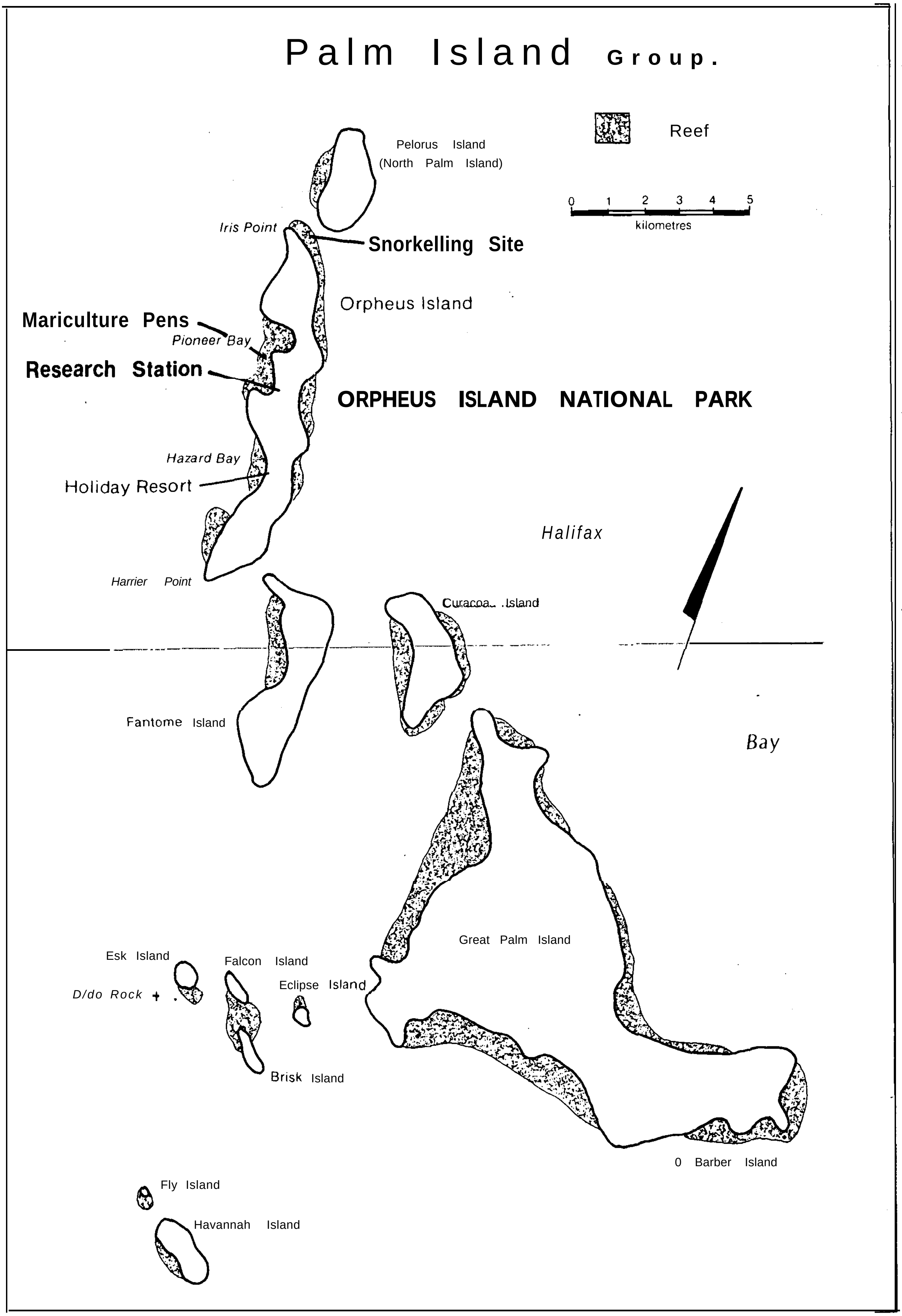
Donald W. Kinsey, Conference Chairman

Following on the report of the last working group, it seems worthwhile to make the comment that there have been quite a number of studies in various parts of the world to consider the direct effects of sediment load on corals and coral reefs. Specific experiments certainly were done in both St Croix and Malaysia and I seem to recall that there have been several others. A literature search on this subject would be well worthwhile.

EXCURSION - DAY 3, OCTOBER 25

A field trip was scheduled for the third day of the workshop. The site, Orpheus Is. fringing reefs, was chosen as it provided, a good illustration of reefs with a high diversity and coverage of corals and algae; yet subject to a variety of uses ('tourism, research) and therefore pressures.. Participants snorkelled at a reef at the northeast end of Orpheus Is. The group then visited the Orpheus Is. Research Station at Pioneer Bay and had a tour of the giant clam mariculture project. This included viewing induced clam spawning in tanks and snorkelling to see clam pens on the reef.

The trip provided first-hand exposure to some fascinating fringing reefs and succeeded in confirming the value of, fringing reefs. .


Palm Island Group.
Reef
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kilometres
Pelorus Island
(North Palm Island)
Iris Point
Snorkelling Site
Orpheus Island
Mariculture Pens
Pioneer Bay
Research Station
ORPHEUS ISLAND NATIONAL PARK
Hazard Bay
Holiday Resort
Halifax
Harrier Point
Curacoa Island
Fantome Island
Bay
Great Palm Island
Esk Island
Falcon Island
Eclipse Island
D/do Rock
Brisk Island
Barber Island
Fly Island
Havannah Island