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WORKSHOP ON THE NORTHERN SECTOR OF THE GREAT BARRIER REEF

Papers and Proceedings of a Workshop held in Townsville, Australia 20 and 21 April, 1978

Sponsored by the Great Barrier Reef Marine Park Authority

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GREAT BARRIER REEF MARINE PARK AUTHORITY
P.O. Box 1379
Townsville, Qld. 4810
Telephone: (077) 71 2191

GREAT BARRIER REEF MARINE PARK AUTHORITY

WORKSHOP ON NORTHERN SECTOR OF GREAT BARRIER REEF

TOWNSVILLE, 20-22 APRIL, 1978

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Session III - Natural features

Session III - (continued)

Session IV - Surveillance and management

Session V - Identification of gaps in knowledge and establishment of priority programmes for research.

Session VI - Criteria and categories for zoning and methods of regulation

Session VII - Development of guidelines to assist the Authority in declaring and zoning a marine park in the area

LIST OF SPEAKERS

Dr. J. Allen, The Chairman, Board of Advanced Educaction, 427 Coronation Drive, Auchenflower, Brisbane Q 4066

Mr. G.R.V. Anderson, National Parks and Wildlife Service, P O Box 636, Canberra City, A.C.T. 2601.

Professor K.J.C. Back, Vice Chancellor, James Cook University of North Queensland, Townsville, Q 4811

Dr. J. Baker, Member, Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville Q. 4810.

Mr. M.W. Buckham, First Assistant Secretary, Facilities Division, Department of Defence, Russell Hill Offices, Canberra, A.C.T. 2601

Dr. J. Bunt, Australian Institute of Marine Science, P.M.B. 3 M.S.O., Townsville, Q 4810

Mr. A.K. Chase, Griffith University, Nathan Q. 4111

Dr. P.G. Flood, Department of Geology, University of Queensland, St. Lucia, Brisbane, Q. 4067

Mr. N. Haysom, Queensland Fisheries Service, P.O. Box 36, North Quay, Brisbane Q.4001

Dr. G. Heinsohn, Department of Zoology, James Cook University of North Queensland, Townsville. Q. 4811

Professor D. Hopley, James Cook University of North Queensland, Townsville, Q. 4811

Mr. R. Isbell, Pastoral Research Laboratories, Commonwealth Scientific Industrial Research Organisation, Townsville, Q. 4810

Mr. H. Jitts, Department of Environment, Housing and Community Development, P.O. Box 1890, Canberra City, A.C.T. 2601

Mr. R. Kenchington, Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville Q. 4810

Mr. C. Limpus, Queensland National Parks and Wildlife Service, Cape Pallarenda, Townsville, Q. 4810

Mr. G. McPherson, Queensland Fisheries Service, c/- P.O. Bungalow, Cairns, 4870.

Dr. G.R. Orme, Geology Department, University of Queensland, St. Lucia, Brisbane Q. 4067.

Mr. R. Pearson, Queensland Fisheries Service, c/- P.O. Bungalow, Cairns Q. 4870

Mr. A. Pomeroy, James Cook University of North Queensland, Townsville, Q. 4811

Dr. I. Price, Department of Botany, James Cook University of North Queensland, Townsville, Q. 4811

Mr. E.A. Purnell-Webb, Department of Primary Industry, Fisheries Division, Canberra City, A.C.T. 2601

Mr. R. Pyne, Department of Primary Industry, Edmund Barton Building, Barton, A.C.T. 2601.

Dr. G.W. Saunders, National Parks and Wildlife Service of Queensland, P O Box 190, North Quay, Brisbane Q. 4001

Professor K. Stark, Department of Engineering, James Cook University of North Queensland, Townsville Q. 4811

Professor F. Talbot, Macquarie University, North Ryde, Sydney, N.S.W. 2013

Dr. J.E.N. Veron, Australian Institute of Marine Science, P.M.B. 3, M.S.O. Townsville Q. 4810

Dr. D. Warne, Australian National University, P O Box 4, Canberra City, 2601.

Dr. G. Webb, Australian Museum, P O Box A285, Sydney N.S.W. 2001

Mr. N.L. Webb, Department of Defence, Canberra, A.C.T. 2601

Captain B. Whiteman, Department of Harbours and Marine, 231 Turbot Street, Brisbane 4000

Mr. J. Wilson, Director General of Tourist Services, 146 Mary Street, Brisbane Q. 4001

Mr. J.T. Woods, Queensland Department of Mines, 18th Floor, Watkins Place, 288 Edward Street, Brisbane Q. 4000

LIST OF ATTENDEES

Mr. J.D. Ballingall, 67 Goldsmith Street, South Mackay, Q4740

Dr. D. Barnes, Australian Institute of Marine Science, P.M.B. 3 M.S.O. Townsville Q. 4810

Mr. A. Birtles, Department of Marine Biology, James Cook University of North Queensland, Townsville Q 4811

Captain W.T. Cain, 5 Boden Street, Yorkey's Knob, Cairns Q. 4870

Dr. D. Connell, Griffith University, Kessels Road, Nathan Q 4111

Dr. C. Crossland, Australian Institute of Marine Science, P.M.B. 3, M.S.O. Townsville Q. 4810

Dr. T. Done, Department of Marine Biology, James Cook University of North Queensland, Townsville Q. 4811

Dr M.F.C. Day, Australian Institute of Marine Science, P.M.B. 3, M.S.O. Townsville, Q. 4810

Mr P.B. Eccles, Department of Transport, Turner, A.C.T. 2601

Mr P. Ellis, Deputy Director, Planning and Environment, Co-ordinator-General's Department, P.O. Box 185, Brisbane, Q. 4001

Dr J. Farrands, Secretary, Department of Science, Scarborough House, Phillip, A.C.T. 2601

Dr E. Frankel, Department of Geology, University of Sydney, Sydney, N.S.W. 2006

Mr R. Garrett, Queensland Fisheries Service, c/- Post Office, Bungalow, Cairns, Q. 4870

Dr M. Gilmartin, Australian Institute of Marine Science, P.M.B. 3, M.S.O., Townsville, Q. 4810

Dr. A. Gilmour, Assistant Director, Marine Pollution Studies Group, Ministry for Conservation, 605 Flinders Street, Melbourne Vic. 3000

Dr G. Goeden, Queensland Fisheries Service, C/- Post Office, Bungalow, Cairns, Q. 4870

Dr B. Goldman, Manage~~r, Li~~zard Island Research Station, P.O. Box 1474, Cairns, Q. 4870

Hon. Ray Groom, Minister for Environment, Housing and Community Development, Parliament House, Canberra, A.C.T. 2600

Mr R. Hardwick, School of Biological Sciences, James Cook University of North Queensland, Townsville, Q. 4811

Mr G. Hawley, Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville, Q. 4810

Mr E. Hegerl, C/- Queensland Conservation Council Inc., "Wyalla" Sunset Road, Kenmore, Brisbane, Q. 4069

Mr H. Higgs, Acting-Chairman, Great Barrier Reef Marine Park Authority, P.O. Box 791, Canberra City, A.C.T. 2601

Dr B. Hill, Queensland Fisheries Service, P.O. Box 36, North Quay, Brisbane, Q. 4001

Professor G.A. Horridge, Research School of Biological Sciences, Australian National University, P.O. Box 4., Canberra, A.C.T. 2601

Dr P. Hutchings, Australian Museum, P.O. Box A285, Sydney, N.S.W. 2001

Mr J.H. Izatt, 279 Lake Street, Cairns, Q. 4870

A/Professor R. Kenny, James Cook University of North Queensland, Townsville, Q. 4811

Mr G. Lui, Department of Aboriginal and Islanders Advancement, George Street, Brisbane, Q. 4001

Dr H. Marsh, Department of Zoology, James Cook University of North Queensland, Townsville, Q. 4811

Dr P. Mather, Queensland Museum, Gregory Terrace, Fortitude Valley, Brisbane, Q. 4001

Dr N. Milward, James Cook University of North Queensland, Townsville, Q. 4811

Professor B. Morton, Australian Institute of Marine Science, P.M.B. 3, M.S.O., Townsville, Q. 4810

Mr P. Ogilvy, Queensland National Parks and Wildlife Service, P.O. Box 190, North Quay, Brisbane, Q. 4001

Dr B. Olafson, Australian Institute of Marine Science, P.M.B. 3, M.S.O., Townsville, Q. 4810

Professor J. Oliver, Department of Geography, James Cook University of North Queensland, Townsville, Q. 4811

Mr A. Pentony, James Cook University of North Queensland, Townsville, Q. 4811

Professor M. Pitman, School of Biological Sciences, University of Sydney, Sydney, N.S.W. 2006

Dr P. Saenger, Australian Underwater Federation, P.O. Box 67, St. Lucia, Brisbane, Q. 4067

Mr C. Smalley, Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville, Q. 4810

Dr D. Smith, Division of Fisheries and Oceanography, Commonwealth Scientific and Industrial Research Organisation, Cronulla, N.S.W.

Mr L. Stewart, Department of Aboriginal and Islanders Advancement, George Street, Brisbane, Q. 4000

Mr. S. Summerhays, Great Barrier Reef Marine Park Authority, P O Box 1379, Townsville, Q. 4810

Ms. A. Wallace, Great Barrier Reef Marine Park Authority, P.O. Box 1379, Townsville Q. 4810

Mr. C. Watkins, c/- Fritz Quintemeyer, Townsville Skindiving Centre, 95 Ingham Road, Townsville, Q. 4810

Mr. R. Williams, Great Barrier Reef Marine Park Authority, P O Box 1379, Townsville Q. 4810

Mr. S. Woodley, Great Barrier Reef Marine Park Authority, P O Box 1379, Townsville Q. 4810

THE GREAT BARRIER REEF
MARINE PARK AUTHORITY WORKSHOP
20 APRIL 1978

ADDRESS OF WELCOME BY PROFESSOR K.J.C.BACK
VICE-CHANCELLOR, JAMES COOK UNIVERSITY.

Mr. Minister, Ladies and Gentlemen,

Today is a most important occasion for James Cook University: firstly, because it marks the opening of this Workshop and secondly, because it was on the 20th of April 1970 that Her Majesty, Queen Elizabeth II gave assent, in person, to the James Cook University of North Queensland Act, thereby establishing the University.

The coincidence of the opening of this Workshop with the University's eighth anniversary gives me the opportunity to review the progress that we have made and to point out the significance of marine science in this progress.

First I must go back to 1964, when the University was the University College of Townsville. I make reference to the report of the "Martin Committee" or to give the full title, "The Report of the Committee on the Future of Tertiary Education in Australia" and I shall quote a sentence from the section dealing with the Townsville development:

> *The Committee believes that the Townsville University College, because of its location in the tropics and because of its proximity to the Great Barrier Reef, has unique opportunities to develop studies in the special problems of tropical areas, for example, ... marine science.*

The general policy guidelines set down in the Martin Report were included in the recommendations of the Australian Universities Commission for the 1967-69 and 1970-72 triennia and, looking back, I think we can say with some confidence that we have achieved the objectives set down in those guidelines.

Our prime objective has been to make James Cook University a centre of teaching and research in a wide range of tropically oriented disciplines. We can, to some extent, measure our success in terms of the increasing activity in hosting and organising workshops and seminars in those disciplines. Today's Workshop is a most significant addition. We have just completed a Seminar on Natural Disaster and Community Welfare held first in Townsville, then in Mackay and next month it will be repeated in Cairns. Later this year we will sponsor a Seminar on Cyclones and Storm Surges and next year, in conjunction with the Australian Development Assistance Bureau, we will hold an International Seminar on Tropical Animal Production. Thus James Cook University can rightfully claim to be a centre of research and teaching in Tropical Science and Technology.

In the field of Marine Science this was the first University to establish a Chair and Department of Marine Biology. We were intimately involved in the planning and establishment of the Australian Institute of Marine Science, a development of which as a nation we can be justly proud. I pay tribute to the Foundation Director of the Institute, Dr.Malvern "Red" Gilmartin for guiding the Institute through the difficult formative years. The completion of the excellent laboratory facilities and the near completion of the Institute's 24 metre Research Vessel must be a source of great satisfaction to him. I am sure you will be most impressed with what you see at Cape Ferguson when you visit the Institute's laboratory complex on Saturday morning.

There is no doubt that the funding of Marine Science in Australia has,until quite recently, been sadly neglected. It is only in the last decade that major advances have been made and I cite as examples the increased emphasis given by universities, the establishment of AIMS and the establishment of the Great Barrier Reef Marine Park Authority with its headquarters here in Townsville. It must not be forgotten however that there has been, for many years, a dedicated group of concerned marine scientists which has campaigned tirelessly for an expansion of effort and funding for marine science research.

I refer of course to the Great Barrier Reef Committee and many of the workshop participants here today are members of that Committee either personally or by institutional membership. These members will know only too well of the struggles and achievements of the Committee and I have no doubt that the recent progress I have outlined is due in no small measure to its dedicated work.

One of the Committee's major achievements was the establishment of the Heron Island Research Station. It was for many years the only research station on or adjacent to the Barrier Reef. It is only recently that other stations have appeared - the University of Sydney's at One Tree Island and, in the far northern region, the Australian Museum's Lizard Island Station. It is with pride and pleasure that I can now announce that James Cook University is in a position to make its contribution to the development of off-shore research stations. Negotiations have been successfully concluded for the acquisition of a Special Lease at Pioneer Bay, Orpheus Island where the James Cook University Marine Research Station will be established. This Station will provide staff and students with easy access to an island with remarkably rich fringing reefs and in close proximity to the main Barrier Reefs. It is ideally located to complement the other research stations being at the mid-point between Lizard Island to the north and Heron Island to the south. The new station will increase still further the capacity of James Cook University to give special emphasis to the teaching and research of marine science. More importantly it will provide an additional facility to marine scientists generally and I see its role as being complementary to, and supportive of, the existing Barrier Reef research stations.

Mr. Minister, this Workshop is the first of a series to be sponsored by the Great Barrier Reef Marine Park Authority and will be a reference point for those seeking information about or conducting research into problems of conservation and management of the Great Barrier Reef, matters which have become so much more urgent with the announcement of the proposed 200 mile zone.

I commend the Authority for its initiative and, in welcoming the participants, and especially in welcoming you, Mr. Minister, I express to you all the hope that this Workshop will prove to be a stimulating, rewarding and thought-provoking experience.

. . . . . .

OPENING SPEECH BY THE HON. RAY GROOM

MINISTER FOR

DEPARTMENT OF ENVIRONMENT, HOUSING & COMMUNITY DEVELOPMENT

The Minister, Hon. Ray Groom: Professor Back, Dr Baker, Mr Mayor, Members of the Authority and Consultative Committee, ladies and gentleman. I'd like to add my own welcome on behalf of the Commonwealth and to say how much we appreciate your attendance at this Workshop today.

One of the Authority's first decisions, was to decide that its headquarters should be here in Townsville. I think today's gathering indicates the wisdom of that initial decision because, of the participants here at the workshop, over a third are scientists living in Townsville and I'm told about half are based in North Queensland.

This is my first chance since becoming a Minister to come to Townsville; though I must say I've been here three or four times previously Mr Mayor, and have enjoyed myself very much. Later today, we're going on to Cairns to visit Green Island before visiting Lizard Island to see the Research Station there. I must say I'm very pleased this programme has been arranged for this time of the year, its becoming rather cool down in Tasmania at the moment.

Green Island is perhaps the most popular tourist attraction on the entire Reef. It serves to remind us of how important it is that Australian and overseas visitors can see such beautiful, unique and characteristic places like Green Island. The Authority, as you know, is concerned to make such visits, brief as they often are, as rich and as rewarding as possible. The impact of something like 180,000 visitors a year on a small cay and reef like Green Island presents many serious management problems, and so tourism in the northern sector of the Reef is one of the matters that I understand you'll be looking at very carefully during this workshop.

The workshop represents a significant step in the Great Barrier Reef Marine Park Authority's progress towards planning for the conservation of the Great Barrier Reef and indicates one of the ways in which this challenging task is being tackled.

I'd like to take a few moments to give you an idea of how the workshop fits into the overall work programme of the Authority, and to very briefly review some of the activities of the Authority in the past year and a half. Of course a great deal of work does lie ahead of us before the complexities of the Reef system can be fully understood and the effects of human use of the Reef area identified and monitored.

Authority staff have been developing techniques in association with other scientists which will permit reefs to be described as rich, varied and beautiful; or damaged, under pressure and in need of protection. Detailed survey and mapping programmes are already in progress. A broad programme of socio-economic studies will also gather information about such things as recreation, tourism, the fishing industry and the associated infra-structure in coastal centres. The results of all the studies carried out by the Authority will form the basis of a number of reports recommending the declaration of parts of the Marine Park. The first report dealing with the Capricorn and the Bunker Group of reefs has already been prepared and it's anticipated that this area before too long might be declared as the Capricornia section of the Marine Park.

The declaration of course is only one step along the road to rational reef management. After declaration the Authority will prepare zoning and management plans; this will include discussion of alternative approaches with the local people who know and use the reefs, scientists working in the area, conservationists and others living in various parts of Australia who are concerned for the proper management of the Reef. The Authority will not only call for formal submissions, but will also be involved in a quite extensive informal public participation programme. Information will be available in the main coastal centres of Queensland and in all State capitals, and that's seen as a most important part of the informal public participation programme. A mobile planning office and information centre will take the plans to the people of Rockhampton, Gladstone and Bundaberg and will ensure that they have adequate opportunities to express their particular views.

A draft zoning plan which will take account of all submissions and comments will then be prepared. This plan will be exhibited for a further period of public evaluation and again further submissions will be sought.

Public participation and co-operative planning have become rather fashionable terms in recent years, but I think it is fair to say that both are probably still more honoured in the breach than in the observance. Steps are being taken in this case to ensure that this will not be true of the approach taken by the Authority. The Authority will combine rigorous scientific appraisal of the reefs and of the many uses of the area, thorough discussion with State Government bodies, and free and open public debate. This should lead to general agreement about the best ways of managing the Reef so that it is protected, and continues to serve the needs of not only present generations, but also future generations.

The gathering of data is the first step in this process and underpins all later activities. That, of course, is what this particular workshop is concerned with. The northern sector of the Great Barrier Reef is one of the great wilderness areas of this country, wild, remote and rarely visited even by scientists. It is radically different from the Capricornia area, which is in comparison, very much used, accessible and which has already been intensively studied. Early declaration and protection of the northern reefs will keep our options open for the future, so that environmental quality should not be gradually eroded or compromised. Research in other areas will indicate what levels of use are compatible with long term conservation; future increases in use will then be able to proceed rationally. Planning for the care of the Great Barrier Reef must not become a rearguard action, attempting to keep up with events, but rather a thorough systematic process of investigation and consultation leading to timely decisions which will be supported by the total community.

I would hope that during the next financial year the Authority's staff numbers will increase to meet those demands and lessen the burden upon those involved. The heavy demands placed on such a small group of people will intensify as successive areas of the Reef come under examination and investigation. Until recently, the Acting Chairman of the Authority was Dr Don McMichael, who many of you would know, has had a long association with the Great Barrier Reef. Dr McMichael was recently appointed the Secretary of the Department of Home Affairs and his place on the Authority has been taken on an acting basis by Mr Horry Higgs, who many of you would know. (Mr Higgs is the Acting Director of Environment in my Department at the present time.) As the planning process gathers momentum, the job obviously will require the attention of a full time Chairman, and I again would expect to make an appointment of a full time Chairman at some stage later in the year.

As well as establishing close relationships with the Australian Institute of Marine Science and the James Cook University, the Authority has been co-operating with the Queensland Fisheries Service, Queensland National Parks and Wildlife Service and with a number of other Queensland Government agencies. For instance, a recent survey of the Fisheries Service has established the extent of the Crown of Thorns starfish in the Swain Reefs area.

From the point of view of my Government, we see this as a joint enterprise with the Queensland Government and with the agencies of that Government. Later this year, the Authority and the Queensland Department of Tourist Services hope to hold a joint workshop on tourism in the region. I regard these co-operative activities as an essential contribution to the proper management of the Great Barrier Reef Region.

I am delighted to welcome to this workshop so many scientists; officers from other Departments, both State Departments and Federal Departments; representatives of the Torres Strait pilots; representatives of the Aboriginal communities in the area and some of the boat owners who make other people's expeditions to the northern part of the Reef possible. I trust that everyone involved has a pleasant time and a most rewarding experience. With those words I have much pleasure in officially opening this workshop.

INTRODUCTION

by

DR. J.T. BAKER - MEMBER, GREAT BARRIER REEF MARINE PARK AUTHORITY

Currently the Great Barrier Reef Marine Park Authority is examining two well known and extensively used areas of the Great Barrier Reef with access from Gladstone and Cairns respectively. These areas have priority for inclusion in the Great Barrier Reef Marine Park. However, it was considered that the relatively little-used reefs east of Cape York Peninsula north of Lizard Island, also warranted attention. This Workshop was arranged to identify and consolidate the apparently meagre and scattered knowledge of these reefs, and to establish the action required to fill the perceived gaps. To ensure that these "wilderness areas" are retained, some of the northern reefs may have to be considered in the Marine Park, in view of the increasing use and exploitation of resources throughout the Great Barrier Reef Region.

Participants involved in the Workshop represented the interests of aborigines, Torres Strait Islanders, fishermen, tourists, miners, armed services, scientists, Federal and State Government Departments and others. The Workshop sought first to identify the level of knowledge and utilization of the physical and biological resources of this region which is believed to be the area least affected by human exploitation of the entire Great Barrier Reef. Subsequently the Workshop sought to identify priorities for research which would aid the Authority in developing a sound management plan for the region.

The objectives of the Authority were also kept in mind to provide the framework for discussion:

(1) "The conservation of the Great Barrier Reef.

(2) "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.

(3) "The regulation of activities that exploit the resources of the Great Barrier Reef Region so as to minimise the effects of those activities on the Great Barrier Reef.

(4) "The reservation of some areas of the Great Barrier Reef for its appreciation and enjoyment by the public.

(5) "The preservation of some areas of the Great Barrier Reef in their natural state undisturbed by man except for the purpose of scientific research."

In the far northern area where there is a distinctive pattern of reefs within close proximity to the Queensland coast, many of the waters remain uncharted, not all reef types have been described, and the influence of the nearby coastal mangroves and river systems on the reefs are little understood.

Queensland National Parks on the adjacent Cape York Peninsula provide safeguards against extensive human modification of the coastal areas in this region and the distance from major cities was seen as a deterrent to heavy tourist involvement with the current methods of sea transport readily available in Australia. Any future introduction of hovercrafts could expose the area to much heavier tourist pressure.

Information presented on current utilization indicated that at this time the area is not under pressure from mining interests except for a small region at the far northern boundary, and that the Defense Department maintains predominately routine surveillance activities over this vast and isolated area. Discussions were held on the uses of lasers and of satellites to assist in mapping the region.

Many of the coastal areas and islands were identified as being of importance to aboriginal anthropology, but current use of the reef by aborigines was indicated as being slight.

Scientific studies on the reef and its communities have been hampered by the very isolation of the area, and the relatively frequent exposure of the reefs to rough seas and strong south east winds. Little information is available on natural reef populations of most species, including fish, mammals, turtles, and crustaceans. Studies on marine macro and micro-algae, reef- and sand-dwelling organisms and marine bacteria have barely been initiated, if at all.

Despite these facts, there has recently been a significant move to study the region closely, through studies by staff of Queensland Fisheries, A.I.M.S., James Cook University of North Queensland as well as scientists from other Australian Universities using the Lizard Island Research Station.

The Authority is particularly grateful that the Australian Institute of Marine Science Council arranged to hold its Council meeting in Townsville in this period, so that their Members could share in the discussions. The Authority was also grateful for the presence and contribution of the Secretary of the Department of Science.

The Workshop achieved several aims. Sessions I to IV assessed and consolidated information about the area, and discussions followed the presentation of papers. Participants met in five discussion groups to identify gaps in knowledge of the area and establish a priority programme for research (Session V). Criteria and categories for zoning and their regulation (Session VI) were then disucssed and the groups subsequently re-assembled to present their opinions. During Session VII, a plenary discussion, guidelines were formulated to assist the Authority in its declaration and the zoning of northern reefs as part of the Marine Park.

Australia's inexperience in management of Marine Parks was highlighted. Specifically, a paper on Park Management Principles attracted attention to the differing challenges of management of marine versus terrestrial parks.

The Authority wishes to thank the contributors for fulfilling the aims of the Workshop. The papers and discussions enhanced both our awareness and knowledge of the relatively isolated northern area of the Great Barrier Reef.

SESSION 1: DESCRIPTION OF THE AREA AND ITS ADMINISTRATION

REEFS OF THE GREAT BARRIER REEF NORTH OF LIZARD ISLAND

G.R. Orme

A B S T R A C T

The diversity of reef types, their distribution, form and orientation, reflects the influence of growth, oceanographic, eustatic, sedimentation, and foundation factors. The shelf-edge "ribbon reef" is characteristic of this region, platform and patch reefs are numerous, and fringing reefs occur in the near shore zone and are associated with the continental (high) islands.

There are contrasts in the physiographic characteristics of the platform reefs due to marked variations in the nature and distribution of reef top accumulations which have been strongly influenced, and stabilized, in part by diagenetic processes.

Investigations initiated during the Royal Society and Universities of Queensland Expedition (1973) have demonstrated the thin and uneven nature of the Holocene reefal veneer, and have indicated the significance of inherited (pre-Holocene) features on Holocene reefs, sediment distribution patterns, and bathymetry of this part of the Great Barrier Reef Province.

I N T R O D U C T I O N

The Great Barrier Reef north of Lizard Island, lying entirely within the Northern Region defined by Maxwell (1968), is relatively shallow (usually less than 30m), has a distinctive pattern of reef distribution, and, for the most part, occupies the narrowest section of the Queensland shelf. In this area, shelf width varies from 33 km in the south to 28 km at its narrowest, opposite Cape Melville, and reaches 160 km off Cape York. Due to fault control and the upward growth of shelf-edge reefs, the continental shelf ends abruptly and the continental slope descends steeply to the Coral Sea Basin and the Queensland Trough. Conspicuous continental islands (High Islands) occur in the Howick Group, the Flinders Group, and in the Torres Strait. The Murray Islands (Mer, Dowar and Wyer Islets), Bramble Cay, and Darnley Island are also continental islands composed of andesitic lavas and ash beds.

There is a lack of detailed information concerning the reefs, or the nature and evolution of the shelf in this northern part of the Great Barrier Reef Province. Interpretations of its structure, geological history, and geomorphology are based largely on surficial features, on the implications of the geology of the adjacent mainland, on geophysical data (aeromagnetic and gravity surveys), on information provided by the Anchor Cay bore hole, and, by inference, on data from bore holes drilled in the Central and Southern Regions. Many areas away from the inner shipping channel have not been surveyed, consequently no bathymetric information is available for large tracts of the outer-shelf on published marine charts.

In recent years investigations of reef complexes in other parts of the world have resulted in a growing awareness of the effects of eustatic sea level changes, and of the influence of antecedent (pre-Holocene) surfaces on the form and distribution of Holocene coral reefs, see e.g. MacNeil (1954), Hoffmeister and Ladd (1944), Purdy (1974a), and it has been shown that Holocene sediment distribution patterns owe much to the influence of relict features (Purdy, 1974b). On the Queensland shelf recognition of bathymetric features that have been accredited significance in terms of Quaternary eustatic sea level changes (e.g. Thom and Chappel 1975, Maxwell 1973), and the detection of 'solution unconformities' in Great Barrier Reef Bores (e.g. Davies 1974) stimulated speculation regarding the thickness of Holocene coral reefs, and the nature and extent of pre-Holocene' antecedent surfaces. Therefore a principal objective of the Royal Society (London) and Universities of Queensland Expedition (1973) was to seek evidence of antecedent surfaces, and to determine the thickness of Holocene reef growth through drilling and the application of high resolution seismic methods.

Initial results were presented at a discussion meeting of the Royal Society in London in January 1976, and papers based on these are now in press (see appendix). Confirmation of the antecedent surface hypothesis was achieved by demonstrating the existence of a prominent sub-bottom reflector representing an extensive, ancient, dissected surface, the remnant of a major phase of marine regression and shelf emergence. This surface represents a hiatus in the development of the continental shelf as a reef province and is believed to have influenced the location and thickness of reefs established during the subsequent marine transgression. Its relationship to reefs and interreef facies is particularly well developed on the outer shelf near Cairns (Orme, Webb, Kelland, and Sargent 1976, 1978).

Shallow drilling at Bewick Island (Thom and Orme, 1976) and subsequent investigations of other reefs in the Northern Region (Hopley, 1977; Harvey, 1977), indicate that Holocene reefal accumulation is relatively thin.

Consequently a new approach to the evolution of the Great Barrier Reef Province has developed, and a re-assessment of many aspects of its geological history is in progress, which will involve a re-evaluation of genetic schemes for classifying shelf reefs.

The 1973 expedition was concerned with the northern part of the Central Region and the Northern Region of the Great Barrier Reef Province. In the area north of Lizard Island many coral islands, islets and cays were mapped, studies of reef-top and interreef sediments were carried out, shallow drilling of two coral reefs, and seismic profiling and side-scan-sonar surveys were undertaken (see Figs. 1 and 2).

In the following account the terms near-shore, inner-shelf, outer-shelf and shelf-edge are used in a geographical sense. The definition of the inner shelf, proposed by Maxwell, is not used.

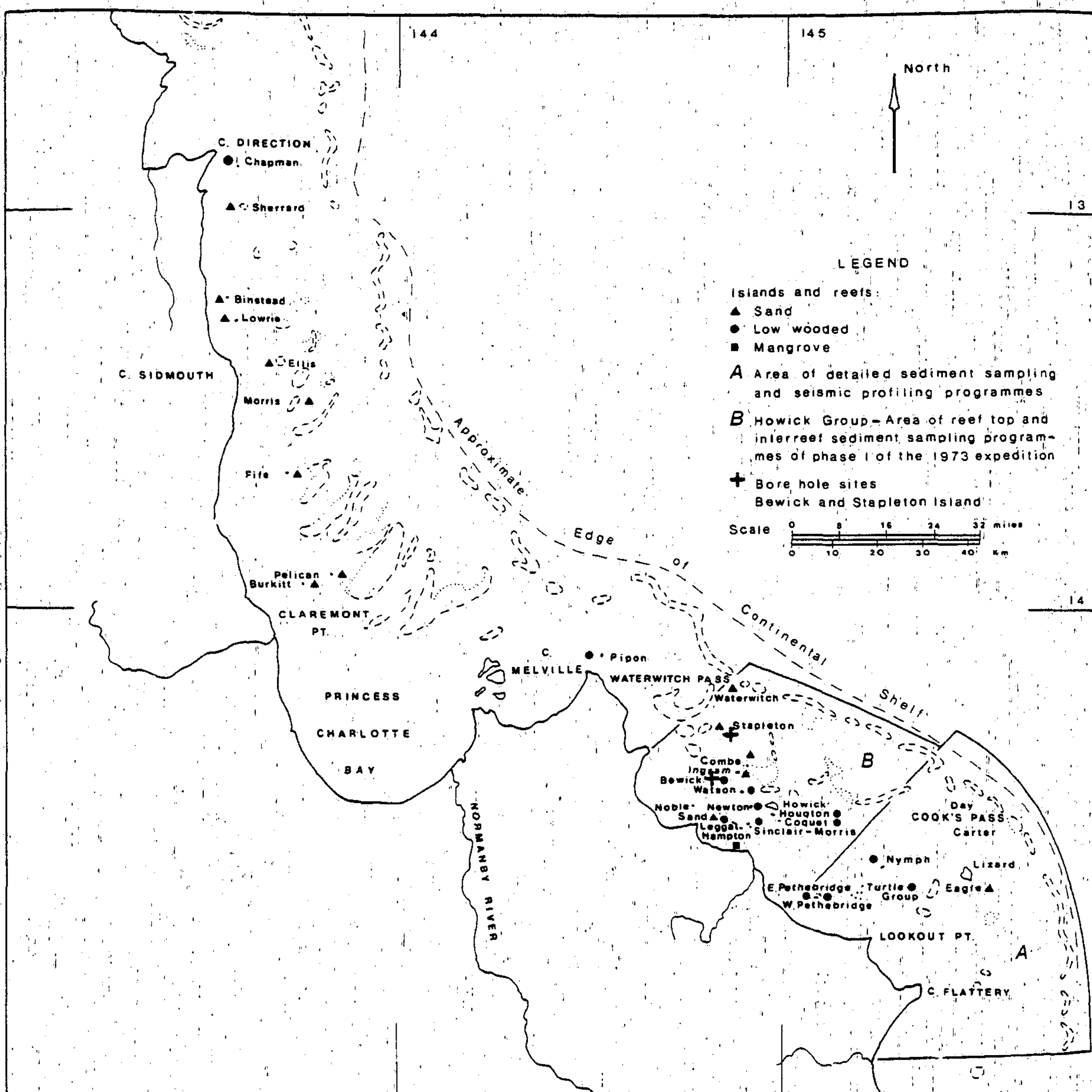

Figure 1: Map of part of the northern Great Barrier Reef showing islands and cays mapped by D.R. Stoddart during the "Royal Society and Universities of Queensland Expedition" (1973), borehole sites, and areas of sediment sampling and seismic profiling programmes.

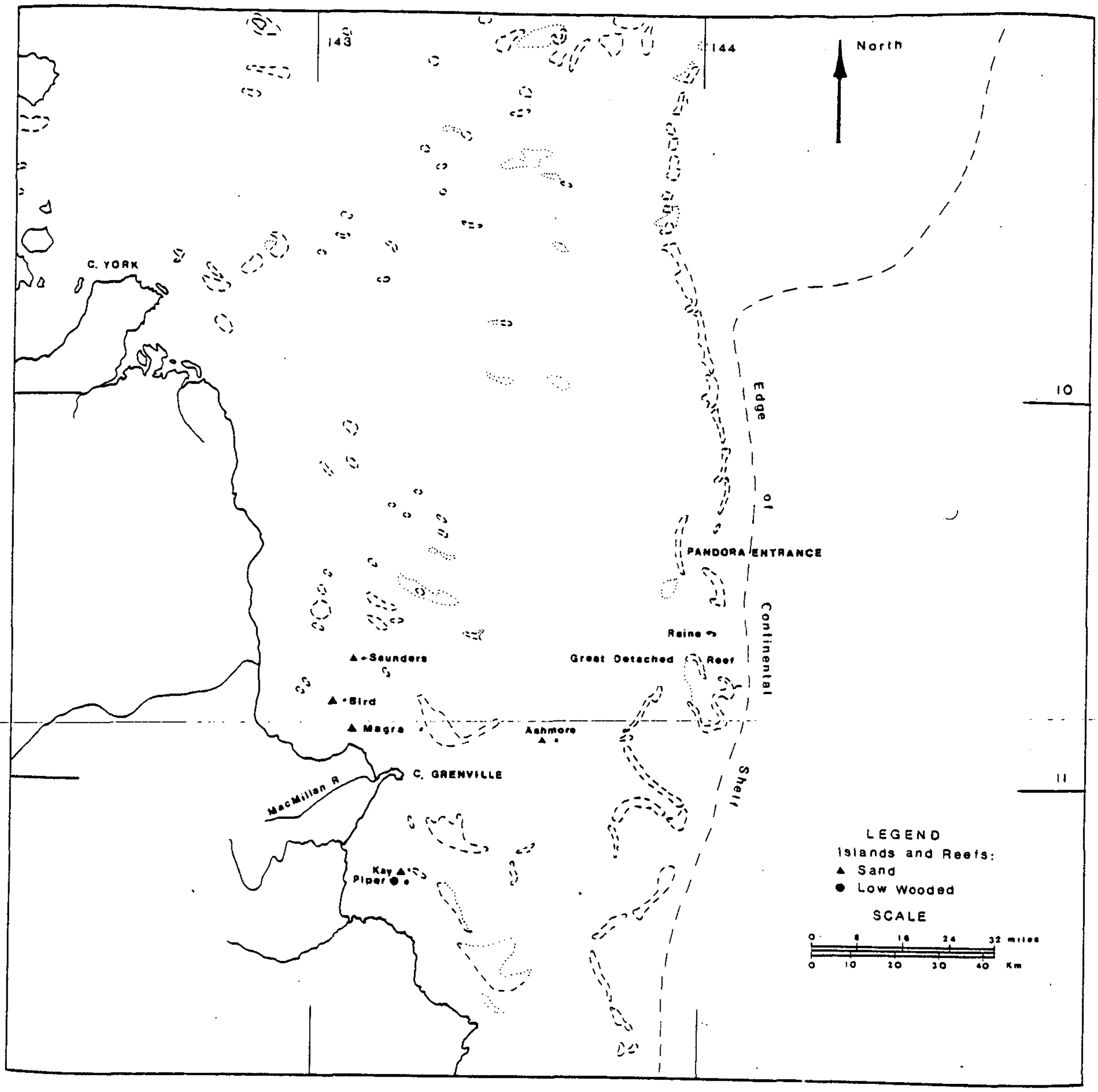

Figure 2: Map of the northern part of the Great Barrier Reef indicating islands and cays mapped by D.R. Stoddart during the "Royal Society and Universities of Queensland Expedition" (1973).

THE GEOLOGICAL SETTING

Mesozoic and Tertiary sediments form the coastal lithologies north of Princess Charlotte Bay, but in the southern part of this region Lower Palaeozoic metamorphic rocks intruded by granite form the main coastal lithologies. The differential weathering of these rock types when exposed on the shelf by eustatic lowering of sea level may still be reflected in the trend of bathymetric contours where not completely eradicated by subsequent planation, reef growth and sedimentation.

The present characteristics of the continental terrace and adjacent Coral Sea provinces were initiated by Tertiary events. Extensive planation of the Australian continent in early Tertiary time was succeeded by widespread crustal warping and fracturing in late Tertiary time; accompanied by arching of the Eastern Highlands and subsidence along normal faults of adjacent areas to the east.

This period of tectonic activity also promoted the development of the Queensland Trough, subsidence of the Queensland Shelf, and the separation of the Coral Sea Plateau as a distinct reef province (Orme 1977). Pleistocene sea level fluctuations strongly influenced shelf geomorphology, the lows permitting drainage systems to extend across it to the continental slope to produce features that are still partly reflected by present shelf bathymetry.

The age of the northern Great Barrier Reef

The bore hole drilled at Anchor Cay proved a Pliocene coral reef, and Tanner (1969) presented evidence for an "ancestral Great Barrier Reef" of Miocene age, which extended from 9^{o}S. latitude northwards across the Gulf of Papua. To the south, the prevalence of a reefal environment on the outer shelf since Pliocene times is implied by the Michaelmas Cay bore hole sequence (Richards and Hill, 1942; Lloyd, 1973).

Continental Shelf Sediments

The regional distribution of sediment facies, described and mapped by Maxwell (1968), reflects the influence of terrigenous sediment from the mainland and the carbonate production of the reefs. Thus, the terrigenous facies fringes the shore in an almost continuous zone in the southern part of this area and is succeeded across the shelf by the transitional facies, impure carbonate facies and high carbonate facies. Under the influence of discharge into Princess Charlotte Bay from the Normanby River, a broadening of the terrigenous and transitional facies zones occurs. However, northward of Princess Charlotte Bay the transitional facies borders the mainland shore and the terrigenous facies is restricted, which implies a significant supply of carbonate sediment from nearshore reefs. The pure carbonate facies also broadens northward extending from the shelf-edge and covering more than half of the continental shelf.

Detailed studies of the shelf sediments and sedimentation have been carried out in Princess Charlotte Bay (Frankel, 1974), and in the vicinity of the Howick Group (Flood, Orme, and Scoffin, 1978). A detailed sediment sampling programme which encompassed the entire shelf width between latitudes 14°30'S and 15°5'S, was undertaken during the Royal Society and Universities of Queensland Expedition. A comprehensive study of these sediments has recently been completed by Orme and Flood, and the results are being prepared for publication. Relict features are important in this area and sedimentation factors are complex.

A recently published bibliography of the geology and hydrology of the Great Barrier Reef and the adjacent Queensland coast is included in a review by Jones (1977).

REEF TYPES AND REEF DISTRIBUTION

A purely descriptive classification of the reefs may be based on readily recognised features such as form (shape, morphological zonation, structure), size, and location. Published classifications of the reefs of the Great Barrier Reef Province incorporate a genetic theme in advocating the sequential development of reef types (Fairbridge, 1950; Maxwell, 1968) due to the progressive response of differential growth to hydrologic and bathymetric factors. Thus, it has been suggested that from an embryonic reef (patch reef) dominantly radial growth results in the formation of a more or less symmetrical platform reef, or under other, less uniformly balanced conditions the embyronic reef may become elongated to form a ribbon (extended wall) reef. Subsequent modifications to both types results in the progressive development of other reef types and the reefs may finally be resorbed (Maxwell, 1968). The generalised physiographic zonation of some common reef types is shown in Fig. 3.

Conditions at the shelf-edge or in the near-shore zone are not suitable for the maintenance of radial growth, consequently platform types are developed on the outer and inner-shelf behind the shelf-edge ribbon reefs.

While variations in the hydrologic-bathymetric-biological balance may account for the major differences between reefs of the near-shore, inner- and outer-shelf, and shelf-edge, other factors may influence the differentiation of reef types (Flood and Orme, 1977) and foundation control, namely the nature and form of an antecedent surface is likely to strongly affect, not only the distribution of reefs, but also their initial form, thickness and orientation (Orme, Webb, Kelland and Sargent 1976, 1978; Davis <u>et al</u>, 1977).

The dense coral reef growth along the northern shelf is attributed to the influx of carbonate rich water (Coral Sea Water) which has risen from the deeper layers of the Coral Sea (Maxwell, 1968). Limited upwelling indicated by small-scale cellular structure in the upper part of the water

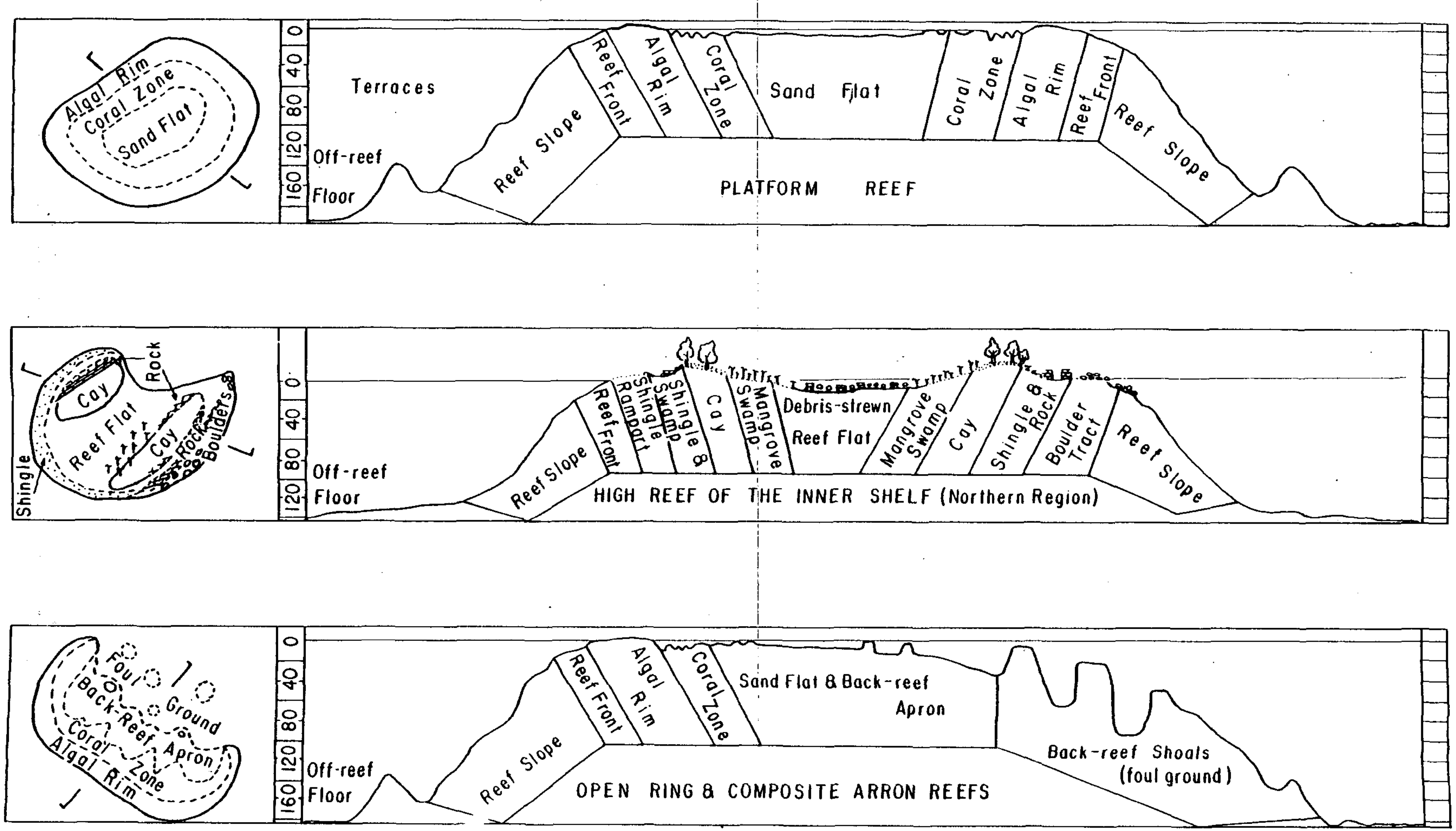

Figure 3: Reef profiles of common reef types showing the general physiographic zonation (after Maxwell, 1968).

column, bringing nutrient rich water into contact with reefs is hypothesized by Brandon (1973) rather than the deep-seated upwelling proposed by Maxwell (1968). Immediately leeward of the strong line of shelf-edge reefs is a zone that has sparse patch reef development which was called the "outer channel" by Spender, (1930), Steers (1938), and Fairbridge (1950), and which is referred to as the "Barren Back-reef Zone" by Maxwell (1968). In some areas this is a zone of relatively thick sediment accumulations and may occupy approximately one quarter of the shelf width. However, the influence of the rich oceanic water maintains a high reef density over most of the narrow shelf, and westward of this depleted back-reef zone large complex reef masses occur; smaller platform reefs occur on the inner-shelf adjacent to the steamer channel.

Data from Wyrtki (1960) indicated that the inner shelf water flows southward under the summer monsoonal influence and northward in winter and spring under the Trade Wind influence. Temperature and salinity characteristics of the northern shelf have recently been described by Brandon (1973).

Reefs of the Shelf-Edge

A chain of reefs extends along the edge of the continental shelf from approximately lat. $16^{\circ}5'$ south, northwards to the Murray Islands ($9^{\circ}58'$S). They range in size from small patches to ribbon reefs (linear reefs, Jukes 1847; extended wall reefs, Maxwell, 1968) several kilometres in length, and they are separated from each other by narrow deep channels in which swift tidal currents flow. Their outer edge descends steeply to the Queensland Trough and their alignment parallel with the shelf-edge affords maximum exposure to the open ocean and the influence of prevailing southeast Trade Winds. Most of these shelf-edge reefs are either submerged or only uncovered during the lowest spring tides. Raine Island ($11^{\circ}36'$S., $144^{\circ}01'$E.), which has recently been studied by Stoddart (1977, unpublished manuscript), is one of the few islands associated with them. Maxwell (1968) distinguished several reef types: 'Cuspate reefs' developed by the

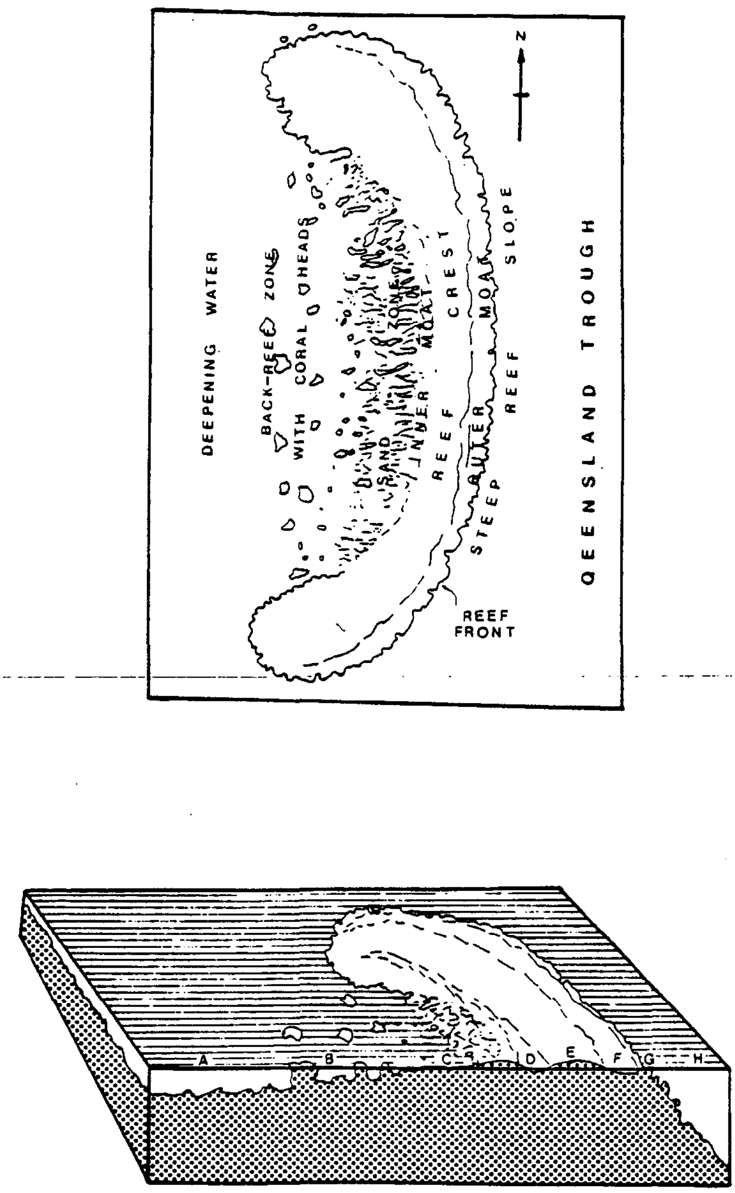

Figure 4: Diagrammatic sketch and cross-section of a typical shelf-edge reef. A-outer channel; B-back-reef zone; C-sand apron or zone; D-inner moat; E-reef crest; F-outer moat; G-reef front; H-reef slope. (after Fairbridge, 1968).

backward growth of the reef ends, the cusps provide shelter for a lagoon-like area (e.g. Day Reef, Carter Reef), and where an extensive back-reef apron or wedge of sediment has accumulated the term "composite apron-reef" has been applied. Prong reefs are those reefs with irregular buttresses or prongs developed normal to the axis of the reef.

Fairbridge (1950, p. 340) described three reefs of annular form at the shelf-edge where it trends east-west at latitude 14°S. These reefs are elongated in the east-west direction, two have a central sand flat with shallow pools, but the ". . . most westerly encloses a fairly deep lagoon and is a true shelf atoll" (closed ring reef). Where the shelf deepens in the far north of the province deltaic reef forms and plug reefs occur which are discussed by Veron (this volume).

From studies made by members of the 1928-29 Great Barrier Reef Expedition on Yonge Reef and adjacent reefs, a picture of the general structure of ribbon reefs has been produced (Stephenson, et al. 1931), Fairbridge (1950), and Bennett (1971). Seven physiographic zones can be recognised (Fig. 4):

The physiographic zones recognised from the outer (eastern) edge to leeward are: The reef slope, which descends steeply into the Queensland Trough and which is the zone of most luxuriant coral growth; the reef front, which is a fairly continuous ridge lying between the reef slope and outer moat, and which is covered by living coral and in places is encrusted by coralline algae. This ridge is narrower and rises to a lower elevation than the reef crest, and well developed spur-and-groove structures are characteristic of this zone. The outer-moat may be up to 30m in width, containing unequal masses or platforms of coral rock heavily encrusted by coralline algae and corals. The floor of the moat slopes gradually oceanward. The reef crest rises to 1.5 m above low water mark and is the most conspicuous feature. It is a broad (100-150m) algae encrusted pavement which is often terraced seawards and except for scattered large reef blocks, and in some areas a leeward boulder zone, is devoid of sediment, coral growth is restricted to shallow pools and most of the crest has a veneer of coralline algae (Lithothamnion, Porolithon, and Lithophyllum). The terms 'radial zone' or 'trickle zone' have been used to describe the wider parts of the reef, where sediment debris and algae form a definite pattern normal to the reef edge. The inner-moat, lying immediately west of the reef crest, has a width of 30 - 50 m, is up to 0.5m deep at low tide and may be partly filled with clumps of living coral, boulders, and bioclastic gravels and sands.

Sand zone (sanded zone) extends leeward of the moat; its floor deepens gradually and is covered with white shell sand. An extensive apron of sediment may develop which is interrupted by large coral patches.

In the back-reef zone the water deepens to 30 - 40m and only a few patch reefs may reach the surface. Recent profiling work at Carter Reef revealed leeside terraces at - 22.5m and - 30m. (See Fig.6 line 61).

Near-shore reefs of the mainland and continental islands

Near-shore reefs, designated fringing reefs by Fairbridge (1950) and others, are subdivided into fringing types and barrier types by Maxwell (1968) on the basis of their back-reef characteristics. They rise from 9m and are best developed along the coast where it is bordered by deep channels, and where penetration of oceanic water across the shelf is most effective.

Fringing reefs occur along the mainland shore between Cape Flattery to Cape Melville; on the west coast of Princess Charlotte Bay, and continue northwards towards Cape York. They appear to favour headlands, but also develop in more sheltered bays and seem to be unaffected by muddy sediment from rivers (Maxwell, 1968). These near-shore reefs have a veneer of sediment and are partly masked by mangroves in the more sheltered areas. Maxwell (1968) maintained that the irregular pattern of the development of near-shore reefs and the unusual constitution of their faunas reflected the influence of heavy summer rains which reduce surface salinities, and the king tides that cause periods of deep immersion and prolonged periods of exposure. Although many reefs have the normal zonation of the outer-shelf and shelf-edge, others have extensive calcareous and non-calcareous algal growth, and prolific occurrences of molluscs.

Reefs also fringe the continental islands, and in the less turbid waters are more vigorous. They are associated with the Flinders Group and the Howick Group. The continental islands of the Torres Strait have fringing reefs with sediment cover and are partially masked by mangrove. The volcanic Murray Islands near the edge of the continental shelf (Mer, Dowar, Wyer) are surrounded by fringing reefs (Mayer 1915, 1918) which were said to have, "one of the most luxuriant coral growths to be found in the Pacific". Jardine (1928 a,b) mapped and described the reef-fringed volcanic Darnley and Bramble Islands, each with broad, (½ km - 1¼ km) flat, reef platforms devoid of mangroves.

Reefs of the inner and outer shelf

The reefs of the inner- and outer-shelf vary considerably in size and form, from small patch reefs to enormous wall and cuspate complexes. The prevailing wind-wave directions have been considered to be the main influence in determining form and orientation of these reefs. However, the reefs of the Corbette-Hedge-Lytton complex may owe their form and orientation to the influence of foundation control (Frankel, 1974). Corbette reef and the adjacent reefs extend eastwards from the inner-shelf, across the outer-shelf almost to the shelf-edge. Corbette and Grubb reefs are characterised by extensive sand-bank development along their inner margins and their large sediment covered surfaces are reported to have negligible coral fauna. The inner-shelf reefs near the steamer channel are smaller, platform types,

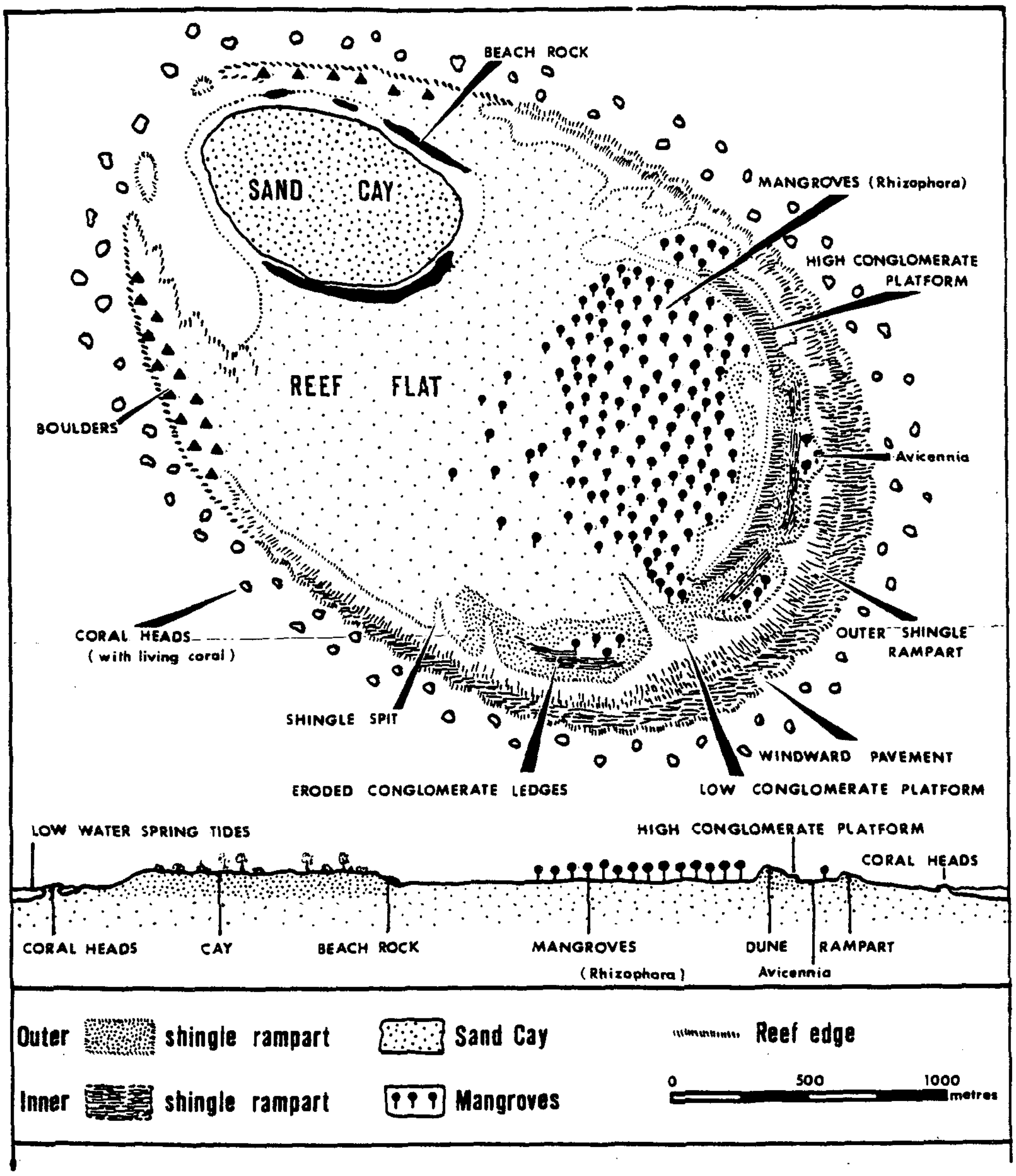

Figure 5: Generalised sketch of a Low Wooded Island (after Steers, 1930).

modified by excessive sediment and the development of a variety of reef top features which may lead to the establishment of a "low wooded island" (Fig.5).

REEF-TOP ACCUMULATIONS - CORAL REEF ISLANDS

The reef-top, especially of shallow reefs, in the area of most active change; under the influence of breaking and translatory waves, and tidal currents, erosion and sedimentation compete with reef growth, influence ecological zonations which in turn affect sedimentation. Large blocks and boulders broken from the reef front maybe contributed to the off-reef sediment or may accumulate on the windward edge of the reef-top to form boulder zones. On the reef flat, especially under the high energy conditions near the reef margin, coral stick gravel may form shingle banks, while 'currents of removal' carry fine debris away to leeward. Large areas of the reef flats of many reefs in this region have a veneer of bioclastic sand which is in transit to the leeward sediment cone (Flood, Orme and Scoffin, 1978; Flood, this volume), as indicated by the current ripples and the avalanching of sand at the leeward margin, e.g. Ingram-Beanley reef. If a reef-top lagoon is present which acts as a 'settling tank' sediment may accumulate there, either temporarily or more permanently, according to the depth and size of the lagoon. In accordance with prevailing physical conditions a leeward sand lens may develop, which may eventually build to the supratidal zone to form a sand cay.

As noted by Spender (1930) there is a progressive change in the types of reef-top accumulations across the shelf. Thus, with the exception of windward boulders, conditions at the shelf-edge generally prohibit the accumulation of sediment on the tops of shelf-edge reefs. Sand cays on the outer reefs occur north of latitude 14°S, but only one occurs south of this point viz. Waterwitch Reef. Some of the exposed outer-shelf reefs that reach sea level have a supratidal sand cay at the leeward margin of the reef-top, which may be vegetated or unvegetated. Exposed ramparts are absent, although scattered boulders at the reef margin may be prominent.

Many of the reefs on the inner-shelf have tops elevated well above L.W.S.T. and have a marked relief due to a leeward sand cay which is commonly vegetated; unconsolidated and lithified shingle ramparts on the windward reef edge are usually present (several sets may develop separated by moats), and boulder tracts may be evident. Mangrove cover becomes more extensive on reefs nearer to the mainland. Such reefs were termed "low wooded islands" by Steers (1929) (Fig.5). Steers (1937, 1938) later extended his investigations and mapped more islands including Bewick Island, which he proposed as a type example. They have been called 'island-reefs' by Spender (1930), 'high islands' by Maxwell (1968), and 'moat islands' (Stoddart, 1965).

Spender's (1930) classification of reefs was refined by Fairbridge (1950), and the suggested sequential development from a leeward sand cay to a 'low wooded island with mature vegetation has, in part, been confirmed by the work of the 1973 expedition (Stoddart, McLean, Scoffin and Gibbs, 1978).

The sea reached its present level about 6,000 years B.P. (McLean, Stoddart, Hopley and Polach, 1976 and 1978) and continued to a height of a metre or more above this level before returning to its present position. Erosion of reefs developed to the higher sea level contributed sediment to reef top deposits, which have been removed from the reefs more open to oceanic attack on the outer-shelf and shelf-edge (Maxwell, 1968). Radiometric dating of samples collected during the 1973 expedition from similar deposits on different reefs gave consistent ages. Several members of the Royal Society and Universities of Queensland expeditions have studied the nature and evolution of reef top accumulations, and the initial results are presented in papers listed in the appendix.

Evidence of Diagenesis in Reef-Top Accumulations

The most apparent result of diagenesis is lithification, and there is widespread evidence of this in the reef-top accumulationsof the Great Barrier Reef, especially in the Northern Region where reef-top deposits are so diverse in texture and form, as is also the range of geochemical conditions associated with them. Apart from the formation of reef-rock through the binding and cementing action of encrusting organisms and the ensuing changes that eventually result in the formation of a complex limestone, shingle banks, boulder tracts, and sand cays may all show evidence of lithification in the intertidal zone, and their lithified counterparts may form extensive pavements. The limestones produced may be specifically described as beach-rock, rampart-rock, and boulder-rock, and to these may be added the supratidal phosphate-rock.

The most common cement produced occurs in the beach-rock associated with leeward sand cays; it consists of accicular crystals of aragonite forming fringes around the component bioclastic grains, which may partially or completely fill intergranular pores and intragrain cavities. Beach-rock, being the result of *in situ* cementation of beach-sand in the intertidal zone, helps to stabilize sand cays. It is well developed on many coral reef cays and islands in the northern Great Barrier Reef forming beds which are gently inclined seawards or sometimes horizontal; its surface may be smooth, pitted, or severely bioeroded (see McLean 1974, for a description of these features). Although Steers (1929, 1937) observed that beach-rock is found only on vegetated cays, it does occur on some unvegetated cays e.g. Waterwich Reef. There has been considerable debate regarding the mechanism of cementation of beach-sand to form beach-rock in general (e.g. Stoddart and Cann, 1965), and of Heron Island beach-rock in particular (Maxwell, 1962; Davies and Kinsey, 1973), but the present consensus appears to favour inorganic cementation. The top 3m of the Bewick core consists of biosparite of this type.

On the other hand, the rampart-rock consists mainly of coral-stick-gravel with a void filling micrite matrix of high magnesium calcite with clay minerals (Scoffin and McLean, 1976, 1978). Radiocarbon dates obtained from samples collected during the 1973 expedition indicate shingle accumulation approximately 3000 to 4000 years B.P., whereas the micritic matrix is somewhat younger (as much as 1500 years) thereby indicating a delay in lithification (McLean, personal communication).

A casual observation will suffice to indicate an association between the presence of a micrite matrix and the occurrence of a mangrove swamp. The movement of water from the mangrove swamp through the shingle ramparts at low tide introduces suspended mud to rampart voids. Consequently the ramparts are influenced by a completely different geochemical regime to that which prevails in the leeward beach-rock, and it is not surprising therefore that there is a difference in void filling materials. Boulder-rock also shows a similar variation in matrices according to its position on the reef top.

Phosphate-rock formed by downward mineralization by phosphate solutions derived from guano has been reported from the high supratidal parts of a number of sand cays in this region e.g. Ingram, Bewick, and Stapleton Islands (Scoffin and McLean, 1978). It occurs at Raine Island (Stoddart, 1977), and has been sampled from elsewhere in the Great Barrier Reef province by the author. The phosphate has been precipitated as a cement between bioclastic carbonate grains, which, in some cases, also show signs of replacement by phosphate. A study of these rock types and their diagenesis has been undertaken by Scoffin and McLean (1976, 1978).

Diagenetic features of the Bewick Core

The Bewick core provided an interesting illustration of the fabric and mineralogical changes that may occur in a sequence of marine carbonate deposits subjected to the influence of periodic environmental changes, brought about by eustatic sea level fluctuations. The bore hole, drilled from the beach-rock on the leeward side of Bewick Island to a depth of 30m, passed through eight lithological units, which indicated deposition in environments ranging from sheltered lagoons depositing carbonate sediment and receiving some quartz silt and iron rich solutions from an adjacent land mass, to the high energy, beach environment represented by the biosparites at the top of the sequence.

The core samples provided evidence of inversion, aggrading neomorphism, solution, iron migration, and replacement; the importance of these diagenetic processes varied with depth and to some extent reflected the presence of disconformities. Thus, at 7m (about 3 - 4 m below L.W.M.) an abrupt change from biosparites and unconsolidated reef flat deposits to biomicrites, coincided with a marked decrease in aragonite which had inverted to low magnesium calcite. At this level there was also a change in radiocarbon dates from 6920 years B.P. to more than 30,000 years B.P. Consequencly this break was considered to represent the 'Thurber Discontinuity' (Thom and Orme 1976, Thom, Orme and Polach 1978).

At lower levels some samples have reached a more advanced neomorphic state and recrystallization <u>sensu stricto</u> has occurred reducing many skeletal fragments to 'ghosts'. The uneven distribution of recrystallization fabrics and/or irregular concentration of impurities, resulted in the formation of pseudobreccias at several levels, and in the lowest parts of the core authigenic quartz emplacement has occurred. It could be inferred therefore, from the petrology alone, that there was a considerable age difference between the rocks at the top and those at the bottom of this bore hole sequence.

ASPECTS OF THE QUATERNARY GEOLOGICAL HISTORY OF THE SHELF

An insight into the Quaternary geological history of the Great Barrier Reef has been provided by an investigation of shelf structure and stratigraphy employing high resolution seismic methods, which was carried out during the Royal

Society and Universities of Queensland Expedition (1973). Although only the southern extremity of the area now being considered was included in this survey, the results have implications for the entire northern Great Barrier Reef.

The most significant feature is a major disconformity (disconformity A, see Fig.6) represented by a prominent sub-bottom seismic reflector which extends across the entire shelf. This reflector is an erosion surface resulting from marine regression, shelf emergence, and erosion, related to glacial low sea levels; it is, in most areas, concealed by sedimentary accumulations and reefs, but is exposed in places, especially near the shelf-edge where it forms a rugged, channelled sea bed.

Reflector 'A' truncates ancient sedimentary deposits and reef limestones, and rises beneath shelf-edge reefs. (Fig.6, line 61). Harvey (1977), by using a seismic refraction method, demonstrated the existence of a surface, which indicates a significant discontinuity at shallow depth beneath Carter Reef. Samples obtained by shallow drilling of the reef flat at the same locality yielded radiocarbon dates, which show how thin the veneer of Holocene reef growth really is (Hopley, 1977).

Overlying this reflector on the outer-shelf, extending from the lee of shelf-edge reefs to approximately the mid-shelf position is a cross-bedded sedimentary accumulation up to 18m in thickness, which forms banks and ridges covered with luxuriant Halimeda growth and surface deposits of Halimeda gravels and sands. The bank-tops are at a fairly uniform depth of -25m, but there is a descent to -30m in intervening channels and rocky hollows. The bathymetric and geologic characteristics of the sea bed of the outer-shelf area have been illustrated by side scan sonar traverses.

Near Cook's Passage the bank forming deposit is absent, the prominent reflector (A) occurs at -45m, it is channelled to -69m and is clear of sediment (Fig.6, line 54). However, to leeward of the shelf-edge reefs some channels were filled by acoustically more transparent sediments, which lie beneath

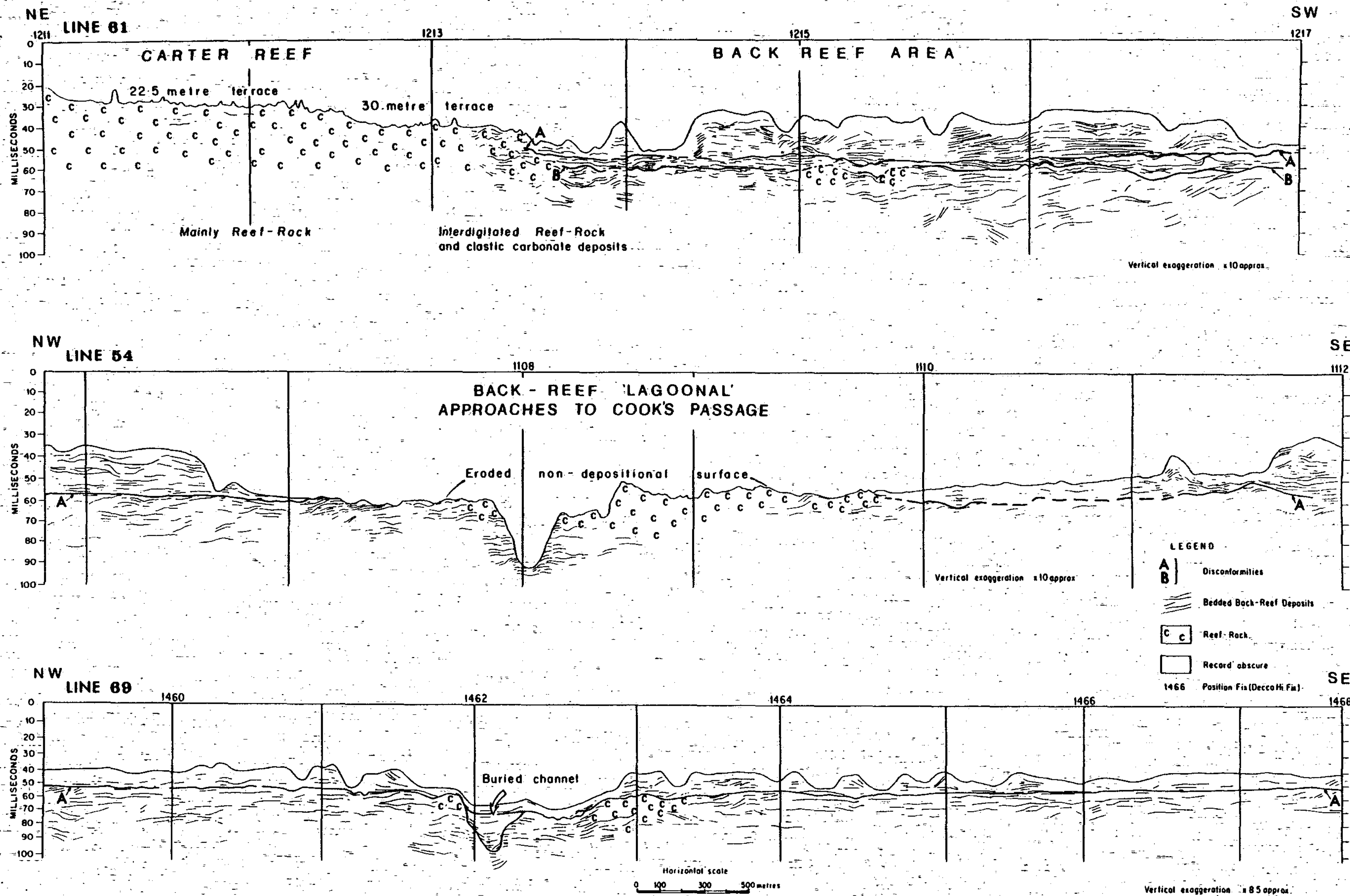
NE
LINE 61
SW
1211
1213
1215
1217
CARTER REEF
BACK REEF AREA
22.5 metre terrace
30 metre terrace
MILLISECONDS
Mainly Reef-Rock
Interdigitated Reef-Rock and clastic carbonate deposits
Vertical exaggeration x10 approx.
NW
LINE 54
SE
1108
1110
1112
BACK - REEF 'LAGOONAL' APPROACHES TO COOK'S PASSAGE
Eroded non-depositional surface
Vertical exaggeration x10 approx
LEGEND
Disconformities
Bedded Back-Reef Deposits
Reef-Rock
Record obscure
1466 Position Fix (Decca Hi Fix)
NW
LINE 69
SE
1460
1462
1464
1466
1468
Buried channel
Horizontal scale
0 100 300 500 metres
Vertical exaggeration x 8.5 approx.

Figure 6: *Interpretations of segments of high-resolution-boomer profiles of the outer-shelf (back-reef) area near Carter Reef (after Orme, Flood and Sargent, 1978).*

Line 61 extends from Carter Reef in a south westerly direction, and is viewed from the northwest. It shows two disconformities which can be traced into Carter Reef. Above the main disconformity (A) lie the bedded deposits of the Halimeda covered 'banks'.

Line 54 trends parallel with the shelf-edge and crosses the approaches to Cook's Passage. This cross section is viewed from the southwest and shows disconformity 'A' exposed as a 'rocky', non-depositional seabed composed of both bedded deposits and reef-rock, Surface 'A' has been channelled to a depth of 69m.

Line 69 shows a cross section of the outer-shelf area along a line running parallel with the shelf-edge to the west of line 54. Disconformity 'A' occurs between the younger bedded deposits of the Halimeda covered banks, and the underlying bedded deposits and reef-rock. The older formations have been channelled to a depth of 66m below sea level. The channel was filled with sediments and subsequently buried beneath the bank deposits.

the bank deposits (Fig.6, line 69).

This suggests that after the dissection of the shelf (reflector A) by streams adjusted to a lower base level, a rise of sea level brought about the deposition of sediments in their channels prior to the re-establishment of normal marine conditions, and before the accumulation of the overlying bank deposits. At the shelf-edge some channels were maintained, others may have been temporarily filled with sediment and were later exhumed.

On bathymetric evidence some channels have been traced landward from passages between the ribbon reefs e.g. Lowry Passage. Nevertheless the seismic evidence indicates that such channels are probably much older than the sea bed features formed by the stratigraphically younger sedimentary and reefal accumulations of the outer-shelf.

As a result of this seismic investigation using high resolution methods it is clear that the sea bed is a complex of both depositional and erosional, inherited and Holocene features. Furthermore, in addition to the reefal shoals shown on marine charts, drowned reefs at greater depths occur on the outer-shelf, which suggests that reefs may have been more numerous previously. The reasons for the bathymetric complexity of the outer-shelf in the area investigated, and for the apparent distribution of different sea bed substrates, are now apparent.

Details regarding the characteristics and evolution of the Outer-shelf have been presented by Orme, Flood and Sargent (1978).

CONCLUSIONS AND RECOMMENDATIONS

Emergence and subaerial erosion of the continental shelf during Pleistocene glacial low sea levels has profoundly influenced the present characteristics of the Great Barrier Reef Province. Ancient eroded rock surfaces and relict deposits inherited from pre-Holocene phases of shelf evolution contribute to its present geological and bathymetric diversity, and may be significant in terms of present shelf ecology.

The Holocene reefal veneer, while responding to contemporary hydrological factors, is related in form and distribution to an antecedent surface, which has truncated both ancient reef masses and sedimentary deposits, so that although reefs may extend upwards from a shelf depth of 30m, only a fraction of their vertical thickness represents reef growth during the last marine transgression. Mean sea level and tidal range are significant factors in determining diagenetic trends in such carbonate complexes, and lengthy periods of subaerial exposure of the biogenic carbonate of the northern Great Barrier Reef due to shelf emergence, are reflected by some of the diagenetic characteristics of the Bewick core.

Only the upper surface of the Quaternary geology has been penetrated by the Bewick bore hole and the seismic work carried out during the Royal Society and Universities of Queensland Expedition, but it has been sufficient to demonstrate how important eustatic sea level changes have been in determining sedimentation and diagenetic trends, and in controlling reef evolution.

Thus, a better understanding of the present Great Barrier Reef is likely to be achieved through an appreciation of its past viscissitudes, which may be strikingly revealed through the application of improved, spohisticated exploration and analytical techniques.

An initial priority for future investigations of the northern Great Barrier Reef should be the acquisition of accurate data regarding the bathymetry of the uncharted areas of the outer-shelf; the extent and form of the large reef complexes which extend to the "barren back-reef zone" should be defined. This is the province of the Hydrographic Department of the Royal Australian Navy. There is a need for detailed studies of the hydrography.

Side scan sonar could be used to map reef boundaries, and the distribution of sediment and rocky outcrops on the sea bed. High resolution seismic methods could be employed to determine reef structure, facies relationships, and the structure of the shelf. Both methods are therefore capable of providing information regarding the distribution and stability of sediment bodies on the sea bed, and of providing information of ecological significance.

To enhance our knowledge of the evolution of the reefs north of Lizard Island, ideally a programme of shallow drilling should be undertaken.

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G.R. Orme
Department of Geology and Mineralogy
University of Queensland
St. Lucia, Queensland, 4067

APPENDIX

The Royal Society and Universities of Queensland Expedition Volumes

Papers presenting the initial results of the expedition will be published in two volumes (in press) of the Philosophical Transactions of the Royal Society. Subsequently the Royal Society will issue the two parts as a separate hardback volume. A list of contents follows:-

Part A: Phil. Trans. A

D.R. Stoddart, R.F. McLean, T.P. Scoffin, B.G. Thom and D. Hopley: Evolution of reefs and islands, northern Great Barrier Reef: synthesis and interpretation.

J.A. Steers: Concluding remarks.

Part B: Phil. Trans. B

C.M. Yonge: Introductory remarks

D.R. Stoddart: The Great Barrier Reef and the Great Barrier Reef Expedition 1973.

J.E.N. Veron and R.C.L. Hudson: Ribbon reefs of the Northern Region.

J.E.N. Veron: Deltaic and dissected reefs of the far Northern Region.

D.R. Stoddart, R.F. McLean and D. Hopley: Geomorphology of reef islands, northern Great Barrier Reef.

D.R. Stoddart, R.F. McLean, T.P. Scoffin and P.E. Gibbs: Forty-five years of change on low wooded islands, Great Barrier Reef.

P.E. Gibbs: Macrofauna of intertidal sand flats on low wooded islands, northern Great Barrier Reef.

T.P. Scoffin and D.R. Stoddart: Nature and significance of microatolls (with an appendix by B.R. Rosen: Determination of a collection of coral microatoll specimens from the northern Great Barrier Reef).

J.E.N. Veron: Evolution of the far northern barrier reefs.

T.P. Scoffin, D.R. Stoddart, R.F. McLean and P.G. Flood: Recent development of reefs in the Northern Province of the Great Barrier Reef.

J.A. Steers: Concluding remarks.

Barrier reefs of the Northern Region

J.E.N. Veron

Abstract

The outer "shelf edge" or "barrier" reefs of the Northern Region are composed of three successive reef types called "ribbon", "deltaic" and "dissected" reefs. The ribbon reefs extend along the side of the Queensland Trench from about the latitude of Port Douglas to an area north of Rain Island where the Trench and barrier reefs diverge and deltaic formations appear.

The deltaic reef system is composed of 96km of reef front characterised by the presence of regular, well defined channels containing very strong tidal currents, and also by the presence of a deltaic pattern at the reef back. The dissected reefs are the northern-most of the shelf edge reefs. They are composed of many small, E-W elongate reefs interspersed by many wide channels. Both reef types are part of the one structure, their differing surface morphologies being attributed to bathymetric and hydrodynamic factors of the present and of the past.

INTRODUCTION

Of the many well-defined reef systems within the Great Barrier Reef (GBR) province, the northern barrier reefs are by far the most inaccessible. They are remote from any port or township and, for most of the year, are pounded by heavy seas driven by the SE trade winds. Thus they have remained unstudied and almost completely undescribed. Nevertheless they form one of the most dominating physiographic units of the GBR province and are potentially one of the most important to the understanding of the GBR's complex morphology, structure and evolution.

Maxwell (1968) has divided the GBR into three regions on the basis of bathymetry and geomorphic changes and correlated these with differences in reef density, morphology and development. The Northern Region, north of 16^{o}S. lat., is characterised by shallow water, the presence of a barrier reef system and prolific reef growth induced by the proximity of a steep continental slope. This paper gives a general description of the barrier system north to the northern limit of the "ribbon reefs" (Fig. 1) and a brief description of the barrier reefs north of the ribbon reefs, the "deltaic" reefs and the "dissected" reefs (Fig. 4).

The deltaic reefs extend northward for a distance of approximately 96km. They are composed of approximately 28 major reefs, 0.4-3.7km in length, which are interspersed by about 33 major channels. Over this distance the deltaic appearance becomes increasingly more cmmplex; major channels become less distinctive and are increasingly confused with an interlocking network of smaller channels. Thus, at 10^{o}10'S. lat. the deltaic pattern consists of a thoroughly confused network or irregular elongate patches intermixed with a mass of channels, most of which are small and shallow. The general appearance is broadly similar to the outer edge of a mature river delta.

From this point north, the barrier line becomes increasingly simplified. The reefs and channels retain their irregular appearance but the channels become less interwoven. At about 10°S. lat. the barrier line consists of alternating elongate reefs separated by relatively well defined, straight channels. For the purposes of this account, these reefs are called "dissected" reefs.

At its northern limit the barrier line consists of an irregular row of very small reefs which become increasingly difficult to distinguish in aerial photographs. Beyond the visible northern limit, Chart AUS 377 indicates a shallow area annotated "strong ripplings".

The only previous description of these reefs known to the author is that of Captain Blackwood (1844): "From Pandora entrance the reef runs N.E.b.N., seven miles, to Olinda Entrance and is intersected by small but narrow openings unfit for shipping, and then gradually turns away N.b.W. running for a space of nearly ninety miles in an impenetrable line of reef, until Murray Island is approached". Navigational charts (2354 and AUS 377) indicate the position of the reef line but no detail given can be recognized in aerial photographs. More recent reconnaissance maps (SC 54-16, 55-13, 54-12, 55-9, 55-5) from satellite imagery distinguish the approximate shape of major reefs, but again, detail is lacking. As with the first paper of this series, the present paper does not give comprehensive accounts; rather it is designed to give a broad simplified description of a large and important section of the Great Barrier Reef which has hitherto remained almost completely unknown.

This study was undertaken during Phase 3 of the "Stoddart" expedition and during the second northern voyage of R.V. "James Kirby" in November, 1974. The following is an extract from the expedition reports noted in the Appendix of the previous paper of this series.

METHODS

Limitations of ship-time and accessibility of the reefs have necessitated a somewhat opportunistic approach to much of the field work undertaken for this study; consequently some methods vary from one reef to the next according to problems encountered. Results were quantified as far as possible in the time available and conditions encountered.

a) Aerial photography

Commonwealth aerial photographs cover the barrier reefs from their southern limit north to $12^{o}35'$S. lat. A further series of 3 runs cover part of the northern deltaic reefs. RAAF aerial photographs of a greatly reduced quality are available for most far northern barrier reefs.

Specific areas of study in the vicinity of Tijou Reef were photographed from a chartered aircraft using 35mm and polaroid cameras.

Zonation patterns discernable in aerial photographs were frequently compared with zones present on the reef. Wilson reef ($13^{o}15'$S. lat.) was described as an example.

b) Bathymetry

Bathymetric data in the vicinity of reefs were obtained from R.V. "James Kirby" using a "Furuno F850 Mark III" sounder. Positions of the vessel relative to reefs were measured directly by a measuring line for distances of 200m or less and by radar from a reflector mounted in a dinghy for greater distances.

More detailed data were obtained by SCUBA divers using depth gauges and underwater measuring lines laid perpendicular to reef faces.

Bathymetric data at greater distance from reefs were obtained from the Hydrographic Office of the Royal Australian Navy and from R.A.N. and British Admiralty charts.

c) Reef transects

Rope transect lines laid perpendicular to the reef front were used by SCUBA divers to measure the width of major reef zones. The depth, nature of the substrate, dominant biota and estimated percentage cover of dead and living coral were estimated every few metres.

These transects were continued across the reef flat and down the reef front (eastern side) and back (western side). Bathymetric profiles (described above) were positioned so as to be continuous with the reef transects.

d) Sampling

Detailed collections of corals were made at the position of each quantitative transect (see below) and at all well-defined biotopes studied.

Samples of the substrate along reef transects were collected where possible. At greater depths, substrate and coral samples were collected using custom made anchor dredges.

e) Quantitative transects

Quantitative measurements were made of percentage area cover of dominant biota and substrate types as well as the percentage area cover of dominant coral species by use of a 30m measuring line laid parallel to the front of Tijou and Great Detached Reefs. Measurements were recorded, for species or substrate type, as the distance covered by the 30m line expressed as a percentage. These quantitative transects were centred as near as possible to the reef transects.

f) Supplementary surveys

Each locality studied was selected on the basis that it was as representative as possible of a large area of reef. Selection was made according to data obtained from aerial photographs, aerial surveys, and survey by SCUBA divers being towed behind small boats.

Other localities were selected for brief survey because they differed greatly from main study localities.

All of the above methods were occasionally supplemented by others. Such cases are indicated in the text below.

THE RIBBON REEFS

GENERAL CHARACTERS OF THE NORTHERN BARRIER REEFS

In the south, the line of barrier reefs starts 43km offshore from Cape Kimberley (16°17'S. lat.) and continues north running approximately parallel with the coast. Off Cape Melville the reef curves closer to the mainland than at any other point in its entire length (25km). The reef then curves northwards away from the coast past Princess Charlotte Bay to be some 65km off Claremont Point. Coast and reef once again converge to be 28km apart off Cape Direction, then diverge increasingly until the reef ends 205km north-east of Cape York, just north of the Murray Islands.

From Opal Reef up to the northern limit of Lagoon Reef (12°23'S. lat.), there is a total distance of 555.5km. Within this distance there are 117 reefs ranging from small plug reefs to long ribbon reefs which collectively present approximately 536km of reef front to oceanic conditions. (Small plug reefs situated just behind the main reef line do not contribute to the length of exposed reef front in this context). Water moves between the reefs through 86 well defined channels, which together account for 116km of the total length of the outer edge.

The general bathymetric features of the Coral Sea are readily available but detailed information concerning the bathymetry of the continental shelf in the area immediately behind the reefs, and even more so of the continental slope on their seaward side, is lacking. Available bathymetric charts of the Coral Sea show that the reefs are situated near to the edge of the continental shelf from Cruiser Pass (15°40'S. lat.) northwards, orientated with their axes parallel to the edge.

In the back reef area the depth of the water is variable and, while it generally does not exceed 36m, it is more commonly in the order of 28m.

Southwards from cruiser Pass, between Lena Reef and Opal Reef, the reefs occur at increasingly greater distances shorewards from the edge of the continental slope. They are not orientated with respect to the continental margin but in a generally south-east direction. There appears to be a plateau at about 55m between the outer limit of these reefs and the continental slope, probably a remnant of the 58m (32 fathoms) strand line (Maxwell, 1968). The sea floor shows a distinct declination eastwards to the outer reefs and in the back-reef area is deeper than that found further north. The depth of water is now greater than 36m and it is possible to distinguish the Marginal Shelf in Maxwell's terminology, as defined by the 36m and 92m (20 and 50 fathom) contours.

The depth of water in the channels between the reefs is largely unknown. Where data are available, the depth would appear to be similar to, or greater than, that of the back reef area. Marked exceptions occur where strong currents flow and deep channels have been cut by former rivers and subsequently scoured, as for example in Lowry Passage between Wilson and Rodda Reefs (13°57'S. lat.). The ends of the reefs normally descend very abruptly.

North of Olinda Entrance (11°14'S. lat.), the appearance of the outer barrier changes greatly, from "ribbon" reefs into "deltaic" reefs, thence into "dissected" reefs. The term "ribbon" reef is used in this paper in its most generalised sense to include all the elongate barrier and detached reefs of the Northern Region south of the deltaic reefs. It has none of the morphological implications that are associated with other names used in the literature.

MORPHOLOGICAL CHARACTERISTICS OF RIBBON REEFS

The enormous variability in shape, size and development of reefs within the GBR province have been classified by Maxwell (1968) into a scheme which associates the present surface appearance of reefs with developmental stages. Most of these developmental stages appear to be well established, at least in principal, and the scheme thus appears to have a general, functional application.

The stages of reef development indicated by Maxwell, represent the results of an interplay of all the factors, past and present, which influence the reef. In localities where these influences are approximately uniform all over, a round platform reef is formed. Continued expansion ultimately leads to the formation of a shallow lagoon, as conditions in the centre of the reef fall below those necessary to maintain coral growth. In other localities, where for example the bathymetry is limiting, reef expansion can occur only in certain directions. If this occurs along the shelf edge, the elongate reefs variously known as "wall", "linear" or "ribbon" reefs are formed. These reefs change, and are changed by, patterns of water movement. Strong currents flowing around the ends cause the ends to curve back, and this appears to lead to "prong and buttress" formation in the back-reef zone. Eventually the arms of the reef may join to form a lagoon. A number of other growth forms are described by Maxwell. As a result of continued growth, hydrological and biological conditions can change to such an extent that reefs appear to decay by some means, a process termed "resorption" by Maxwell.

The outer edge reefs are mostly elongate. They occur in an almost continuous series, separated by channels of varying widths as described below. Of the considerable variation in size and surface shape found amongst them, ten distinguishable types (elaborating Maxwell's scheme) can be distinguished (Fig. 3). They range from simple ribbon reefs (Types A and B) to closed ring reefs (Type C), a variety of plug reefs (Types H, J and K), and finally to a few reefs that show resorption-like decay (Type L). With the exception of the J-type plug reefs the different reef morphologies all appear to be elaborations of a basic unit - the short wall reef (Type A). Plug reefs develop in the openings between reefs or are remnants of earlier existing reefs. Coral growth occurs parallel with the current, and so leads to the formation of a triangular plug reef with the apex directed upstream.

The reefs lying between and including Opal Reef at the southern limit of the region and Cruiser Pass ($15^{o}41'$S. lat.) represent the transition from the scattered patch reef development, so characteristic of the Central Region, to the linear reefs that typify the Northern Region. Within this section the reefs are generally crescentic with, in some cases, considerable secondary coral growth in the back-reef area. They appear, however, to be undergoing some form of decay and are thus Type L. The orientation of these reefs would appear to be determined more by the influence of the S.E. trade winds than the edge of the continental shelf.

North of Cruiser Pass the outer reefs are orientated along the very edge of the continental shelf. Consequently they face in any direction between north and south east; they are not aligned according to dominant wind direction.

Several natural divisions occur in the line of reefs that mark recognisable changes in the pattern of reef development. These divisions correspond roughly with the five major water exchange sites referred to above. The line of reefs extending north from Cruiser Pass to Ribbon Reef consist of a series of elongate reefs, mainly Type D, showing thickening of the ends and some infilling of the back-reef area with secondary coral growth. The average length of these reefs is 7,930m (range 14,190-2,750m). The width at their narrowest central part ranges from 950-470m (mean, 720m). Ribbon Reef itself is a Type C reef. It is extremely long (35,030m), but only 1,300-610m wide. One, two or three plug reefs (Type J) are located in almost every channel between the linear reefs, some distance behind the reef front. A group of three plug reefs are grouped radially behind the channel at the south end of Ribbon Reef. The occurrence of these reefs is indicative of strong currents especially to the north and south of Ribbon Reef which inhibits E-W water flow by its great length. Between Lena Reef and the south end of Ribbon Reef the ratio between the length of exposed reef front, and the width of the channels between the outer reefs is 4.8:1.

The group of reefs which includes Yonge, Carter, Day, Hicks and Hilder Reefs between Ribbon Reef and two-mile Opening are Type E, with two exceptions. Hilder Reef, situated between Two-mile and One-and-half-mile Openings, is a large advanced plug-reef. The small reef in Cormorant Pass is a small plug-reef. Type E and H morphologies are relatively unusual in the reef line, being found nowhere as well differentiated as in this section. The marked curvings of the ends of these reefs and the extensive secondary broken reef formation in the back-reef area appear to be indicative of good water circulation. The Open Ring formation, in Maxwell's terminology, develops progressively northwards in this section, which suggests that this region is one of the major sites for water exchange between the inner reef and oceanic waters and that major currents pass through Two-mile and One-and-half-mile Openings. Possible influence of the S.E. trade winds is seen in the greater coral growth in the southern recurved arms. The seaward reef flats are 780-600m wide. Their average length is 6630m (range: 3460-8650m). The ratio between length of reef front and channel width from Yonge Reef to Hilder Reef is 5.4:1.

North of Two-mile Opening the reef continues as a series of narrow ribbon reefs, Types C and D, to Waterwitch Passage ($14^{o}12$'S. lat.). The strong currents at the southern end of this section and the long fetch over unobstructed water in the inner reef region for the prevailing S.E. trade winds, appears to have led to the inward extension of Jewell Reef and its continuation in a line traversing the inner shelf by Parke Reef and Waining Reef. These appear very similar to the linear reefs, Type A and Type B respectively, of the outer edge. The presence and shape of sand levees indicates that strong currents flow in a north-westerly direction between these inner reefs. A kite-shaped plug-reef (Type J) occurs as an outer reef off the northern end of Jewell Reef. It is followed by four elongate reefs, 3,780-13,580m in length which have an average width of 900m (range: 690-1,150m).

A single large irregular Type C reef, 49,050m in length with a variable width of 1,340-3,370m, separates Waterwitch Passage from the group of Passes from North-Broken Passage to Lowry Passage (collectively referred to as Melville Pass). This is the longest and widest reef in the Northern Region. Two reefs similar to ribbon reefs, of which the innermost is S. Warden Reef, have developed across the shelf off the southern end of this reef. Sand levees have formed behind and to the sides of the channels between them. The development of the narrow inner shelf reefs, the presence of sand levees and the breadth of the outer reef all indicate that strong currents flow north-westerly on the inside of this reef towards Melville Pass.

The three reefs situated in Waterwitch Passage and the six in Melville Pass are subject to strong currents, favourable for coral growth. Thus the central reef in Waterwitch Passage and Wilson Reef in Melville Pass are of the closed ring type where the ends of the reef have grown around to enclose a lagoon (Type G). Apart from the obvious plug reefs present in both passes, Tydeman, Davie and Rodda Reefs in Melville Pass, and the northernmost reef in Waterwitch Pass, all appear to be derived from short linear reefs (Type A), modified by considerable back-reef development, either in the form of thickening along the entire axis as soon in Tydeman Reef, or by prolongation of the back-reef to form a triangular reef with its base seawards (Type K). All these reefs have sand banks or unvegetated cays at their north-westerly ends.

The position and curvature of Corbett Reef and the backward north-westerly directed extension of the southern end of the first reef north of Rodda Reef suggest there are still strong currents flowing northwards inside the reef. North of this point, however, indications of strong currents gradually decline. Between Rodda Reef and First Three-mile Opening the reefs have a varied morphology but are mostly relatively wide (1,200-2,660m) and long (3,440-15,310m).

North of First Three-mile Opening, the barrier becomes composed of reefs of similar width following closely after one another. They are mostly Typ-s A-D, and are generally shorter and narrower than the reefs to the south (except for 27,800m long Tijou Reef). Excluding the various plug reefs and Tijou Reef, the average length of the linear reefs is 6,600m (range: 11,510-3,160m) and their average minimum width 830m (range: 1,150-590m). The channels between these reefs are significantly narrower than those of the southern sections. Secondary coral growth infilling back-reef areas is markedly reduced.

Strong tidal currents occur in Second Three-mile Opening. This is the only site of major exchange between reef and oceanic waters in this section, although strong currents also appear to occur in the narrow channels between the reefs. Two small Type K reefs, one unnamed, the other Franklin Reef, are situated in Second Three-mile Opening. These reefs, in common with the two larger Type K reefs (Ham and Derry) that continue the barrier line north, have sand banks on their west or north-west sides. A number of small plug reefs (Type J) have become established close to the rear margins of the reefs in the strong currents running through several narrow channels. These currents have in places led to marked but narrow rearward growth of the ends of some reefs, while in others the ends of the reefs have thickened. In some cases, e.g. Long Sandy Reef (12°31'S. lat.), the ends of the linear reefs remain unmodified. Presumably the currents round these reefs are slight. Several short linear reefs (Type A) show overall thickening to create short broad rectangular reefs, similar in appearance to those described above in Melville Pass and Waterwitch Passage, although smaller. These reefs suggest that great water movements and exchange occur in their vicinity.

In this section of the reef there appears to be a reduction in the total width of the channels penetrating the reef line. The ratio between the length of exposed reef front and the width of the channels is 9.1:1.

Lagoon Reef at the northern limit of this section is unusual. It is approximately triangular, has reef front along two sides, and has a deep lagoon towards its apex which is open to the sea. In some respects it resembles a large, well developed plug-reef, Type H. However, it is at about this point that the long linear reefs give out and the outer barrier continues as a series of short reefs which cease to show strong affinities with the elongate linear reefs to the south.

THE DELTAIC REEFS

Fig. 5 compiled from direct observation using SCUBA, is a three-dimensional reconstruction of the deltaic system. The following is an account of a transect across the deltaic pattern of deltaic reef 2.

At its northern end, the transect covered a terrain of soft calcareous sand and rubble from a depth of 18m. The slope to the first reef flat was covered by extensive outcrops of *Acropora intermedia* (Brook) and *Porites andrewsi* (Vaughan) at depths below 3m. Above 3m *A. palifera* became dominant and, with *Stylophora pistillata* (Esper), *Pocillopora verrucosa* (Ellis and Solander) and *A. humilis*, formed a coral cover of approximately 80% of the area of the first 100m of reef. Calcareous algae were abundant and the whole reef surface was well cemented.

Between 100 and 330m were three tributary channels, respectively 50, 20 and 60m wide. These channels had rugged, irregularly eroded surfaces of limestone and coral debris with little or no faunal or algal cover. The upper edges of the channels were covered with corals of the species dominant on the reef flats plus thickets of *Millepora tenera* (Boschma). Their floors were covered with sand and rubble except for the small channel which had a cemented limestone floor.

Between 330 and 720m there were two converging areas of reef flat which make up the southern and northern walls of the third tributary channel and the first main channel respectively. Coral cover on these flats was approximately 20% and was dominated by *A. palifera*, *A. humilis* and *Porites lobata* (Dana) with some *Stylophora pistillata*. The reef surface was very hard and well cemented by calcareous algae. Toward the edge of the main channel the reef became corrugated by small regular grooves about 30cm deep.

The deeper area between these reef flat areas, which represents an extension of the open sea and sea floor, was mostly flat and was covered with sand and rubble with large patches of blue-green algae and *Acropora* species.

The reef flats adjoining the main channels were similar to the first reef flat area described above. Coral cover decreased markedly with increasing distance from the channels. The transition zone between the reef flat and the deeper areas that are extensions of the open sea floor was composed mainly of poorly cemented reef with approximately 5% coral cover, dominated by *Porites* spp. and the hydroid *Agloaphania cupressina*. Below approximately 6m the reef surface became covered with soft calcareous sand and an almost continuous although sparse cover of *A. formosa* (Dana).

THE MAJOR CHANNELS

The major channels, reaching the reef front, are mostly uniform in size and general appearance. Those of the northern half of the deltaic system are up to 0.7km across and 5.5km long. Further south the channels become wider and shorter and the deltaic pattern less distinct.

Depth soundings taken along the centre of four channels (one channel south of deltaic reef 1, two south and one north of reef 2) indicated that their depths were mostly uniform throughout their length, with an overall range of 18-35m.

The sounding south of reef 1, reproduced here as Fig. 13, is characteristic. At the outer edge of each channel is a ridge connecting the two adjacent outer slopes. The ridge is saddle-shaped with the axis of the saddle lying along the reef front.

Tidal currents in the channel were very strong, especially within 2-3 hours of low tide when little water movement occurs over the reef surface. One estimate of 3.8m/sec was made from the "James Kirby" while maintaining a constant position inside the outer ridge on an ebb tide. On the ridge itself the current forms standing surface waves up to approximately 2m high. These waves appear in aerial photographs as finger-like projections from the channels for distances of up to 1.7km.

The surface of the outer ridge was hard and well cemented. To a depth of approximately 7.5m about 60% of the surface was almost exclusively covered with flat, encrusting _A. palifera_ colonies which gave the appearance of a flat, irregular pavement. Mixed coral species then occurred to a depth of 12m, at which point the coral cover was approximately 10%. Between 12 and 21m (on the outer slope of the outer ridge) the coral cover decreased to <1%; soft corals, especially _Lobophytum_, were dominant. Only occasional corals, mainly favids, were found below 21m; the still hard substrate had a sparse cover of filamentous red-brown algae, filamentous green algae, Halimeda and fine hydroids.

Various profiles of major channels were compiled. In each case the walls descended vertically to a depth of 12-19m, then curved in a regular fashion to form the channel floor at depths of approximately 25-33m. The vertical walls were always deeply pitted; sometimes the pits were in the form of horizontal, current-worn grooves up to 2m deep. The curved parts of the channel walls were mostly slightly pitted or smooth. The flat channel floors were mostly smooth and hard; in some places regular current worn undulations were formed, in others, ridges of coarse sand and/or rubble.

Small, elongate reef patches frequently occurred in the centre of major channels. Their bases are much more elongate than their tops, so much so that the bases of successive reefs appear to connect to form a central ridge running along much of the centre of most major channels.

A second type of reef frequently occurs at the backs of major channels where they fork or branch into smaller channels leaving roughly triangular reefs with sharply defined apexes pointing east, and irregularly shaped inner slopes. Many such reefs are illustrated in Fig. 5.

The apex of one of these reefs studied was similar to the eastern point of the channel reefs. It gradually sloped to a depth of 31m. To a depth of 2m, the coral cover was approximately 10% and consisted almost exclusively of A. palifera. The coral cover increased to approximately 60% at 2-10m depth with encrusting species of Millepora and Porites becoming dominant. At 10-18m the consolidated reef gave way to rubble at which point soft corals, especially Lobophytum became dominant. Few hard corals were observed below 26m.

The western side of this reef is well protected from wave action and currents and is essentially similar to the backs of the major reefs. The floor consisted of soft calcareous sand which sloped gently to a depth of 7.5m, 170m from the centre of the reef back. Very large massive Porites spp. and P. andrewsi colonies, occurred between approximately 50 and 170m. Beyond 170m from the reef back the depth increased and the substrate became a coral-free mixture of sand and rubble.

THE DISSECTED REEFS

The dissected reefs, as noted above, extend northward from the northern limit of the deltaic reefs for a distance of approximately 35km. Over this range they become progressively simplified in appearance, so that toward their northern end they resemble a continuing series of small elongate plug reefs.

Two reefs called "dissected reef 1" and "dissected reef 2", were selected for study. They both lie eastward of the Murray Islands and have approximate latitudes of $9^{o}53'$ S. lat. and $9^{o}50\frac{1}{2}'$ S. lat. respectively. Reef 2 is the northernmost major reef of the shelf edge system; reef 1 is a small elongate reef which is more representative of other reefs in the area.

Figure 6 is a three-dimensional reconstruction of some dissected reefs. They are not described here as they are north of the area under discussion.

DISCUSSION

The remoteness and inaccessibility of the northern barrier reefs are largely responsible for the lack of previous descriptions of them and for this reason they have been largely omitted from the discussions of earlier writers on the theory of reef evolution and even from more recent accounts of the GBR itself (notably Dakin, 1963; Maxwell, 1968; Bennett, 1971); Darwin (1842) mostly restricted his observations on the GBR to the conclusion that " ... if instead of an island, the shore of a continent fringed by a reef were to subside, a great barrier reef, like that of NE Australia would be the necessary result."

Yet Darwin's concepts of reef development have indirectly influenced all subsequent attempts to define and categorize reef systems within the GBR province. The most recent of these, Maxwell (1968), is generally applicable to the GBR if not to reef systems in general. Maxwell divided the GBR into the three Regions already noted, and each Region into six more-or-less bathymetrically defined, semi-meridional zones. Of these, the outermost is the zone of the "Shelf Edge reefs". These occur in the Southern Region as the "Pompey Complex" and in the Northern Region, the subject of the present study.

Ribbon reefs differ substantially from other reefs within the GBR province. Their position and general shape is determined bathymetrically, but is modified by various hydrodynamic influences which are mostly of their own making. Their surface features are further modified by the climate of the Region, a climate dominated by the Trade Wind system which generates a heavy oceanic swell for approximately 8 months per year.

As with their general appearance, the surface features of ribbon reefs are very distinctive, being above all characterised by extremely well defined zones. The zones of the reef front and the reef back are dominated by coral, usually the one polymorphic species, Acropora palifera, which forms much of the substrate and probably much of its volume also. The outer reef flats are markedly characterised by the absence of coral and, perhaps are even more remarkably by the absence of calcareous algae; certainly nothing resembling an algal ridge was observed.

Yonge Reef, east of Lizard Island, the only other ribbon reef to have been described (Stephenson et al. 1931), has been re-examined by the authors and others and will be re-described in detail elsewhere. However, it may be noted here that not all the major zones described by Stephenson et al. were noted on other ribbon reefs. Their description of the "reef crest" (corresponding to the outer reef flat of this paper) is appropriate. "A pavement of solid coral rock, swept clear of coral debris, over 3 miles in length and over 160 yards in breadth". Their "inner" and "outer" "moats" and their "outer ridge", representing very minor irregularities in the height of the reef surface, were not observed by the authors in other reefs and are not usually visible in aerial photographs. These, along with many other morphological features of ribbon reefs noted in this paper, await further, more detailed study.

The differences between the ribbon deltaic and dissected reefs appear to have both a bathymetric and a hydrodynamic origin. The deltaic and dissected reefs are basically extensions of the shelf edge reef system occurring beyond the influence of the Queensland Trench. They do not form the western rim of the trench as do the ribbon reefs and hence their outer faces do not plunge to great depth. Perhaps as a result they do not have the deep openings and passes which separate most successive ribbon reefs and which permit the passage of the tidal currents to and from the continental shelf. They form an effective 131km-long barrier to tidal movement. However, tidal range, which is uniformly near minimal for the GBR throughout the whole distance of the ribbon reef system, increases rapidly towards the Torres Strait (Maxwell, 1968). So does the volume of water involved, as the continental shelf widens over the area of the Torres Strait and the western Gulf of Papua. These factors combine to produce the very strong tidal currents characteristic of the whole Torres Strait region.

Clearly, the northern shelf edge reefs, which provide such a formidable obstacle to tidal movements, have their present morphologies largely determined by them. This applies especially to the deltaic reefs, where the barrier continues both to the north and south.

Reefs of the Pompey Complex in the Southern Region of the GBR have been described by Maxwell (1970) as being "deltaic", and certainly that term can be applied equally to both reef systems. Both are characterised by the presence of well defined channels containing very strong tidal currents. As Maxwell stated, the currents serve to scour the passages while the reef body serves to localise depositions which provide bathymetric elevations suitable for reef colonization.

In other respects, however, the Pompey Complex differs greatly from the northern reefs; primarily in being composed of a multitude of enclosed and semi-enclosed lagoons interspersed through a matrix of channels, reef zones of varying elevations and sand zones. Brief personal observation indicates that the major channels are not as steep-sided as those of the northern reefs; those investigated were asymmetrical, having western walls steeper than eastern ones, with currents running obliquely to them, over the reef flat. The single channel sounded had a relatively uniform depth of 98-109m throughout its central portion (i.e. about three times the depth of the northern reefs), and a very wide outer region rising to a relatively uniform 32m.

Soundings perpendicular to, and parallel with, the outer reef slope revealed a broad continental slope scoured to about twice normal depth seaward of the openings of major channels.

No other reef systems within the GBR province appear to have much in common with those described in this paper. None have similar bathymetric or hydrodynamic situations, nor have other reefs had a comparable evolutionary history. It is these three all-important factors, in combination, which have given the northern shelf edge reefs their present distinctive morphologies.

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LIST OF FIGURES

(abbreviated for use with the present extract)

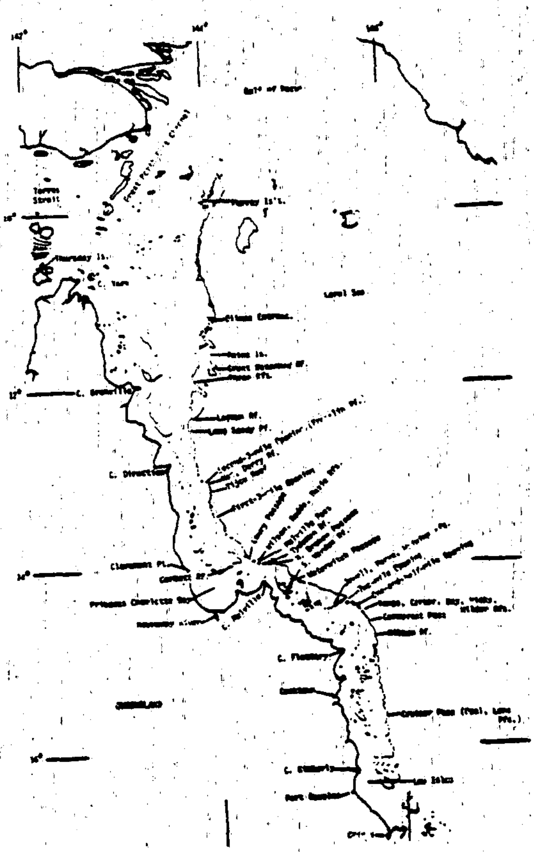

Fig. 1 Reefs referred to in the text

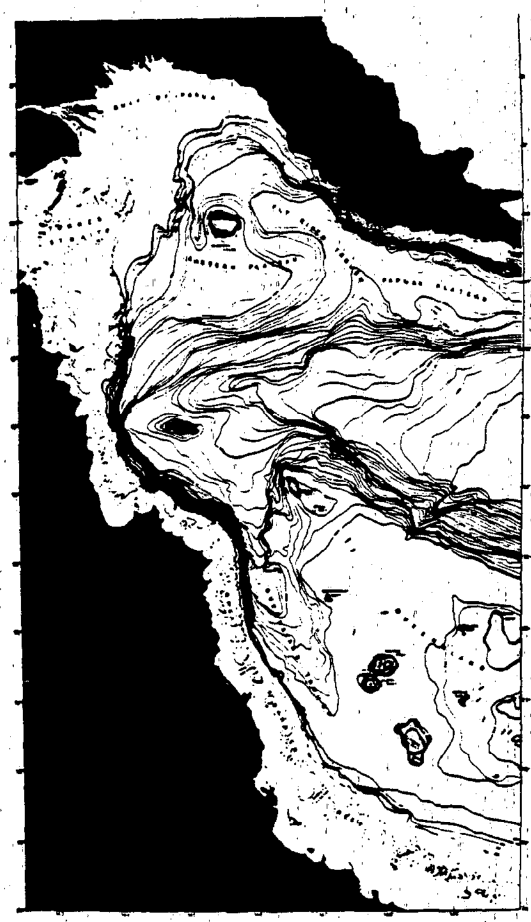

Fig. 2 Bathymetry of the western Coral Sea

Fig. 3 Morphological variation in outer edge reefs, elaborating Maxwell's (1968) classification (see text)

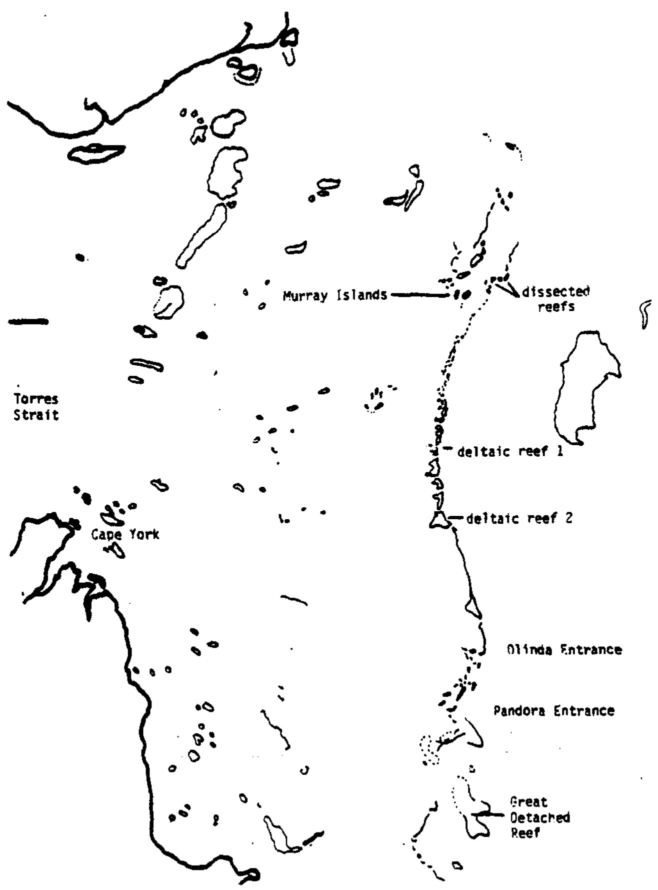

Fig. 4 Deltaic and dissected reefs referred to in the text

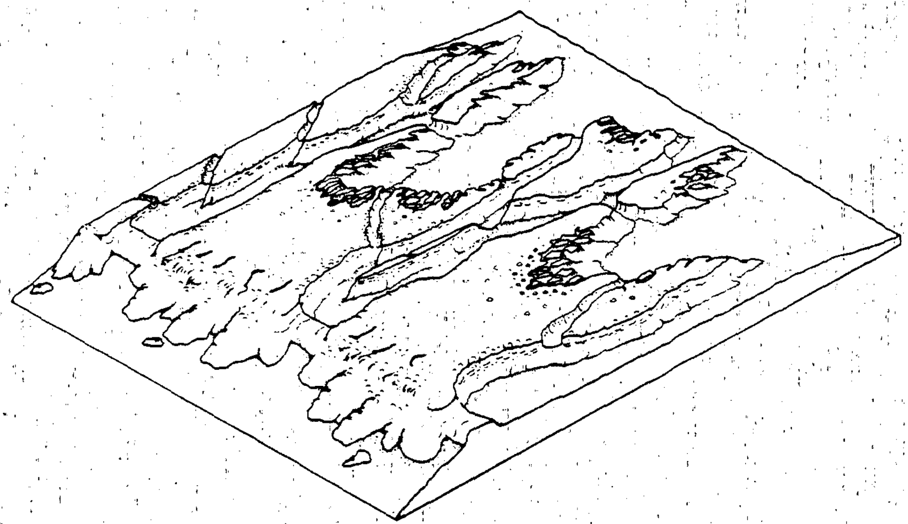

Fig. 5 Three-dimensional reconstruction of deltaic reefs

Fig. 6 Three-dimensional reconstruction of dissected reefs

LAND AND RIVERS SYSTEMS INFLUENCING THE GREAT BARRIER REEF IN THE LIZARD ISLAND-CAPE YORK AREA, NORTH QUEENSLAND

R.F. ISBELL

CSIRO Division of Soils, Davies Laboratory,

Townsville.

Abstract

The Cape York Peninsula catchments which drain to the Coral Sea are mostly small with the exception of those to the south of Princess Charlotte Bay. The region has a moderately high but strongly seasonal rainfall. Mainland geology is relatively simple and relief is generally low except in the central and south eastern parts. A number of diverse vegetation communities is present although woodlands and open forests predominate. The soils may be grouped into five major classes, almost all are of low fertility and many suffer from seasonal waterlogging.

The region has been little-modified by man, and although data are inadequate to give any indication of levels and kind of dissolved and suspended solids entering the sea, it seems likely that present mainland events are having little effect on the reef ecosystems, at least over the longer term. The likelihood of future agricultural and pastoral development in the region is discussed, together with possible effects this could have on the Great Barrier Reef.

I. Introduction

This paper is concerned with that part of Cape York Peninsula north of Lizard Island ($14^{\circ}35'$ S) which drains to the Coral Sea (Fig. 1). This area is approximately 41,000 km^2. A number of stream catchments are involved but with the exception of those draining into Princess Charlotte Bay, all are small and most streams are short. Much of the area has a low relief, consisting of mostly narrow coastal plains. The main exceptions are the hilly to mountainous areas which comprise much of the Pascoe and Lockhart River catchments, where the highest lands are commonly about 300 m and may rise to about 700 m, and a highland region in the extreme south east.

The entire region is very sparsely settled and by comparison with elsewhere in coastal Queensland, disturbance due to man is minimal. In recent years considerable areas in the north, center, and south east have been declared National Parks (discussed elsewhere in this Workshop), and for the remainder of the region sparse beef cattle grazing is the main form of land use. The only agriculture practised is restricted to a relatively small area near the headwaters of the Normanby River. Minor mining activity has occurred in a few localities in the past.

Insert Figure 1

II. Physical Environment

(a) Climate

The area has a monsoonal-type climate. Mean annual rainfall is mostly between 1500 and 1800 mm. The driest area, to the south of Princess Charlotte Bay, receives between 1000 and 1200 mm. The rainfall is strongly summer dominant and is highly reliable by Australian standards. A feature is the extreme falls that may occur over short periods due to the influence of tropical cyclones. Temperatures are high with an average daily summer maximum of 30°-32°C and an average winter minimum of 16°-20°C. Mean annual evaporation is of the order of 1500 mm. Additional climatic data are given by Bureau of Meteorology (1971).

(b) Geology

Cape York Peninsula basically consists of a stable shield of Precambrian metamorphic rocks, Middle Palaeozoic granites and lesser Upper Palaeozoic acid volcanics, overlain by gently dipping Mesozoic and Cainozoic sediments. In the southeast at the headwaters of the Normanby and Jeannie Rivers there are Middle Palaeozoic greywackes, siltstone and slate. The lower courses of all southern streams traverse Cainozoic sediments, while those streams to the north of the Pascoe River have catchments consisting almost entirely of Mesozoic and Cainozoic siliceous sediments. Of particular interest are the considerable areas of aeolian sand deposits - mostly in the form of elongate parabolic dunes with some ridges up to 30 m high - in the region to the north of Shelburne Bay and around Cape Flattery.

Additional details of the geology may be found in de Keyser & Lucas (1968) and Willmott et al. (1973).

(c) Vegetation

The plant communities of Cape York Peninsula have been described by Pedley & Isbell (1971) and Story (1970) has discussed the southern part of the area. A number of distinctive communities are present, they may be summarised as follows.

(i) Mangroves and salt pans.

These occur adjacent to the coast and or the tidal reaches of streams. The largest salt pan areas with their mostly bare surfaces (except for a few halophytes) occur fringing Princess Charlotte Bay and the Cape Melville-Cape Flattery part of the coast. Although mangroves (a considerable number of genera are involved) occur bordering most stream estuaries and tidal inlets, the largest areas are found around Newcastle Bay in the north and at the mouth of the Lockhart River.

(ii) Grasslands

Only small areas occur and they are mainly confined to low-lying marine plains dominated by *Sporobolus virginicus* at the base of Princess Charlotte Bay. More limited grassland areas adjacent to the Lockhart River are dominated by *Imperata cylindrica* var. *major*, these are probably induced and maintained by fire. Small grassy "balds" on the mountainous plateau north east of Coen probably have a similar origin.

(iii) Heath

Appreciable areas of both closed and open heath ranging from about 1 to 2 m tall and with some emergent shrubs of *Grevillea glauca* to 4 m occur in the far north and south east. A large number of species are present but the ground cover is very sparse and the main constituent is *Schoenus sparteus*.

(iv) Woodlands

These are most common in the south and there are a number of distinctive communities. The lowest and more open are those with *Melaleuca viridiflora* and *Petalostigma banksii*. Other woodlands are mainly dominated by eucalypts. The most extensive are those with *E. leptophleba*, *E. polycarpa* and *E. alba* and occur mainly in the Jeannie River catchment. Small areas of an *E. cullenii*-*E. dichromophloia* woodland occur in the Olive-Pascoe Rivers catchment.

The ground cover of the Melaleuca woodlands is moderate but very variable and annuals are often prominent. In contrast the eucalypt communities tend to have a denser cover of perennial grasses.

(v) Open forests

Most of these are dominated by eucalypts and range in height from about 10 to 20 m; many are layered. Most common in the south is an E. tetradonta-E. sp. aff. polycarpa community which is moderately dense. A similar community is prominent in the north but possesses a dense shrub layer 1-2 m tall. In both instances the ground cover is usually fairly open. In contrast there are also in the north of the region a number of areas that have a layered mixed low open forest; a number of species are involved but none has a high constancy. The ground cover is usually fairly open. In the Lockhart River basin there are distinctive low open forests of Melaleuca viridiflora with associated Acacia brassii and Grevillea glauca.

(vi) Vine forests

These are relatively restricted in the region, being confined to the Lockhart-Olive-Pascoe Rivers catchments and small areas in the far north. Those in the former area are best known. Here, at lower altitudes semi-deciduous mesophyll vine forest occurs, and is replaced above about 500 m by notophyll vine forest with emergent Araucaria cunninghamii. Steep upper slopes support drier and depauperate types in which Acacia aulacocarpa is common.

Although climatic factors largely determine what plants occur in the area, edaphic factors to a large extent control the distribution of plants within the area. Because almost all soils of the region are characterised by low levels of chemical fertility it seems likely that the main edaphic factor involved is soil moisture.

A severe deficiency occurs during the latter part of the dry season in many soils while excess soil water is a feature during the wet season. Fire is also an important factor affecting plant distribution, although its role is difficult to assess. At present much of the region is burnt every year, with the exception of the fire-sensitive vine forests and to a lesser extent the heaths. The vegetation as a whole is so well adapted to fire that frequent burning must have been a feature of the environment for much longer than the period of human occupation.

Most of the plant communities have been little-disturbed by man and the pressure of grazing by native or introduced animals is low, particularly in the north, and the vegetation has probably been little-affected. Small areas of vine forest have been cleared in the Pascoe-Lockhart Rivers catchment, and also small areas of woodland near the headwaters of the Normanby River.

(d) Soils

The soils of Cape York Peninsula have been mapped by Isbell *et al*. (1968) and the relationships with the vegetation have been discussed by Pedley & Isbell (1971). The soils may be grouped into five broad classes. Names in italics are those of Stace *et al*. (1968), other soil names are those of Northcote *et al*. (1975).

(i) Shallow stony soils

These are mostly *lithosols* and are widespread on many of the metamorphic and igneous rocks, on some sandstones, and on the Palaeozoic sediments in the south. They usually occur on upland sites and soil texture is largely governed by the nature of the underlying rocks. The more siliceous parent materials give rise to sandy soils whilst loamy textures are more common on the less-acid rocks.

(ii) Deep sandy soils

These are most common on the aeolian sand deposits, on some deeply-weathered granitic rocks, on some of the Mesozoic sandstones, and on pediments and fans. Some soils have developed podzol features while others are siliceous sands with minimal profile development.

(iii) Fine-textured soils

Two main forms occur. On most of the salt pans the soils are typical solonchaks. They are usually clayey and highly saline and often become strongly mottled at depth. They have a dominantly bare soil surface often with a white salty crust, and a saline water table is usually present at about 0.5 m. Thus the solonchaks are almost sterile soils. The soils of the mangrove areas mostly consist of fine-textured often peaty sediments, usually stratified, that have undergone little pedological development. The grassland areas adjacent to the southern part of Princess Charlotte Bay have cracking heavy clay soils that are poorly drained and often are covered with surface water during part of the wet season period.

(iv) Soils with gradational texture profiles

These show gradual increase in texture with depth; there are two major groups. Those with massive, porous subsoils - red earths, yellow earths, grey massive earths - are widespread. In the south they have formed on deeply weathered Cainozoic and less commonly Mesozoic sediments, and alluvium. In the far north yellow and to a lesser extent red earths are derived from Mesozoic sandstones. All these soils are deep, often > 3 m, and they may have varying amounts of ironstone nodules or laterite in the profile.

The other major group is characterised by red or yellow clayey subsoils - often mottled - which have a moderate grade of structure. Both red (red podzolics) and yellow (xanthozems) forms occur mainly in the higher-rainfall central parts of the region on igneous or metamorphic rocks. They are moderately deep to deep soils (1-2 m), often with relatively high organic matter contents in their surface horizons.

(v) Soils with texture-contrast profiles

This group has sandy or loamy surface horizons overlying medium or heavy clay subsoils and hence internal drainage is slow. They are widespread on the lowland alluvial areas adjacent to Princess Charlotte Bay; most are solodic soils, their subsoils are often alkaline and free carbonate may occur. In some wetter sites, e.g. adjacent to the lower reaches of the Lockhart River, the soils are acid and their subsoils are strongly gleyed (gleyed podzolics). Throughout the metamorphic-igneous rock upland areas small areas of mostly shallow soils with red or yellow clay subsoils (red and yellow podzolics) are common on more gentle slopes.

Some general comments on the soils may be made. While most of the soils of the upland areas are shallow, those under vine forest are deep, as are most other soils throughout the region. With the exception of some of the poorly-drained lowland sites, many of the soils elsewhere are permeable, usually strongly leached, mostly acid, and free of salt. Almost all soils in the region are of low chemical fertility, the major exception being a small area of friable red soils (kraznozems) derived from basalt at the south eastern margin of the Normanby River catchment.

Although many of the soils are moderately to highly permeable, the high rainfall concentrated in a short wet season period leads to extensive waterlogging. The main exceptions are those soils on steeper slopes, the red earths, most of the siliceous sands, and the soils under vine forest.

III. The Drainage Basins

(a) Physical Features

Fig. 1 shows the drainage basins adopted by the Australian Water Resources Council (1976). Some of their general physical features are given below.

(i) Jacky Jacky Creek

The basin is of low relief and all streams are short, most drain Mesozoic sandstones with deep red and yellow earth soils supporting layered open forest with small areas of vine forest and heath. In the south of the basin some short streams drain the dune fields.

(ii) Olive-Pascoe Rivers

This basin is diverse in that several distinctive catchments are involved. The Olive River catchment is very similar to those in the Jacky Jacky Creek basin, whereas the larger Pascoe River catchment has much greater relief and a more diverse physical environment. Much of it is hilly to mountainous with igneous and lesser metamorphic rocks. Many soils are present although lithosols occupy a considerable area. The vegetation is dominated by eucalypt woodlands and low open forests although small areas of vine forest and heath also occur.

(iii) Lockhart River

Here again there is some catchment diversity. All major streams rise in areas of considerable relief and then traverse narrow coastal plains before reaching the coast. The upland areas have granitic or metamorphic rocks with moderately deep xanthozem or red podzolic soils that support vine forests. The lower reaches of the streams traverse alluvial plains with *Melaleuca viridiflora* low open forests on deep texture-contrast soils.

(iv) Stewart River

This small basin is very similar to the southern part of the Lockhart River basin although headwater relief is somewhat lower. It is a drier catchment and this is reflected in the soils and vegetation of the upper reaches of the major streams. Lithosols with eucalypt woodlands are most common on the upland areas. At lower altitudes are pediments with deep sands, and old fans with red earths and eucalypt open forest. The alluvial coastal plains have texture-contrast soils and *Melaleuca* woodlands.

(v) Normanby River

This is the largest basin and it also has the lowest rainfall. Relief is generally low throughout with the exception of the headwaters of the Normanby River, and much of the catchment consists of gently undulating plains. The higher areas in the south east are mainly Mesozoic sandstone mesas that are often dissected to form narrow and deep valleys. Soils are shallow to moderately deep sands with open forests dominated by *Eucalyptus dichromophloia* and *E. phoenicea*. In addition there are other hilly areas of Middle Palaeozoic sediments with shallow stony soils and eucalypt low woodlands.

The headwaters of streams to the south and south west of Princess Charlotte Bay - e.g. the Kennedy, Hann and Morehead Rivers - are much lower. Here the Mesozoic and Cainozoic sediments give rise to mostly deep sandy soils and red earths, and the vegetation is usually eucalypt woodland. The middle reaches of most streams are flanked by extensive old fans or remnants of Cainozoic sand and gravel deposits which have very deep red earth soils and eucalypt open forests.

This basin has large areas of alluvial plains adjacent to the middle and lower reaches of all streams. The soils range from extensive areas of yellow earths and grey massive earths to solodic soils and some cracking clays adjacent to the coast. Vegetation ranges from Melaleuca and Eucalyptus low woodlands to grassland.

(vi) Jeannie River

This basin has few major streams and all are short. They rise in highlands of the same Mesozoic sandstone and Palaeozoic sediments as do the headwaters of the Normanby River. The narrow alluvial coastal plains have mostly yellow earths and some solodic soils with eucalypt woodlands. In the extreme south east are dunefields with deep sands similar to those in the north of the region.

(b) Hydrological Features

Table 1 gives a number of characteristics for the basins (Australian Water Resources Council 1976). Included for comparison are the Burdekin and Fitzroy Basins, these two are the largest rivers influencing the Great Barrier Reef. The Johnstone River basin which drains one of the highest rainfall areas in north Queensland is also included. It may be noted from Table 1 that with the exception of the Normanby basin, all the others in eastern Cape York Peninsula are small catchments. Their estimated total yields are relatively small although average annual run-off is moderately high by Australian standards.

Insert Table 1

Although data are largely lacking for the Cape York Peninsula streams, it should be remembered that as elsewhere in eastern Australia, discharges are subject to considerable variation. Thus the maximum annual discharge may be from 200 to 400 per cent of the average annual value, and monthly maximum discharges are of an order of several thousand per cent of average monthly values.

There are too few analyses available for the region to give an indication of levels and kind of dissolved and suspended solids, particularly when it is realised that considerable variation will be experienced at different times of the year, and often within short periods. However, some idea of possible values may be gained from the results of Douglas (1967 a, b, 1969) who has studied stream catchments further south in north Queensland. He found that in high rainfall granite catchments with complete vine forest cover, solute content was low at all times, rarely exceeding 60 ppm. Suspended sediment concentration was also low, although subject to significant variation. The most important factor affecting total sediment load in such catchments is the frequency of intense storms, and evidence indicates that such events have even greater significance in non-vine forest catchments, particularly if they occur when ground cover has been reduced by overgrazing or temporarily removed by fire.

IV. Mainland Influences on the Great Barrier Reef

Although the outer Reef is at least 50 km offshore for much of Cape York Peninsula, many smaller reefs occur much closer to the coast. Hence it is probable that mainland events can have some influence on at least the closer reefs. The most likely effects on coral reef ecosystems are those due to excess freshwater inflow, sediment load, and deleterious effects due to fertilizer and pesticide residues.

It has already been pointed out that by comparison with other coastal Queensland regions, disturbance by man in this area is minimal. Agriculture and the use of improved pastures are extremely limited, hence any effects due to fertilizers and pesticides are likely to be negligible at present.

The excess freshwater inflow and sediment load factors are closely related because there is a general relationship between suspended sediment yield and run-off (Douglas 1967 a). However, because the greater part of the area concerned has been little-modified by man it seems safe to conclude that present mainland events are having little effect on the reef ecosystems, at least over the longer term.

It remains to look at possible future developments in the mainland region. Obviously any agricultural, pastoral or mining developments that lead to increased run-off and erosion could have an effect on total freshwater discharge and amount of suspended sediment carried to the sea. Gilmour (1971) has demonstrated that in some north Queensland forestry areas poor logging practice can cause a marked increase in sediment load as some vine forest soils are particularly susceptible to erosion if the vegetation is removed.

Any agricultural development based on annual cropping is likely to present a serious erosion hazard unless adequate safeguards are maintained. This is not so much a matter of erosion-susceptible soils but more a consequence of intense storm rains when land is bare prior to sowing. Increased stocking rates on existing native pastures could also lead to greater run-off and erosion, but this seems unlikely to occur in view of the extremely poor quality native pastures which barely maintain present low stocking rates. The sowing of improved pastures, which are largely dependent on some fertilizer input and may or may not involve timber clearing, will probably not lead to increased erosion if successfully carried out because the resulting increased plant cover can be expected to reduce run-off.

Future agricultural and pastoral development in the region is dependent on a number of factors, and the more important of these are economic. The region is remote in terms of source materials and markets, is largely lacking in any infrastructure, and hence development costs, particularly those involving transport, are high. Soil fertility is generally low and hence agriculture and any more-intensive pasture development will require high fertilizer inputs. A more likely possibility involves the upgrading of native pastures through use of legumes better adapted to conditions of low soil fertility, but even this will probably require some minimum input of phosphorus fertilizer and a marked improvement in the present economics of the beef cattle industry.

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Table 1

Some hydrological features of the drainage basins

Drainage basin	Area (km^2)	Average annual discharge ($m^3 x 10^6$) Fresh	Brackish & saline	Total	Average annual run-off (mm)
1. Jacky Jacky Creek	2770	1540	570	2110	762
2. Olive-Pascoe Rivers	4350	2730	140	2870	660
3. Lockhart River	2825	1500	200	1700	602
4. Stewart River	2795	1120	240	1360	486
5. Normanby River	24605	7510	20	7530	306
6. Jeannie River	3755	1900	650	2550	679
Johnstone River	2330	4470	550	5020	2155
Burdekin River	129,860	8520	250	8770	68
Fitzroy River	142,645	5940	50	5990	42

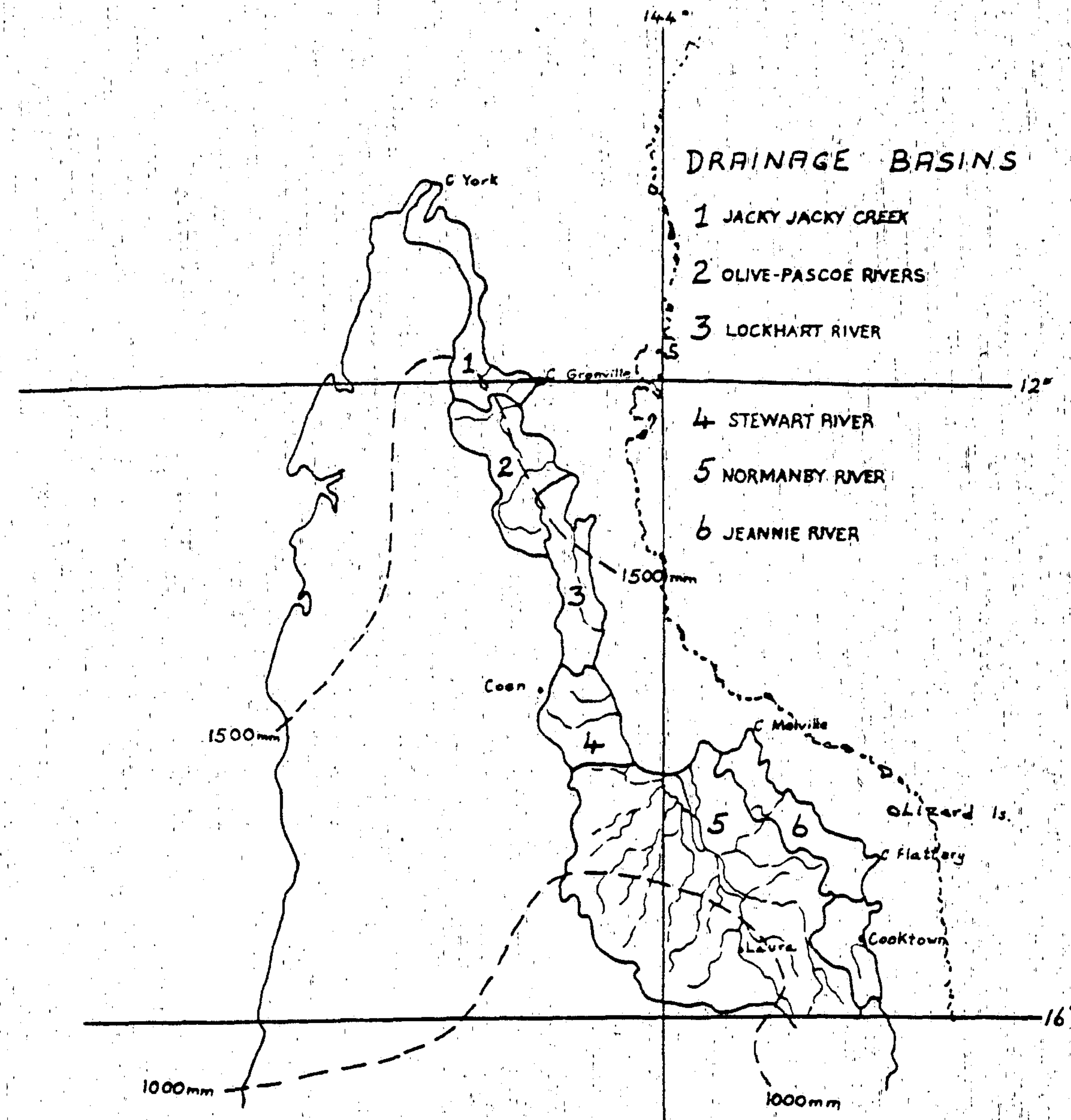

Fig. 1. Drainage basins of eastern Cape York Peninsula.

NATIONAL PARKS IN THE AREA AND ADJACENT AREAS

by

Dr.G.W. Saunders, Director, National Parks and Wildlife Service of Queensland

INTRODUCTION

The National Parks and Wildlife Service is the Queensland Government authority responsible for nature conservation on the land mass and islands that make up the State of Queensland. This responsibility in the case of land is presently confined to national parks, environmental parks, and fauna reserves. In the case of native fauna responsibility extends over all lands within the State. In the case of native flora, outside parks and reserves it is limited to gazetted species on some lands.

The region identified for consideration at this workshop is of major significance for nature conservation purposes. It contains widespread and diverse natural areas which on present world standards must be regarded as almost pristine.

EXISTING NATIONAL PARKS

A. ISLANDS

Hope Islands N.P. 151. *Government Gazettal 2.12.39.*
Area: 430 acres (174 hectares)
35 km S.E. Cooktown.

Three Islands N.P. 150. *Government Gazettal 2.12.39.*
Area: 100 acres (40.47 hectares)
9 miles N.E. Cape Bedford.

Two Islands N.P. 149. *Government Gazettal 2.12.39.*
Area: 36 acres (14.57 hectares)
7 miles S.E. Cape Flattery.

Significance

- all representative of an island formation consisting of:
  - vegetated sand cay
  - shingle rampart
  - mangrove swamp.
- southern extremity of this type of system marked by Low Isles.
- Hope Islands - known breeding area of Torres Strait Pigeon.

Lizard Island N.P. 153. Government Gazettal 2.12.39.
Area: 2,500 acres (1,012 hectares)

Significance:

Historical - 12 August 1770 Captain James Cook discovered passage through outer barrier from summit.

2 October 1881 Mrs.Watson threatened by Aborigines left the island in beche-de-mer tank.

Remains of stone house still exist, thought to have been Watson residence.

Vegetation - unusual variety of vegetation for an island in that area.

Physical - no other island in northern area of such structure or height.

Fauna - unusual number of reptiles for an island so far offshore.

Background:

Physical - 20 miles N.E.Cape Flattery. High, granite, continental island. Maximum altitude 360 metres.
5 land systems
- granitic soils
- siliceous sands
- calcareous coastal sand dunes
- freshwater swamps
- mangrove vegetation

Flora - 11 distinct plant communities
communities changed little since Cook's visit 1770
flora similar to comparable sites on Cape York Peninsula and Arnhem Land
no endemic species
60% of island is treeless grassland *(Themeda)*

Fauna
16 species of reptiles (C. Limpus 1977)
Cook named island after plentiful number of lizards seen
22 sp. seabirds and waders (S. Domm 1977)

History
European
1770 Cook "Endeavour"
1819 King "Mermaid"
1820 King "Mermaid"
1821 King "Bathurst"
1839 Stokes "Beagle"
1844 Blackwood) "Fly"
MacGillivray)
1848 Stanley) "Rattlesnake"
MacGillivray)
1872 Mosesby "Basilisk"

all stopped at Lizard during charting and biological expeditions of Queensland coast.

2nd October 1881 Mrs. Watson fled from island in beche-de-mer tank with son Ferrier and Chinese gardener: not found until 19 January 1882 on No.5 Howick Island - died of privation.

History

Aboriginal — Known as "Dyiigurru" in local language (Guugu-Yimidhirr) claimed jointly by three landholding units from opposite mainland.
Possible ceremonial significance re stone arrangements and attack on Mrs. Watson.
Seasonal food source re middens.

Present day

Research Station-
Special Lease No. 37520 granted 1st July 1973 over approximately 5.34 ha.
to Australian Museum as Trustee of Lizard Island Research Station.
Ideal site for study of marine and terrestrial systems of northern Great Barrier Reef:
within 15 mile radius most of the reef and island types characteristic of entire G.B.R. province are found.

Tourist

Resort - Special Lease No. 33210 granted 1 September 1967 over approximately 19.84 ha.
to Lizard Island Pty. Ltd. for resort.
Also special leases for airstrip and water supply.
Resort open by end of 1974.

Turtle Group *N.P. 148. Government Gazettal 2.12.39.*
Area: 225 acres (91.05 hectares).

Significance

Physical — of similar structure to Hope, Two, Three Islands.
Unusual formation in that mangroves have grown around the central sand cay rather than in lee of shingle rampant.

Background — 6.9 miles N. Point Lookout.

Possession Island *N.P. 23. Government Gazettal 17.9.77.*
Area: 510 hectares.

Significance

Historical — Marks the beginning of Australia as a nation.
22nd August 1770 Captain James Cook took possession of the whole eastern coast from the latitude above to New South Wales for British Crown.

Background

- island consists of - a low ridge aligned N.E. to S.E.
  sandy beaches on S.E. and N.E. sections
  rest of coastline - small sandy beaches

rocky outcrops
mangroves
mudflats

Vegetation   low sclerophyll
mangrove swamps on centre of eastern section

History
- gold discovered 1896 by J.T. Embly
- reefs worked 1896-1907 to depth of 60 feet
- 3365 tons mined for 2480 oz. bullion

prior to gazettal:
- 256 ha. leased by Cape York Pearling Co. Pty.Ltd. Lease was to have expired 1984.
- 4 ha. Scenic Reserve plus monument erected by Federal Government. Cancelled 10 September 1977 G.G.
- rest vacant Crown land
- whole of island a provisional gold and mineral field until 29 October 1977 G.G.

Flinders Group - N.P. 3. Government Gazettal 12.2.39.
Area: 7320 acres (2962 hectares)

Significance
Aboriginal sacred sites - decorated shelters
- burial sites

Background - 16 miles W. Cape Melville
- consists of 5 islands - Flinders
Stanley
Blackwood
Maclear
Denham
- in 1937 Flinders Island was a transhipping station for passengers and cargo carried by S.S. Wandana for Point Stewart. Transport to port was then via lugger.

B. MAINLAND

Starcke N.P. 215. Government Gazettal 5.11.77.
Area: 7960 hectares.

Significance
1. Rugged compact area of high scenic value containing a variety in geology, soils and vegetation types.
2. Preserves a small sample of plateau and escarpment type sandstone scenery at its wetter range.
3. Contains vegetation types uncommon on the Peninsula.

Background

Geology Patchwork of various metamorphic rocks with minor basalt, and remnants of a former sandstone layer as broken capping. Maximum elevation 490 metres.
Sharp changes on eastern side from sea level to 455 metres.

Flora Higher sandstone plateaux carry heath and shrubland elsewhere heavily vegetated ranging from grassland to a number of types of well-developed rainforest and closed sclerophyll communities.
Northern limit of *E. tereticornis* occurring in habitat type and in association with peculiar range of species not discovered elsewhere on Peninsula.

CAPE MELVILLE N.P. 4. Government Gazettal 27.10.73.
Area: 16,470 hectares.

Significance

Scenic
1. beaches
2. Melville Range - many miles of range separated by narrow bands of low vegetation. Unusual granite boulder formations with no covering vegetation.

Vegetation
1. Broad flat plain heavily wooded with low forest to the west of the Range.
2. Minor tableland formation supporting low evergreen scrub north of Abbey Peak in the south western region.
3. Rainforest vegetation developed on basalt in the southern region.

Historical
1. Monument marking disaster of the late 1800's when a large pearling fleet was wrecked by storms and several people lost their lives on the western shores of Cape Melville.

Extension

Government Gazettal 29.10.77. Area: 19,700 hectares bringing total area of N.P. 4 to about 36,000 hectares.

Significance - to include a number of important vegetation types absent or poorly represented in existing national park.

1. Areas of medium to tall *Eucalyptus tetrodonta* forest in basin of Eumangin Creek and on colluvial material of western side of Melville Range.
2. Extensive areas of heath and shrubland dominated by *Grevillea pteridifolia* between southern extremity of Melville Range and right bank tributary of large N.S. creek known as Muck River.
3. Complicated patterns of heath, shrubland and low layered vegetation developed on young quartose sand dunes occupying most of the southern half of the proposal.

4. Two large swamps fed by water from sand dunes situated on Muck River: carrying extensive swamp forest of a complexity and degree of development occurring nowhere else between Point Lookout and Rocky River at southern end of McIlwraith Range.

IRON RANGE N.P. 8. Government Gazettal 24.12.77.
Area: 30,800 hectares.

Significance

1. Contains largest remaining area of lowland rainforest to be found in Australia; almost completely free from disruptive influences of cyclonic winds and human activities - of international scientific interest.

2. Contains a large number of plants and animals not recorded elsewhere in Australia, including many New Guinea species.

3. At least 10% of flora collected represents unknown or undescribed species.

4. Aesthetics - colourful forests and wildlife
   - abundant freshwater streams
   - wild coastline.

Background

Flora: 4 classifications of rainforest vegetation:-
(a) *Blepharocarya* sclerophyll vegetation - vine forest
(b) Semi-deciduous mesophyll vine forest
(c) Vine thickets
(d) Sclerophyll vine forest complexes of coastal country.

JARDINE RIVER N.P. 26. Government Gazettal 5.11.77.
Area: 235,000 hectares.

Significance

1. Jardine River is Queensland's largest perennial stream and yet the whole of its catchment area is in virgin condition.

2. Unparalleled reserve in Queensland of a large virgin wilderness in the high rainfall belt.

3. Contains vast areas of wetland country, perennial rivers and streams - important resource for future wilderness type recreation.

4. Preservation of Jardine River - in a continent where such streams are a rarity.

5. Limited exploration has revealed unique forests - complex of constantly changing vegetation patterns.

6. Consists of the largest development of medium to tall mangrove forest in Queensland.

7. Escape River area of historical significance; Jardine Brothers, R. Logan-Jack, Kennedy.

ARCHER BEND N.P.3. Government Gazettal 12.11.77.
Area: 166,000 hectares.

Significance

1. Preserves a complex of the vegetation associations of the levee banks and flood plain of one of the larger rivers of Cape York Peninsula.

2. Contains river scenery of the Peninsula at its best.

3. Doubtful that a number of the significant vegetation types represented are included in any other national park.

Background

Consists of

(a) Broad bands of alluvial flats of the Archer and Coen Rivers.

(b) Woodland and savannah developed on heavy clays and loams of shale and mudstone formations.

(c) Low ridges of sandstone with minor ironstone carrying *Eucalyptus tetrodonta* - *E. nesophila* forest community at S.W. border.

Flora :

Ranges from: tall gully rainforests of the levee banks to "thorn scrubs", eucalypt and melaleuca woodland.

MITCHELL AND ALICE RIVERS N.P. 5. Government Gazettal 29.10.77.
Area: 37,100 hectares.

Significance

1. Affords a cross-section of the woodland and grassland vegetation of the extensive alluvial plains of the lower rainfall regions of the Peninsula.

2. Scenic - permanent water and gallery forests of the large streams.

Background

Vegetation on further inspection expected to be different structurally and in a number of floristic aspects from the major vegetation types of other Peninsula national parks.

STAATEN N.P. 2. Government Gazettal 12.11.77.
Area: 467,000 hectares.

Queensland's second largest national park. This substantial area of typical lower Peninsula Gulf lowlands provides a viable sampling of the range of ecosystems occurring along and adjacent to the Gulf flowing rivers. This includes extensive areas of *Melaleuca viridiflora* and areas of gallery rainforest and flood plain vegetation along both sides of the Staaten River.

PROPOSED NATIONAL PARKS

The following areas are proposed for national park or similar reservation or warrant special consideration within the terms of existing land tenure.

A. ISLANDS

RAINE ISLAND AND PANDORA CAY *Area : 28 hectares.*

Significance

Fauna — Largest, densest green turtle rookery ever recorded in the world.
Of international significance as declining resources in other countries.
Only known breeding site for: red-footed gannet
red tailed tropic bird
Trinidad petrel

Background

Fauna — 1974/75 rookery size exceeded 100,000 turtles
1976/77 rookery size exceeded 12,000 turtles

Significant interchange by turtles between Raine Island and Pandora Cay.

Supports bird population probably exceeding 25,000 at certain times of the year.

Nankeen night heron normally nests in trees is a ground nester on Raine.

Historical -

Shipping beacon erected 1844
Guano extracted 1890-1892
1815 Raine "Surry" named island

1843	Blackwood) Beete-Jukes)	"Fly"
1844	Blackwood) Beete-Jukes)	"Fly" to construct beacon
1845	Yule) Sweatman)	"Bramble"
1874	Nares) Mosley)	"Challenger"

B. MAINLAND

LAKEFIELD AREA

Significance

1. Central location in relation to other national parks in Cape York for establishment of management facilities for the whole of the peninsula.

2. Wetlands - most extensive series of lakes of this kind in the Princess Charlotte Bay region.
Abundance of associated wildlife.
All major streams flowing into Princess Charlotte Bay coalesce on Lakefield and form a vast flood plain.

Normanby)	
North Kennedy)	plus tributaries
Hann)	
Morehead)	

3. Marine plains - grasslands occupy $^1/3$ of the northern end of the property.

Vastness broken by spectacular palm *Corypha elata* forming scenic relief of a type not found elsewhere in north Queensland.

4. Salt flats The southern end of Princess Charlotte Bay has the greatest development of salt flats in Queensland outside the lower Gulf of Carpentaria.

Between the North Kennedy and Normanby Rivers tidal influence ranges over 10 kilometres.

5. Wildlife Abundance of wildlife associated with permanent lagoons.

Occurrence of rare Golden-shouldered parrot *Psephotus chrysopterygius* expected to be associated with extensive areas of Melaleuca woodland at the western and southern boundaries.

6. Visitation Most accessible part of the Cape York Peninsula.

Usually larger number of visitors than any other region of the peninsula.

7. Scenic River and lagoon scenery.

Series of flat topped hills rising starkly from the Normanby Plain.

Jane Table Hill 160 metres and the monsoon forest on upper slopes dominate the landscape of the southern shores of Princess Charlotte Bay.

McILWRAITH RANGE - NESBIT RIVER AREA

Significance

1. An essential area for which there can be no substitute if there is to be a serious attempt to preserve the major vegetation types on Cape York Peninsula.

2. Contains the Peninsula's richest biological resources along with Iron Range area.

3. Scenic wilderness resource - mountains, gorges, waterfalls, forests and plains.

4. Immense variety of flora and fauna - one of Australia's richest future fields for biological exploration.

5. Opportunity to preserve a continuous spectrum of the complex of rainforest and sclerophyll type vegetation, on a range of soil types, from sea level to extensive higher altitude plateau.

Background

Flora

(a) high plateau rainforest - investigation so far indicated differences in many important respects from Iron Range area - occurring at 450 metres.

(b) low layered forests of *Melaleuca viridiflora*
- forest form rarely covers extensive areas
- unusually large number of associated species.

(c) grassland communities of lower Nesbit occur nowhere else except along the Lockhart River.

OLIVE RIVER - CAPE GRENVILLE AND ADJACENT ISLANDS

(a) Olive River

Significance

1. Contains most concentrated and varied wetland scenery on the Peninsula.

2. Scenic resource - sand dunes, vegetated and moving
   - lakes, lagoons, littoral aspects

3. Together with Jardine River National Park it will help provide a significant sample of the range of vegetation on the extensive sand dune masses of the Peninsula east coast.

Background

Contains samples of all major wetland types, both saltwater and fresh, to be found in wetter country of eastern Cape York:

freshwater swamp forests
open lagoons
sedge swamps
billabongs
heath swamps
perched dune lakes
bogs
mangroves
saline and brackish swamps

The area is of mineralogical interest for silica sand and coal.

(b) *Cape Grenville*

Geology — Great number of rhyolitic, volcanic and pyroclastic rock types in a relatively small area.

Scenic — Rocky headlands and sandy beaches.
Surrounding archipelago of small rocky islands - Hicks, Clerke, Penny and Nab, Orton, Gore, Haggerstone Islands.
Fringing coral reefs.
Low heath vegetation of Cape and islands afford excellent views.
Virtually inaccessible by land.

All islands except Hicks Island are Aboriginal Reserves.

LOCKERBIE-SOMERSET

Significance

1. Historic - sites of Lockerbie and Somerset.
2. One of most important historic type localities for 'type' material of flora and fauna.
3. Representative of vine forest type found elsewhere only in Iron Range area. Unique in the combination of species, fauna which inhabits it and parent material of which it is formed.
4. Outstanding scenery.
5. Northern most land point on the Australian continent.

Background

Area of 16,089 hectares under consideration.

Flora - Because of establishment of Somerset settlement much biological material was collected and described from the area long before there were any other settlements in northern Australia.

Vine forests - separated by considerable distance from other similar vine forests.

Evidence indicates these forests were never continuous with others.

Geology Parent material - indurated, ferruginized sandstone. Unique in supporting tall rainforest.

Historic End point of - Jardine Brother exploration
- R. Logan-Jack expedition.

Much of the area is Aboriginal Reserve and not available for national park gazettal.

RESEARCH

The subject of research by the National Parks and Wildlife Service on Cape York Peninsula is a difficult one not only by reason of the complexity of the flora, fauna and landforms there, but also because of the obvious logistical problems with attendant high cost factors.

The region is reasonably familiar to Service research personnel. The work of Service botanists has been instrumental in having large, representative areas identified. Subsequent work, for example on exhaustive inventories of fauna species in the major tract of Peninsula rainforest that is McIlwraith Range (in collaboration with the Australian National Parks and Wildlife Service), on comprehensive inventories of some flora, viz. Orchidaceae, and on other taxonomic and ecological matters e.g. native rodents, vegetation of Jardine River catchment, etc., is providing for a better understanding of some of the management aspects.

There still remains the need to establish some basic matters of primary concern to this Service. What are the anthropogenic factors that apply in such remote and difficult circumstances? How are these minimized to retain the peculiar features of the region? In what order of priority should these inevitably expensive procedures be tackled? And on which areas?

Priority can be attributed to "terrestrial" rather than "marine" situations because of our mandatory responsibilities. But while this may be more feasible and tidier, it may prove folly. What about Lizard Island National Park or Raine Island Fauna Sanctuary. What about the Torres Strait pigeon, or the island-hopping migratory waterfowl.

Marine turtles that are so vulnerable because of their land-based breeding rookeries constitute a large and formidable topic. Mr. Limpus, of my Service, discusses these problems elsewhere in this Workshop.

My Service proposes, for conservation purposes, to prepare plans for the region that fulfil two major purposes (as well as many minor ones)-

(a) To prepare a map (or set of maps) of appropriate scale whereby the natural resources (flora, fauna, landforms) are defined (with textual technical justification) to provide for a comparative analysis of these features and hence a ranking of their importance.

(b) For reservation purposes, to reconcile this against the alternative land uses proposed for the region so that an acceptable realistic strategy of land use may be promoted.

The above research scheme is ambitious and may well prove to be premature for other than scientific reasons. Manpower is deplorably lacking, especially considering that even if it were possible financially to overcome this, then experienced scientists of appropriate perspective willing to spend the field time necessary to acquire relevant management programmes are a rare commodity.

A modified programme of this research is presently being compiled; it may rely on a floristic approach to represent fauna and landforms to best advantage. It will depend on our ability to devise sound techniques applicable to these situations; and it will depend on tolerance in order that we are not forced to impose management devices perhaps best left in the very different region from which they have been no doubt hastily adapted. After all, the Jardine River is probably no different today as a park from yesterday. Our concern is for the future, and we should strive to remember this and invest wisely of our effort to secure it.

MANAGEMENT

Although half the national park estate in Queensland now lies within the Cape York region, to date the Queensland National Parks and Wildlife Service has exercised management options resulting in development on only one national park, namely Lizard Island.

On Lizard Island National Park the national park authority has permitted three leases to be issued - one for the development of a tourist resort, one for the development of a research station, and the other for the development of an air strip. Because the issue of these leases has resulted in increased human activity on the island national park, the Service has been forced into exercising other management options, these are - construction of a walking track to Cook's Look, erection of park signs, provision of a camping area, and more regular visits by rangers and other personnel to police the legislation and liaise with the lessees.

Mention should be made that the Queensland Forestry Department (the National Parks and Wildlife Service predecessor in national parks management) was proposing to gazette a large marine national park over the reefs and waters surrounding Lizard Island. This was not proceeded with pending clarification of the jurisdictional position with regard to off-shore areas. So far as the Queensland Government is concerned the matter of carrying forward that proposal would now rest with the Queensland Fisheries Service.

The Queensland legislation governing national parks states that the cardinal principle to be observed in their management shall be the permanent preservation to the greatest possible extent of their natural condition. It follows that the aim of management must be to cater for legitimate use while preserving this natural condition.

All too often parks are surrounded by manipulated environments and subject to many quite unnatural influences. This statement is less true of the area under discussion than it is of most other parts of coastal Australia.

Ideally, each national park and similar reserve needs to be thoroughly studied and assessed to decide what purposes and functions it is to fulfil and how best to manage it to that end. Unthinking developments can alter the nature and quality of the recreational experience which may be enjoyed by the visitor. Each individual has his own specific recreational requirements. If all visitors are to have a chance to fulfil those needs, it will be necessary to plan to provide the evident range of recreational facilities differing in degree of isolation, relative comfort, sophistication, accessibility and cost, while ensuring that the essential nature of the resource is not altered.

It is too early for me to predict where the Queensland Service will next exercise some management options in this region. With over a thousand vehicles arriving at the Jardine River crossing in 1977 it is obvious there are several thousand people visiting the Peninsula in the winter and spring months. Something has to be done about managing these people. With its airstrip and importance for nature conservation Iron Range could be the logical place for the Service to establish its first presence in the Peninsula.

CONCLUSION

Management of the islands, particularly the coral cays cannot be divorced from management of the surrounding waters, reefs and submerged lands. The reverse also is true. Therefore in the Australian non-unitary political situation it becomes a matter of cooperation. The National Parks and Wildlife Service of Queensland is committed to that end.

ACKNOWLEDGEMENTS

The researching of the background information on the national parks and proposal areas was undertaken by Cathy Jones. This work is gratefully acknowledged.

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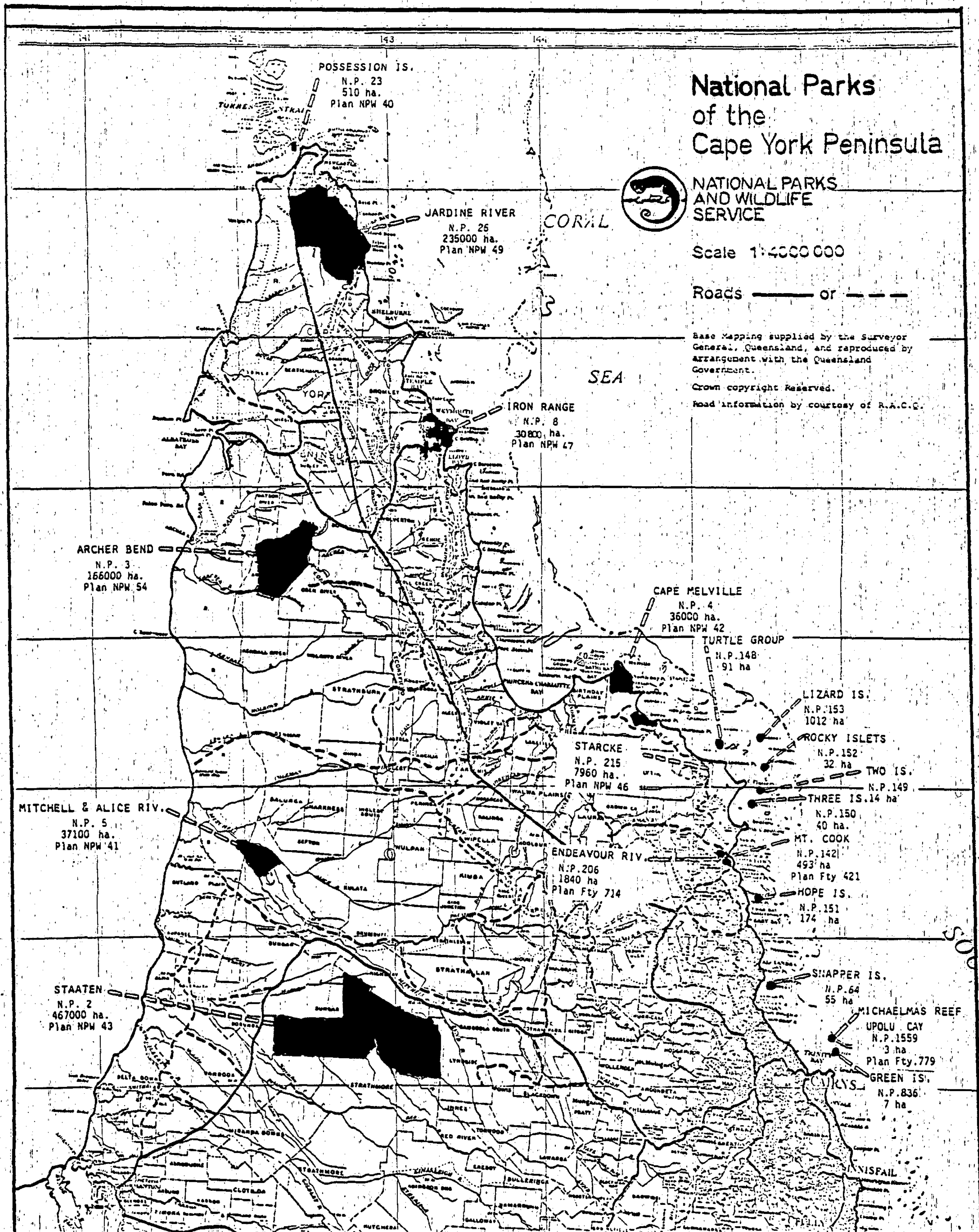
National Parks
of the
Cape York Peninsula
NATIONAL PARKS AND WILDLIFE SERVICE
Scale 1:4000 000
Roads
Base Mapping supplied by the Surveyor General, Queensland, and reproduced by arrangement with the Queensland Government.
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Road information by courtesy of R.A.C.Q.
CORAL
SEA
POSSESSION IS.
N.P. 23
510 ha.
Plan NPW 40
JARDINE RIVER
N.P. 26
235000 ha.
Plan NPW 49
IRON RANGE
N.P. 8
30800 ha.
Plan NPW 47
ARCHER BEND
N.P. 3
166000 ha.
Plan NPW 54
CAPE MELVILLE
N.P. 4
36000 ha.
Plan NPW 42
TURTLE GROUP
N.P.148
91 ha
LIZARD IS.
N.P.153
1012 ha
ROCKY ISLETS
N.P.152
32 ha
TWO IS.
N.P.149
THREE IS.14 ha
N.P.150
40 ha.
MT. COOK
N.P.142
493 ha
Plan Fty 421
HOPE IS.
N.P.151
174 ha
STARCKE
N.P. 215
7960 ha.
Plan NPW 46
MITCHELL & ALICE RIV.
N.P. 5
37100 ha.
Plan NPW 41
ENDEAVOUR RIV.
N.P.206
1840 ha
Plan Fty 714
SNAPPER IS.
N.P.64
55 ha
MICHAELMAS REEF
UPOLU CAY
N.P.1559
3 ha
Plan Fty.779
GREEN IS.
N.P.836
7 ha
STAATEN
N.P. 2
467000 ha.
Plan NPW 43
CAIRNS
INNISFAIL

INTERNATIONAL CONVENTIONS AND LAW APPLICABLE TO THE AREA

by H.R. Jitts
Marine Branch, Department of Environment, Housing and Community Development, Canberra, A.C.T.

ABSTRACT

As elsewhere, a variety of international conventions and a body of international law to which Australia adheres are applicable to the waters and seabed of the Great Barrier Reef Region. In recent years, the Third United Nations Law of the Sea Conference has been attempting to codify these and a range of newly evolved principles into a single comprehensive convention on the Law of the Sea.

The paper will outline the main existing international laws which affect the area, indicate the consequences of the current draft Law of the Sea Convention, and how these affect the capability of the GBRMPA to plan and manage the area.

I. INTRODUCTION

With the Great Barrier Reef Marine Park Act of 1975, Australia created its first legal instrument for dealing with the Great Barrier Reef on a regional basis. The Act declared a GBR Region, created the Authority and described the role and functions of that Authority. Dealing as it must with the sea, the seabed, the living creatures of both of these, as well as man's actual and potential activities in the Region, the Authority will need to find its way through the maze of international laws pertaining to these. Without claiming any legal or cartographic expertise, the author intends to describe some of these laws, both conventional and customary and both in force and prospective. Some of the implications of these laws for the work of the Authority will also be described.

II. INTERNATIONAL LAW PERTAINING TO THE SEA

The concept of a coastal state's sovereign rights over the sea adjacent to its shore was only developed slowly. In early days, some nations of vigorous navigators and colonisers did attempt to arrogate to themselves sovereign rights to huge portions of the world ocean but these received very little recognition. In more recent history the concept of territorial waters adjacent to the coast became widely accepted; the most common width of this territorial sea was accepted as three nautical miles, the range of a good cannon shot. For the rest of the oceans the concept of freedom of the high seas became widely accepted. Under this regime the coastal state had the right to control activities within its territorial sea, but all nations were free to engage in whatever activities they chose to in the seas beyond.

With the coming of industrialisation, increasing trade and the increasing dependence of many states on the resources of the sea, it has become necessary to codify the customary international laws pertaining to the sea. The first successful international conventions on the law of the sea were achieved at Geneva in 1958 under the aegis of the United Nations. There were two Geneva Conventions in 1958, one on "the Territorial Sea and the Contiguous Zone" and the other on "the Continental Shelf".

Under the Convention on the Territorial Sea and the Contiguous Zone, contracting parties established the right of a coastal state to a territorial sea adjacent to its shore and described in some detail how this sea should be charted and the nature of the rights and obligations of the coastal state. However, the Convention failed to describe the width of the territorial sea. Many nations ascribed to the customary three mile limit, however, an increasing number insisted that the limit should be twelve miles. Some South American states claimed a "patrimonial sea" up to 200 miles in width. The main problem was the inability to reconcile the desire of coastal states to control the exploitation of marine resources with that of trading nations to maximise freedom of the sea for navigation. In spite of its shortcomings, this Convention represented a major step forward in the law of the sea.

The Convention on the Continental Shelf was significantly more successful. It established the sovereign right of the coastal state to the mineral resources of and the living resources on the continental shelf adjoining its shore to a depth of 200 metres or greater to the limit of exploitability. With developing technology the latter limit is posing serious doubts as to its present day acceptability. Two significant new concepts were included in this Convention. The first was that other states could conduct research on the continental shelf of a coastal state only with the consent of the coastal state, but that this consent should not normally be withheld. The second was that a coastal state, in exploiting the resources of its shelf, should ensure that freedom of navigation and the living resources of the overlying waters should not be adversely affected. These concepts for the first time recognised certain obligations on the part of the coastal state regarding the seas beyond its sovereignty.

Apart from the preceding two Conventions, there are numerous others dealing with the regulation of specific fisheries and of shipping and navigation. The formation of the Intergovernmental Maritime Consultative Organisation (IMCO) has led to the formulation of several conventions regarding threats to the marine environment from shipping. The most significant of the latter is the 1954 Convention for the Prevention of Pollution of the Sea by Oil, with several subsequent amendments. This Convention obliged tankers to refrain from discharging oil or oily wastes less than 50 miles from the nearest land, and other vessels to discharge their wastes as far as practicable from land. Furthermore, it strictly controlled the conditions of discharge even beyond 50 miles. In 1971 the Convention was amended concerning "the Protection of the Great Barrier Reef", whereby the definition of "the nearest land" with regard to the north-east coast of Australia was to be a line (shown in part in the Figure) which extended seaward of most of the Great Barrier Reef. This 1971 Amendment is of great importance to Australia, not only in enhancing the protection of the Reef, but also in that for the first time it gives international legal recognition of Australia's special interest and responsibility in the GBR Region.

III. THE THIRD UN CONFERENCE ON THE LAW OF THE SEA (UNCLOS)

Since the 1958 Geneva Conventions, apart from the already mentioned weaknesses of these Conventions, four matters have arisen which have made urgent the need for a new Law of the Sea Convention. The first is the world's increasing need for both nutritional and mineral resources, the second is the desire of developing nations for a greater share of these resources, the third is the discovery of important potential mineral resources on the deep seabed, and the fourth is the increasing recognition of the need to protect the world environment. Related to the first three matters is the emergence of the concept that the resources of the sea beyond national jurisdiction form part of the Common Heritage of Mankind and should be exploited for the benefit of all nations, whether coastal or not, particularly the developing nations. The fourth matter was brought into focus at the UN Conference on the Human Environment at Stockholm in 1972, where nations agreed in principle to the obligation of all nations to protect man's environment, including the marine environment, from the threat of pollution resulting from increasing industrial activity.

As a result of these pressures, the United Nations convened the Third UN Conference on the Law of the Sea in 1974, giving the Conference an exceedingly ambitious mandate to prepare an international convention on all matters pertaining to the law of the sea. The Conference has worked intensively at succeeding sessions and is now engaged in its Seventh Session. This Conference is undoubtedly one of the most important activities undertaken by the UN since its inception. If successful, it will have prepared the most comprehensive set of international law yet attempted. Even if it fails to achieve a convention, the Conference is creating a whole series of concepts which are achieving universal acceptance and which will, and indeed have already, become the basis for customary international law.

Until the present, the Conference has worked in three concurrent, almost independent, committees and a fourth series of informal plenary sessions. The First Committee is charged with matters related to the exploitation of deep seabed minerals. The Second Committee deals with questions of national jurisdictions, freedom of the high seas, as well as living resources and access to them. The Third Committee deals with the protection of the marine environment, marine scientific research and the transfer of technology. The Informal Plenary Sessions deal with the settlement of disputes. A wealth of informal documents has emerged from succeeding sessions of the Conference, each leading closer to a universally acceptable Convention. At the Sixth Session held in 1977 the work of the four groups was amalgamated into an Informal Composite Negotiating Text (ICNT), consisting of just over 300 separate Articles with 7 lengthy Annexes.

The ICNT has not yet achieved the status of a draft Convention. In fact, many important nations and groups of nations still find the text unacceptable as a whole, to the point where there is a real danger of the Conference collapsing. Nonetheless, the remarkable fact is that the great majority of the 300 Articles have become informally accepted by consensus of the some 150 nations participating in the Conference. The ICNT treats all the matters referred to in the first paragraph of this section, even though with varying success. A delicate balance has been achieved between the rights of the coastal state and freedom of the high seas. The major points of disagreement remaining relate to exploitation of deep seabed resources, and to the right of access of land-locked and geographically disadvantaged states to the living resources of the sea under coastal state jurisdiction.

One of the most important concepts that has emerged from the Conference is that of the regime of the 200 mile Exclusive Economic Zone (EEZ). Under this regime a coastal state has the right to declare an EEZ extending 200 miles from the baselines from which it constructs its Territorial Sea (accepted in the ICNT as 12 miles). In its Territorial Sea, the coastal state has the right to enact whatever national legislation it considers necessary, provided that this does not unduly hamper the innocent passage of ships through these waters. The coastal state also has sovereign rights over the resources in its Territorial Sea. The coastal state has the right and the obligation to enact and enforce legislation to protect the environment in these waters. Some of these rights and obligations are specified to extend to the EEZ. With regard to living resources of the EEZ, the coastal state is obliged to grant access to other states to exploit that portion of the resource beyond its capacity to exploit. The coastal state's obligation to protect the marine environment of the EEZ is limited in that any legislation must be in accordance with generally accepted international rules and agreements. The ICNT specifies that in the EEZ other states can conduct scientific research only with the consent of the coastal state, and that the coastal state has the right to participate in the research.

An Article in the ICNT of particular relevance to the future management of the GBR Region is Article 212, paragraph 5. This would enable the coastal state to establish within its EEZ a "special area" wherein national laws and regulations may be applied which go beyond general international rules regarding the control of pollution from ships within an EEZ. Such "special areas" and proposed national regulations require the approval of the competent international organisation (e.g. IMCO).

Under the regime proposed in the ICNT, all states will have both the right and the obligation to establish and to enforce national laws and regulations to prevent, reduce and control pollution of the marine environment from all sources of pollution.

IV. AUSTRALIAN LAW PERTAINING TO THE SEA

Australia is a signatory to the two Geneva Conventions, to the many IMCO Conventions on pollution and safety related to shipping as well as to the London Dumping Convention of 1972. Australia has ratified the Geneva Conventions and some of the IMCO Conventions, but not the others. To do so in most cases requires the passage of national legislation. While matters are in hand for this to be done as soon as possible, the process in Australia is necessarily complex and time-consuming.

The basic Australian national legislation is the Seas and Submerged Lands Act of 1973, whereby Australia has implemented both of the Geneva Conventions. Under this Act, Australia has established its sovereign rights within the Territorial Sea and on the Continental Shelf. The Act does not specify the breadth of the Territorial Sea, but Australia at present adheres to the 3 mile limit. The Act does permit the determination by Proclamation by the Governor-General of the breadth of the Territorial Sea and the baselines from which this is to be measured. Work is underway to complete the enormous task of charting these baselines.

Australia's legislative control of the Great Barrier Reef is reinforced by the Continental Shelf (Living Natural Resources) Act (1968-1973) with respect to sedentary organisms and by the Great Barrier Reef Marine Park Act (1975) under which Australia asserts environmental control over the GBR Region, subject to international law.

Related matters are dealt with by other Australian legislation which includes the Navigation Act (1912-76), the Fisheries Act (1952-73) and the Petroleum (Submerged Lands) Act (1967-74). As well there are Acts implementing some of the IMCO Conventions.

On the basis of justification under recently established customary international law, most of the major coastal states have declared either a 200 mile Fisheries Zone or a 200 mile EEZ off their coasts. The Minister for Foreign Affairs announced in 1977 that Australia, in concert with its neighbours of the South Pacific, intends to establish a 200 mile Fishing Zone and that this represents the first step towards Australia exercising at some future stage its full rights under a 200 mile EEZ.

V. IMPLICATIONS OF RECENT DEVELOPMENTS IN INTERNATIONAL LAW

Under existing legislation, Australia has unquestionable control over all seabed activities in the GBR Region. The imminent 200 mile Fisheries Zone legislation will reinforce Australia's control over fisheries activities in the Region. The 1971 amendment to the IMCO Convention on oil pollution from ships gives Australia adequate rights in this respect but domestic legislation is still needed. The main jurisdictional uncertainty remaining is in the overlying waters in the Region, with respect to shipping, tourism, pollution and even research.

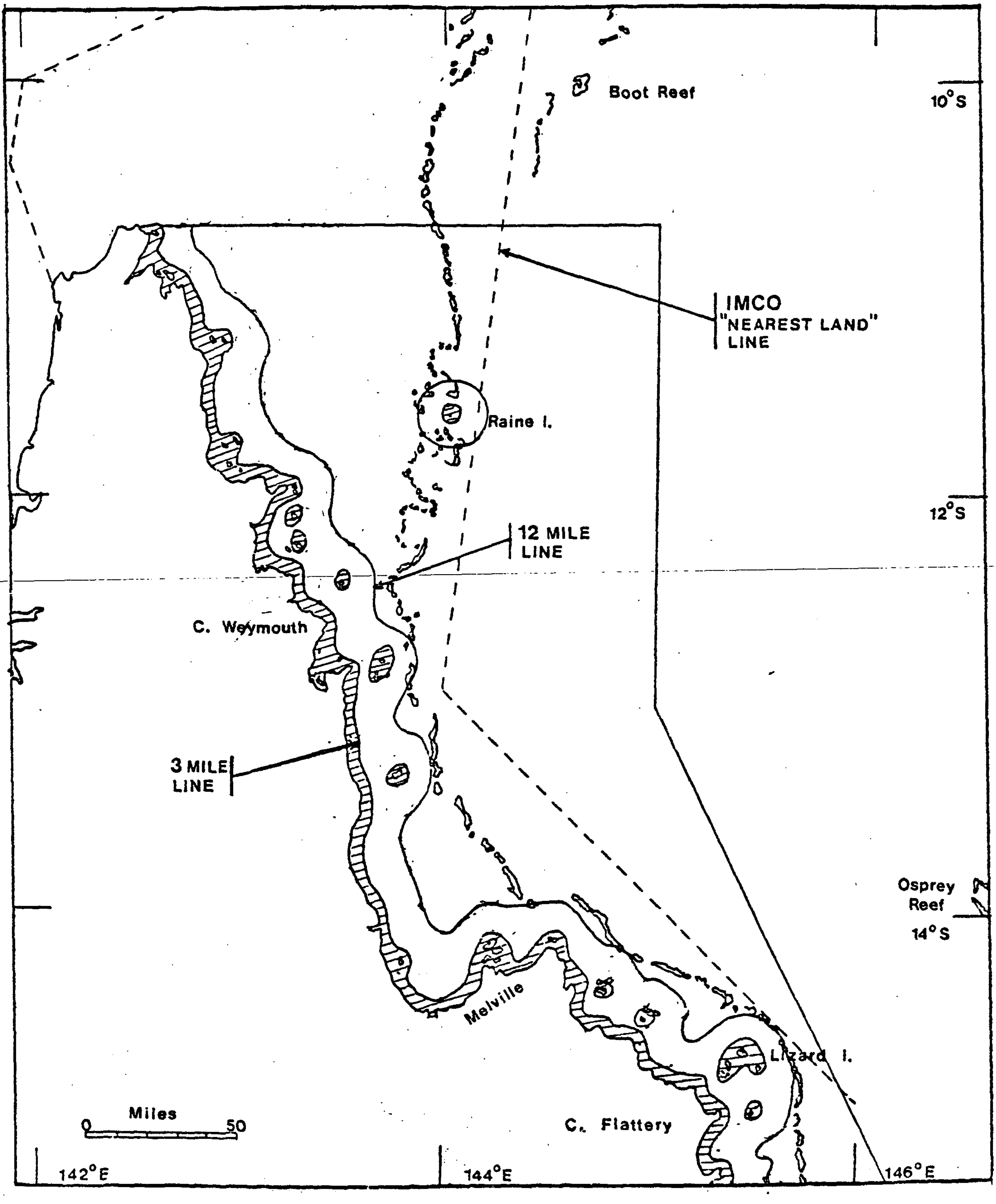
On the chart attached, lines have been drawn approximately 3 and 12 miles off the mainland and around islands in the Region. These do <u>not</u> purport to represent either present or possible future Australian Territorial Seas as these will require very careful determinations of baselines. However, they do illustrate that a 3 mile Territorial Sea covers only a very small proportion of the Region, and that much of the international shipping passing along lanes inside the reef is in waters beyond Australian jurisdiction. With a 12 mile Territorial Sea, most of the shipping lanes would come under Australian jurisdiction (although subject to international law on passage through straits); however, the greater part of the waters of the Region would still be beyond Australian jurisdiction.

Unquestionably, Australia's ability to legislate for the protection of the marine environment of the Region will be greatly enhanced by the declaration of a 200 mile Exclusive Economic Zone such as envisaged in the ICNT, particularly if Australia were to declare the GBR a "Special Area". Such a Zone would more than cover the whole Region. Under such a regime Australia could, if necessary, control within certain limits all shipping in the area with respect to where and when they sail, stop, the activities they undertake (e.g. research) and the pollution they cause. Australia could also take some measures to protect the Region from sources of pollution outside the Region.

There is no certainty as to when, or even if, a new Law of the Sea Convention will be achieved. However, the negotiations at the Conference have produced such a growing consensus on the nature of the EEZ that it will undoubtedly become part of customary international law in the near future. An increasing number of nations assert that it already has.

GREAT BARRIER REEF REGION

NORTHERN AREA



DISCUSSION SESSION I - DESCRIPTION OF THE AREA AND ITS ADMINISTRATION

CHAIRMAN: DR. J. BAKER

E. Frankel: I would like to make a comment concerning Mr. Isbell's statement. In the Normanby-Kennedy catchment area a huge wedge of sediment flows out into Princess Charlotte Bay with about 80% mud suspended in coastal waters and gradually decreasing with distance (offshore). Because of the mud, some of the inner reefs particularly Corbett, Hedge and the like are extremely depauperate on their more southerly extremities. The Fly River of southern New Guinea has a tremendous influence on the northern end of the Barrier Reef. I think the influence of the sediment discharge and fresh water of the Fly is the controlling factor in the northern end of the Barrier Reef. Mainland factors, particularly fresh water run-offs and associated sediment are extremely important in formation and control of reefs.

R. Isbell: I think that is a very fair comment. The thing we have to keep in perspective is the time scale. Has the Reef been subject to catastrophic events in our lifetime or in the context of historical man? Some records are now being established on past climatic change in northern Queensland for example, Mr. Peter Kershaw from Monash University has shown that the Atherton Tablelands region has been subject to considerable changes in rainfall over the last 50,000 to 60,000 years. We must expect that over that kind of time span there are going to be events having a marked effect on the Barrier Reef.

D.W. Connell: In pursuing that point a little, the salinity variations in coastal areas throughout Australia have had a dramatic impact on some marine areas and coral reefs, for example, in Moreton Bay. I was just wondering whether there are any data available on salinity variations in the northern part of the Reef.

There is a Masters Thesis on that subject by Braddon which has some data on salinity variations for around Princess Charlotte Bay.

Chairman: Is there any geological evidence of the past history of run-off?

J.E.N. Veron: Cores have been taken from around Mud Island and there is a lot known about the fossil coral sequence in Moreton Bay. Lovell's study during the big flood enabled him to map the coral communities before and after the flooding.

F. Talbot: I would just like to make a comment here on the problems of sediment potential and land run-off. One of the things we seem to lack is information on the hydrography of the area. Why is this information not presented in our symposium?

P. Mather: C.S.I.R.O. Fisheries and Oceanography Division who have done most work on the hydrology around Australia are aware of the shocking lack of information in the Great Barrier Reef region. I think it would be very useful for this meeting to emphasise how very much needed this information is.

Chairman: As to Professor Talbot's question, the Navy was approached but declined to speak on this particular area.

E. Frankel: There are eleven publications on hydrographic surveys of the Great Barrier Reef.

D. Barnes: At least three and perhaps four people have mentioned the apparent great age of the Reef, perhaps one of the speakers would like to comment on the actual age of those processes.

D. Hopley: Research programmes we have been involved in over the last three years have involved shallow drilling into a number of reef caps. I think we have gone into sixteen reefs now, and the C^{14} dating that we have for those reef caps indicates that the material within 25cms of the surface of present reefs dates as old as 6,100 years, and I think the youngest date we have for any of these reefs we have drilled for that depth, is 2,000 or 2,500 years. In other words, the indications are that the present reef flats are relatively old and that present run-off is not affecting reef tops.

D. Barnes: In fact 20,000 years ago the sea level was 350 feet below its present height and everything that we now see as living coral units on the Great Barrier Reef would not be older than 20,000 years and probably younger than 6,000 years.

E. Frankel: I agree. I thought the whole thing could be summed up in an expression which says that "the present expression of the Great Barrier Reef is no older than 10,000 years" because if you take accepted sea level curves world wide, sea levels started rising to about where the bottom of the reefs start now about 10,000 years ago, more likely 8,000 years ago - that is when it all started in its present expression.

R. Orme: Could I just make a comment? The major surface that we discovered with seismic methods is assumed to have been produced during shelf emergence during low stands of sea level. In fact the evidence suggests that it could have been produced over a number of phases of shelf emergence caused by regressions, and there is no guarantee that it precisely correlates with that level, and it is pure conjecture that the deposits lying above it are Holocene. Furthemore with regard to the banks north of Lizard Island that are covered by Halimeda at the moment, we merely say that those banks are covered by Halimeda meadows, and by Halimeda gravel and sand. We do not say they are composed of Halimeda. They have sedimentary structures which indicate active sedimentation and as to their composition, it is still doubtful.

M. Pitman: May I ask Mr. Jitts about Australia's sovereignity in the northern section of Reef in consideration of Papua New Guinea's 200 mile zone?

H. Jitts: The deliberations of the Law of the Sea Conference were largely concerned with the 200 mile zones. Regarding Papua New Guinea, I think I am correct in saying that if you define the Great Barrier Reef Marine Park Region as paralleling the top of Cape York Peninsula, then there is no conflict at all. Treaty negotiations are proceeding with Papua New Guinea on the subject of the limitations between Australia and Papua New Guinea and these are complex for all sorts of reasons, but I do not think it affects the Great Barrier Reef Marine Park Authority at all with the Region's boundary being level with the top of Cape York Peninsula.

B. Goldman: I would like to see some clarification in this talk about the geological history of the reef - differentiating between the geomorphological and the biological history. Despite sea level changes, I would assume that there has always been some sort of coral reef community on the fringe of the continent during evolutionary time. Is this the case? Or has there been in the past a system where the coastline has abruptly stopped and there have been no fringing or coral reefs?

J.E.N. Veron: On the far northern Barrier Reef an oil exploration company sunk a well near Bramble Cay which went right down to Miocene deposits while still going through coral reef in a relatively continuous sequence.

B. Goldman: So from the evolutionary point of view, there has been a continuation of a coral reef community.

J.E.N. Veron: We believe so. In all probability there must be something about the edge of the Queensland trench to make the present situation possible.

A. Birtles: You stressed the fact that mainland events are having little effect on the Barrier Reef system at the moment and you do not stress future agricultural development. I would just like to emphasise the importance of base line studies. When you consider slightly more developed areas further south than the area at which we are looking, there is a great deal of discussion and disagreement about previous conditions. Magnetic Island is an example where there has been a demonstrable change in the reefs around the island; whether this is to do with dredging, agricultural practices or the city of Townsville it is really impossible to say, because there were no baseline studies.
Sir Maurice Yonge was really quite depressed by what he felt had happened to Low Isles in the last 50 years, because of increased run-off from the Daintree and Mossman area as a result of agricultural development. Dr. Saunders emphasised that this northern area is largely pristine and it is fine and proper to set up baseline studies to monitor possible changes in the biological system.

Chairman: I would agree with this and expect that the Authority's planning will involve co-ordination with Queensland Government bodies.

J. Woods: Now that Dr. Veron has established the longevity and viability of the reef systems, I would like to ask Mr. Jitts of what significance is the Premiers' Conference resolution of October 21, 1977 involving the transferance of jurisdiction of the territorial sea to the States and what effect this will have on the future declaration and management of Marine Park areas?

H. Jitts: The legal situation recognised at present is that the "Seas and Submerged Lands Act" of the Commonwealth Government is the law. At the Premiers' Conference last October the question was not whether or not this is the law, but what should be done to live with this law. Under the policy of the government of the day, what the Federal Government has been seeking is a system whereby those things that have been traditionally controlled by the States should continue to be controlled by the States. The object is to find some administrative means of doing this that does not cause any legal problem. At the Premiers' Conference there was a comprehensive discussion, but they finished up with an agreement of what they would like to see take place. The problem is that having agreed to that, the lawyers have not been able, up till now, to find a way of making that legally possible. Whatever happens as a result of ongoing consultations on this matter, the position with regard to the Great Barrier Reef Marine Park Authority will not really change. The Great Barrier Reef Marine Park Authority's basis has always been one of co-operation between the Federal Government's needs and aspirations and those of the States, and I think that this situation will continue whatever the outcome of the Premiers' Conference. There might be a slight shift in balance from State to Federal predominance of legal instruments, but no other great change.

H.J. Higgs: I would just like to add to what Mr. Jitts said concerning what was discussed subsequent to the Premiers' Conference. The Solicitors General and Attorneys General have been discussing whether, in those areas of overlap, there can be some joint authority type mechanisms for fishing etc. In fact, the Great Barrier Reef Marine Park Authority is almost a prototype of joint Authority action.

Chairman: Could I on your behalf, thank the speakers? Through Dr. Orme and Dr. Veron, we have been given a very sound description of the Reef Region and many points of the Reef north of Lizard Island I am sure have highlighted our inadequate knowledge. The very poor state of knowledge on the Reef's bathymetry was stressed by Dr. Veron and he also showed the marked contrast between the northern area and what we know of the south. I think that he gave indications to the Great Barrier Reef Marine Park Authority on some regions that do need protection or consideration for protection even now, and we will hear much more about Raine Island and the deltaic reef systems in the future.

Ray Isbell, in speaking about the land masses, gave us the heartening news that there is relatively little disturbance due to man at this state: if there are to be studies on the effect of man-made changes to the environment this is an area in which the Authority should keep a close watch. He stressed, and Dr. Saunders later reinforced, the need for collaboration between different bodies if any meaningful studies are to be undertaken.

In Dr. Saunder's paper, we saw the benefit of a sound development of national parks as long ago as the 1930's and how we in Australia are benefitting from those actions to-day. He stressed and again supported Mr. Isbell that you cannot divorce land from sea and therefore in all considerations of the Authority, it is essential that we collaborate with State bodies. I think this should be discussed in a later session.

The public conception of the Great Barrier Reef is tremendously important to the Authority, because as Dr. Saunders said, most people imagined it as something around Magnetic Island, Heron Island or Green Island, and its a much larger problem than that.

Mr. Jitts, in finalising this session, brought to our notice the changes in legislative procedures involved in the Great Barrier Reef Region and the significance of the 200 mile economic zone. I think that we have been given food for thought for the subsequent sessions and I would like you to join me in thanking the speakers for their contributions.

SESSION 11: USE OF THE AREA - CURRENT & PROJECTED

DEFENCE INTEREST IN THE GREAT BARRIER REEF

Malcolm W. Buckham

First Assistant Secretary, Facilities Division
Department of Defence
Canberra

Abstract

Past, present and likely future use by Defence of reef areas are described, and general Defence interest in the reef is discussed

DEFENCE INTEREST IN THE GREAT BARRIER REEF

The Great Barrier Reef is not only a major asset in Australia's National Estate; it is also a natural weapon of continental defence, forming, as it does, a bulwark to protect our north-east coast against threat of seaborne invasion.

Captain James Cook twice fell victim to the reef, in June and August of 1770, while exploring Australia's east coast. In his Journal, he describes the reef as:

> "...a wall of coral rock rising almost perpendicular out of the unfathomable ocean".

The efficacy of this 'wall' against attack from the sea was proved during World War II. After coastal vessels had been used as minelayers to block passages through southern sections of the reef it afforded good protection to Australian convoys travelling north from Brisbane with troops and supplies for the New Guinea theatre of war. The potential of the reef as a defence against unfriendly maritime activity along the north eastern coast of Australia is an enduring factor.

Since World War II, the Australian Defence Force has maintained an interest in training and exercising in the Great Barrier Reef region, and there will be a continuing need to use the area for such purposes. During peacetime these activities are carefully planned to ensure that they have the least possible detrimental effect on the environment.

I would now like to give you an outline of present and proposed military activities in the area. I hope that this description of the program will convince you of its necessity and worth and offer reassurance that it will not have any undue environmental impact on a delicate and irreplaceable part of that national heritage which, we should bear in mind, it is part of our task to defend. It may also be useful to recall that an additional safeguard stems from the requirement that all Defence activities, including works and land acquisition proposals, are subject to the provisions of the Environmental Protection (Impact of Proposals) Act. Under this Act, we are obliged to determine the ecological and social impact of every proposal and to pay particular attention to proposals which may affect any part of the National Estate.

It is vital to the operational proficiency of the armed forces that they have access to a variety of bombardment and firing ranges. Not only is it necessary to have such ranges situated in a number of areas representative of different conditions and terrain types, but it is also important to have available more than one example of each such category of range. Restriction to, say, one maritime bombing range, would very significantly reduce training efficiency, since crews would quickly become over-familiar with landmarks in the area and training tasks would thus fail to produce sufficiently challenging problems.

It is also important that some bombing ranges and exercise areas should be situated in those parts of the continent which might be subject to attack should a threat arise. However remote such a possibility might seem at present, it must be considered prudent for the Defence Force to maintain operational familiarity with the northern part of Australia and surrounding waters.

Two further factors which govern the choice of range areas are the location of the units using them and a sufficient degree of isolation. The latter is becoming more difficult to satisfy within the limits imposed by base locations. Urban development, for example, threatens existing ranges in the Darwin area.

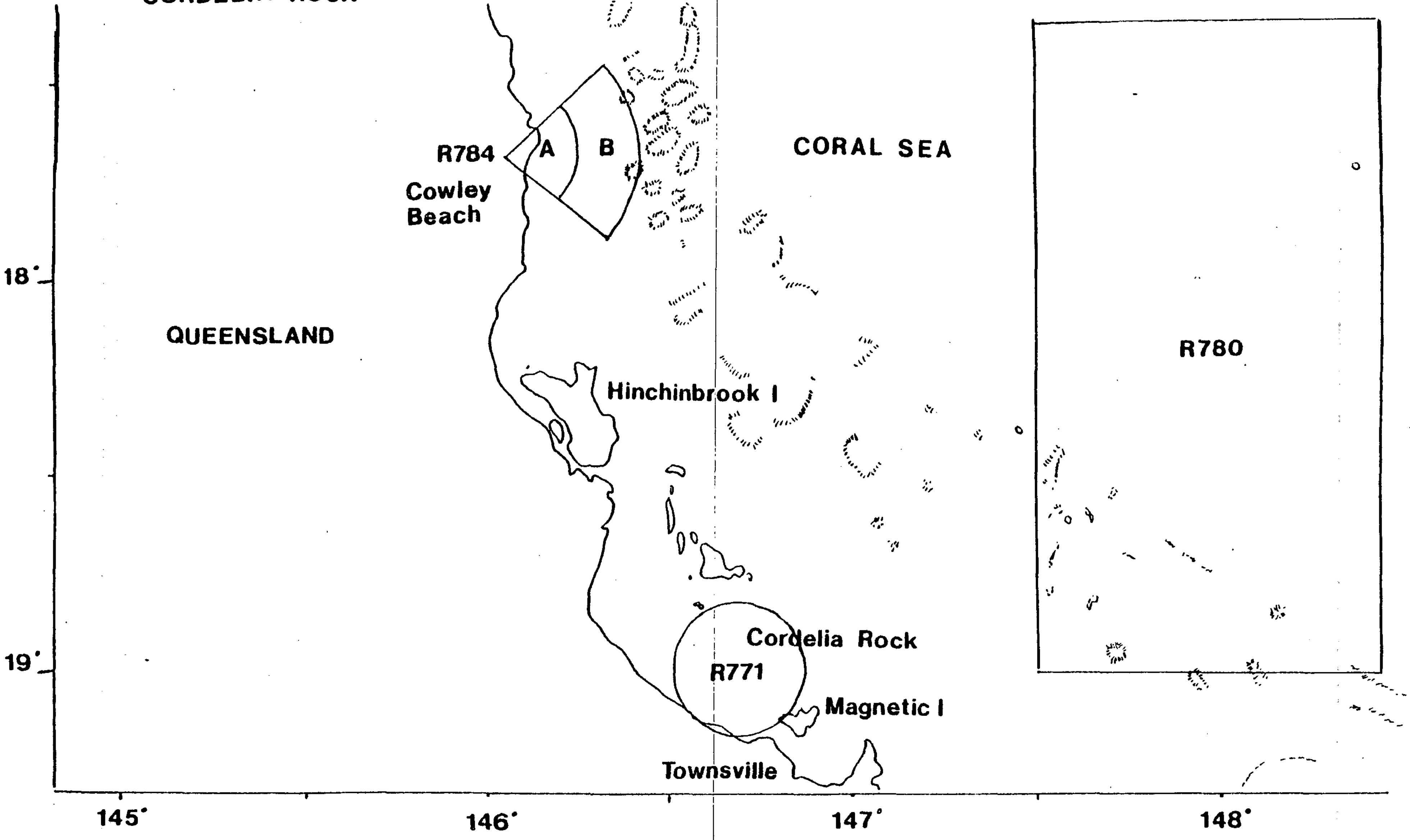
There are two RAAF live bombing ranges in the Great Barrier Reef area. Both involve relatively small areas and in neither case do their impact areas include any part of the reef itself. You will see on this map that the first of these is Cordelia Rock in Halifax Bay, and the second is Townshend Island. This latter is also the site of a Navy firing range administered by Army and, as part of the total Shoalwater Bay Training Area, is at present the only area where joint training exercises may be carried out. Such exercises, tri-Service and multi-national, using the Shoalwater Bay region, play a vital part in the development of joint Service and international tactical defence cooperation. For this reason Townshend Island is an area of importance to Defence; and there are plans to upgrade its facilities as a bombing range by the installation of new targets and equipment to record bombing accuracy.

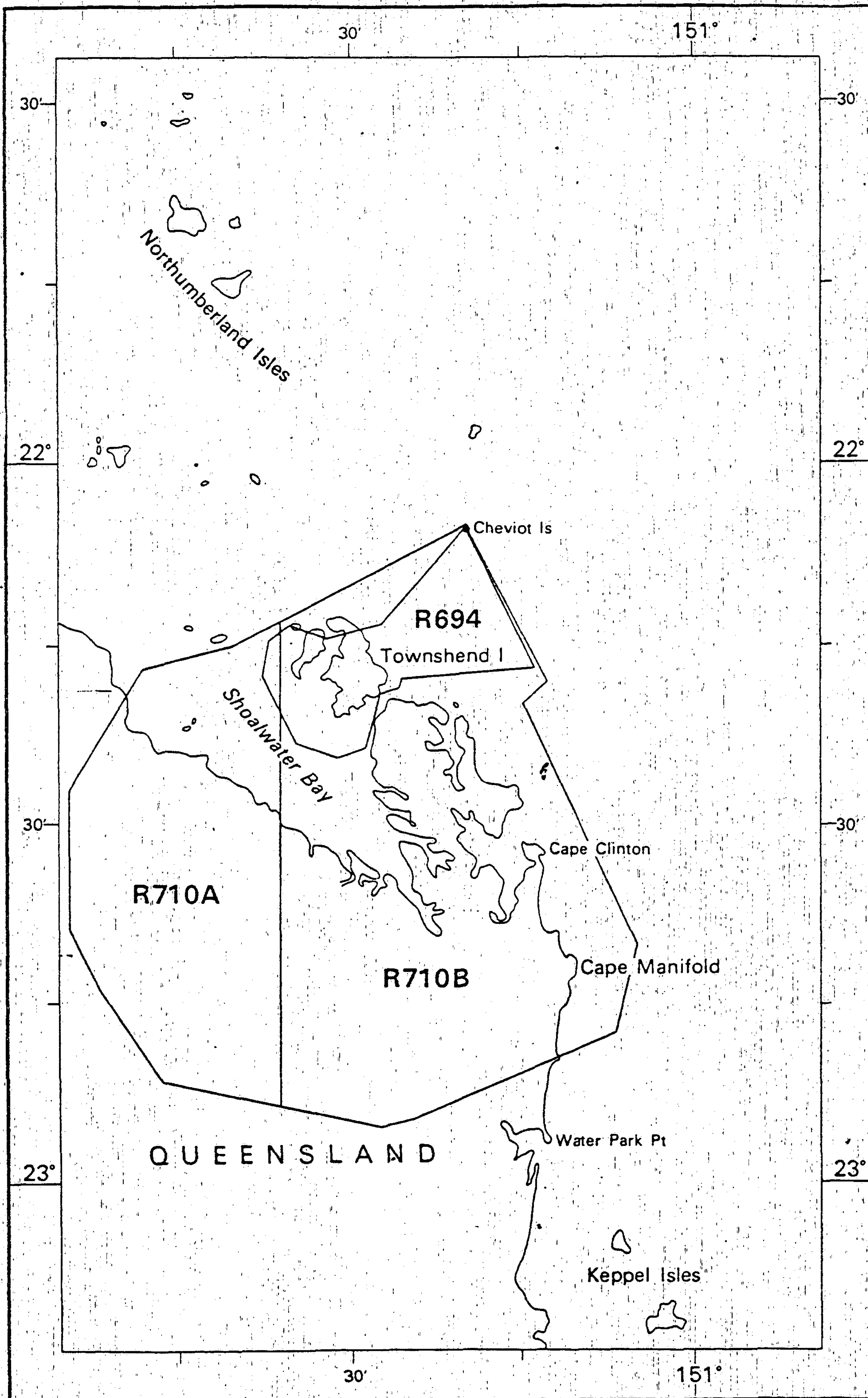
Careful consideration, however, is being given to the preservation of some features of the island. A gunnery range may, for example, be moved - on the suggestion of the CSIRO - to preserve an area of sand-dunes in the northern part of the island.

The future development of Townshend Island should be seen in the context of past and present activity. The island has been subjected to bombardment for a number of years and the problem of unexploded ordnance is one which already exists. Any development contemplated would not entail a change in usage, but could involve an increase in the frequency of such usage beyond the current average of two weeks per year. You might care to note that the denial of Townshend Island for live firing would only result in the pollution of an alternative site with unexploded ordnance and that there could be no guarantee that Townshend Island could be successfully cleared of unexploded ordnance.

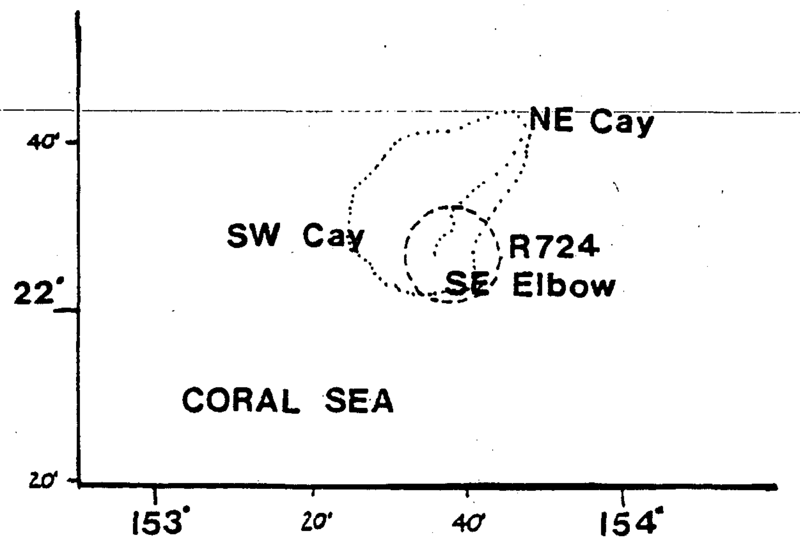
Apart from these two areas, the only other relevant RAAF bombing range is at Saumarez Reef, which amendments to the legislation place outside the Great Barrier Reef Marine Park area. The wreck of the SS FRANCIS P. BLAIR on the reef provides a valuable radar contact and navigation aid. Only practice bombs, smoke and flash are dropped on Saumarez. The RAAF is occasionally called upon to bomb objects in the area which

CORDELIA ROCK




30'
151°
30'
30'
22°
22°
30'
30'
23°
23°
30'
151°
Northumberland Isles
Cheviot Is
R694
Townshend I
Shoalwater Bay
Cape Clinton
R710A
R710B
Cape Manifold
Water Park Pt
QUEENSLAND
Keppel Isles

SAUMAREZ REEF



are, or threaten to become, hazards to navigation. Such tasks are undertaken at the request of State or Federal authorities.

The RAAF also has an air-to-air firing range over the reef north-east of Townsville. The status of this area is currently under review to determine our continued need for it.

At this stage it should be pointed out that reviews of range requirements are carried out periodically. After a review, undertaken only a few years ago, a number of areas were derestricted, including the Holmes Reef live bombing range, about 200kms east of Port Douglas. It is Defence policy to retain only those areas which are necessary. It should be noted that in many cases where it is considered necessary to retain an area as a range its rate of usage may still be low. For example, it might be used only one week every two or three years.

Such low usage rates apply to the majority of Naval gunnery ranges in the Great Barrier Reef area. Three of these are situated off Cairns. Only the most northerly is used more than once a year. The RAN also uses Townshend Island which I have mentioned, and has a further three ranges off the Queensland coast - Lizard Island surface and anti-aircraft range, Fairfax Island Naval bombardment and live bombing range, and Hervey Bay Naval gunnery range. These, as their designations imply, serve a number of different purposes and are also used infrequently.

Other Naval activity in the area is limited. Apart from participation in major exercises, use of Barrier Reef waters is chiefly confined to transit purposes. Two training cruises are conducted each year in the Whitsunday Passage area* to instruct midshipmen in navigation. Three patrol boats which carry out surveillance of coastal waters are based at Cairns, where refitting work is also done on patrol boats from other bases.

One further firing range is the Sea Test Range operated by the Tropical Trials Establishment at Cowley Beach near Innisfail**. This area was last used during the period November 1976/February 1977 for trials of 105/155mm howitzers using high explosive rounds which detonate on impact with the water. Care

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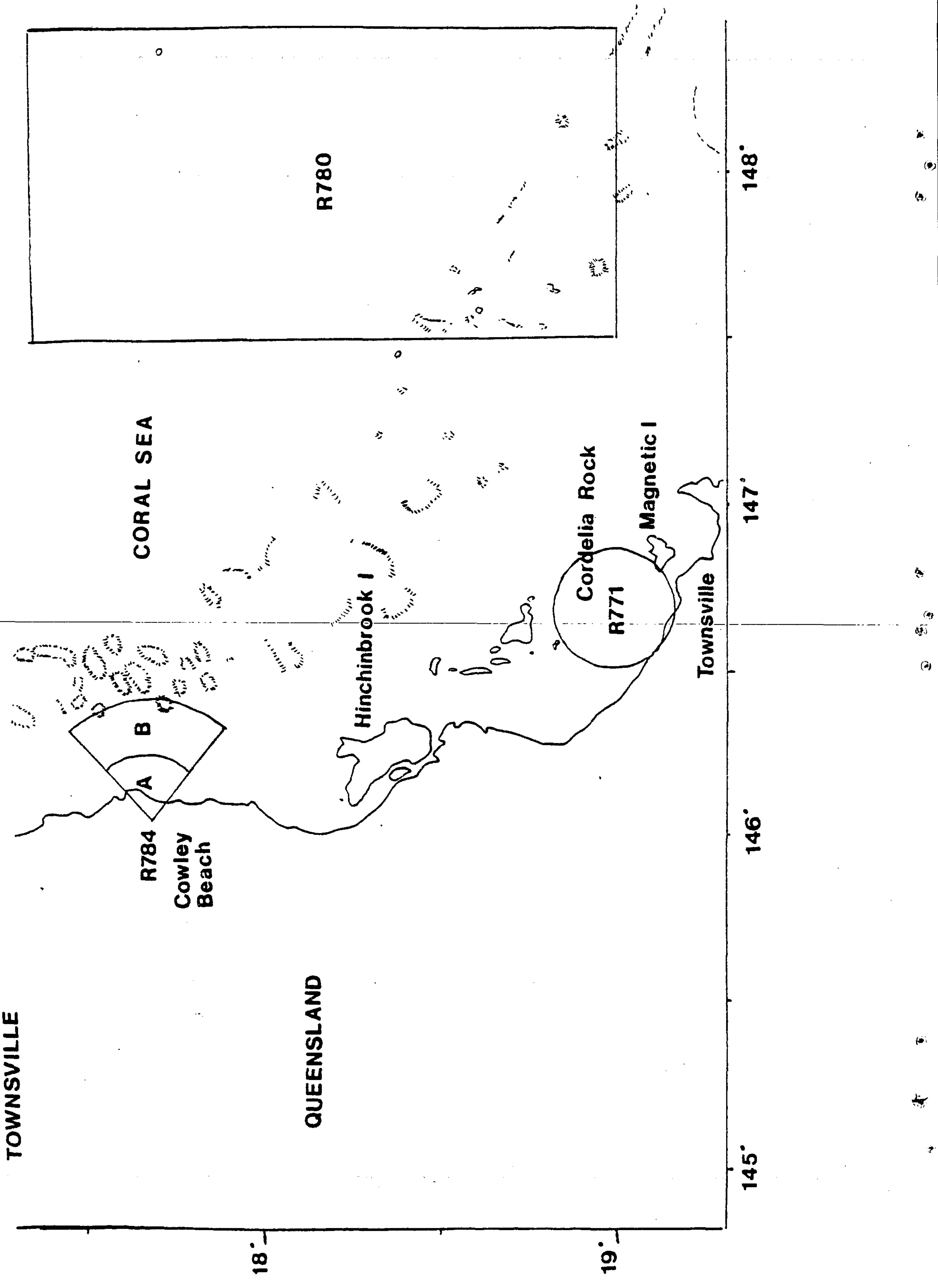
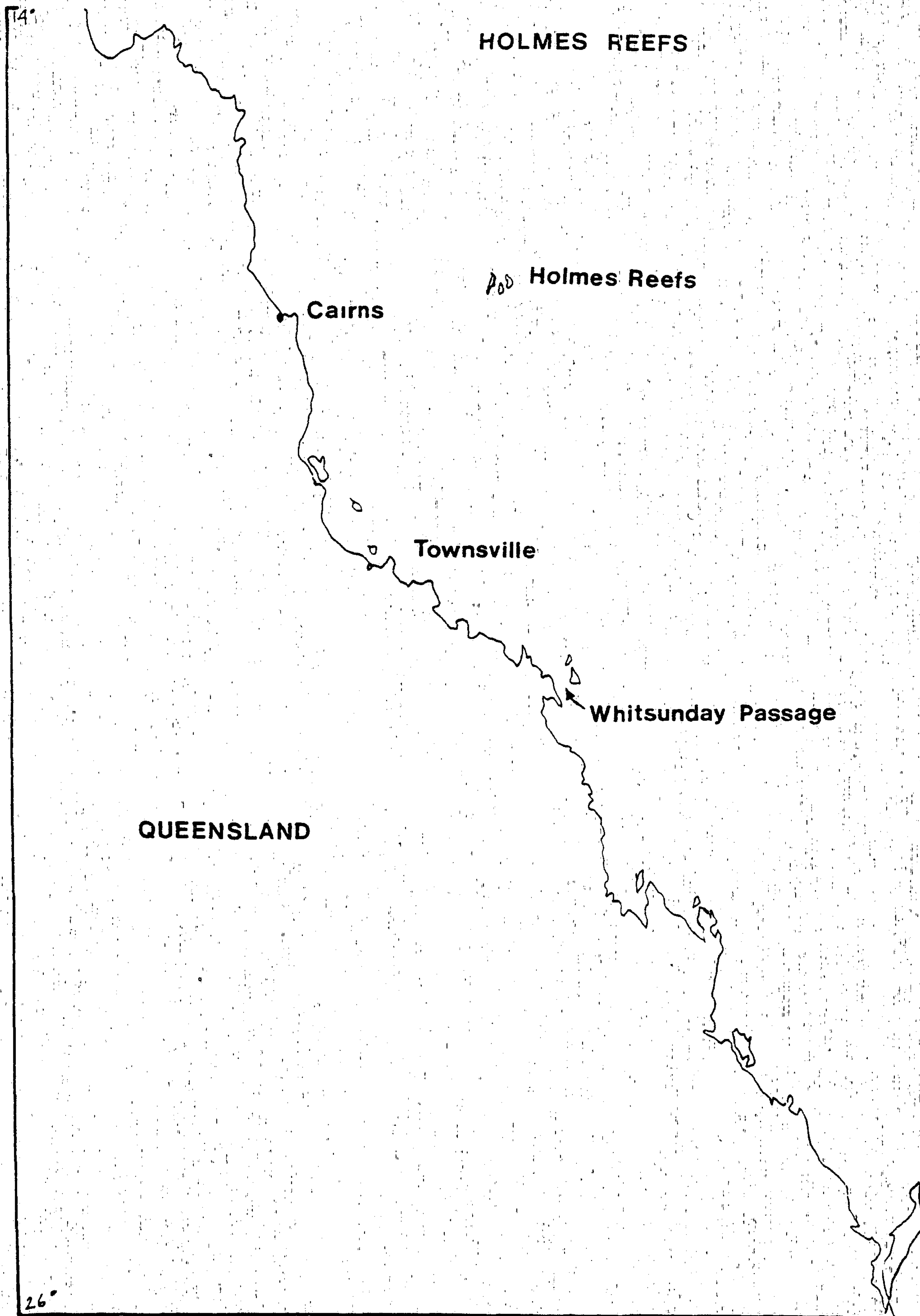
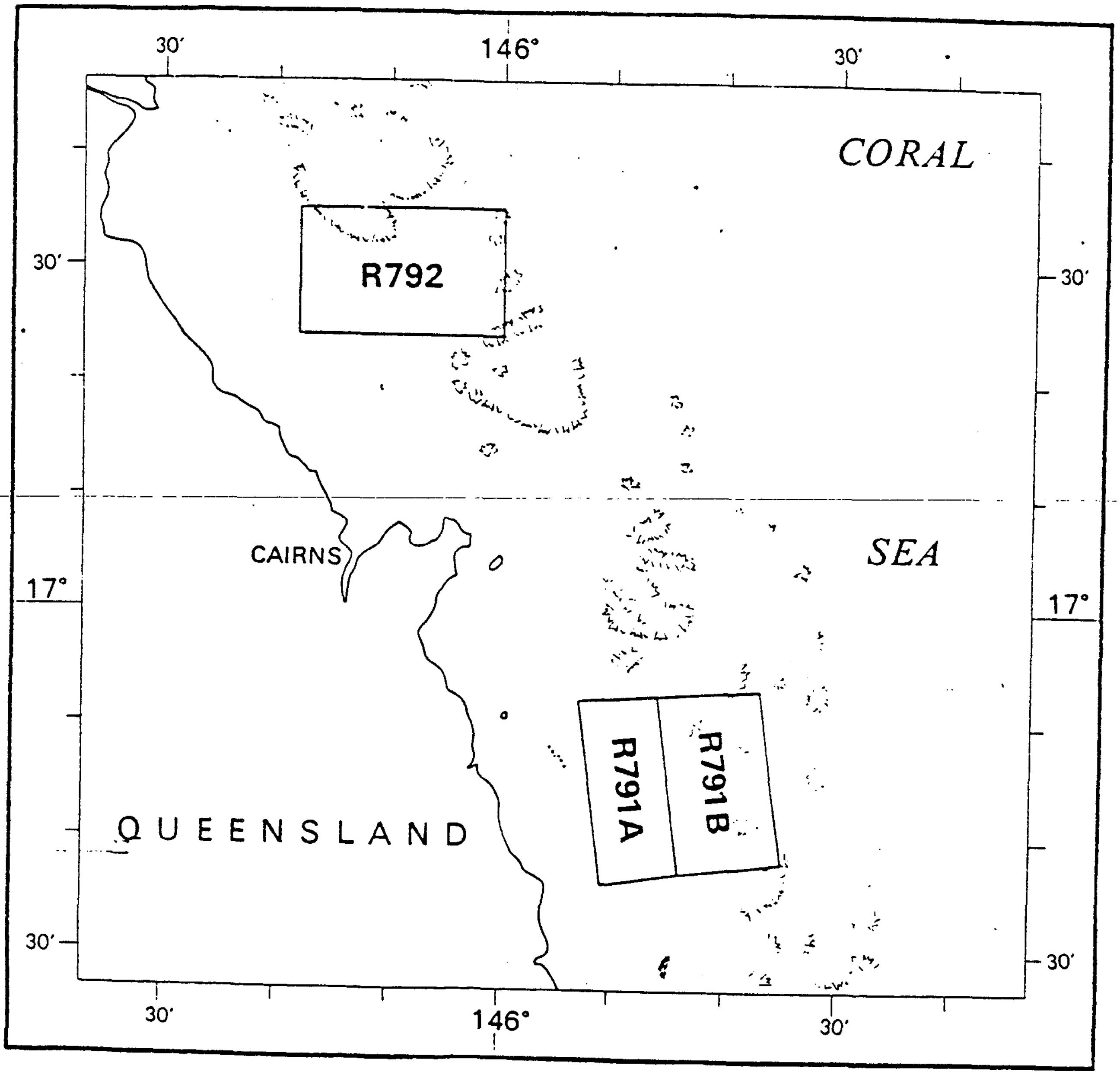
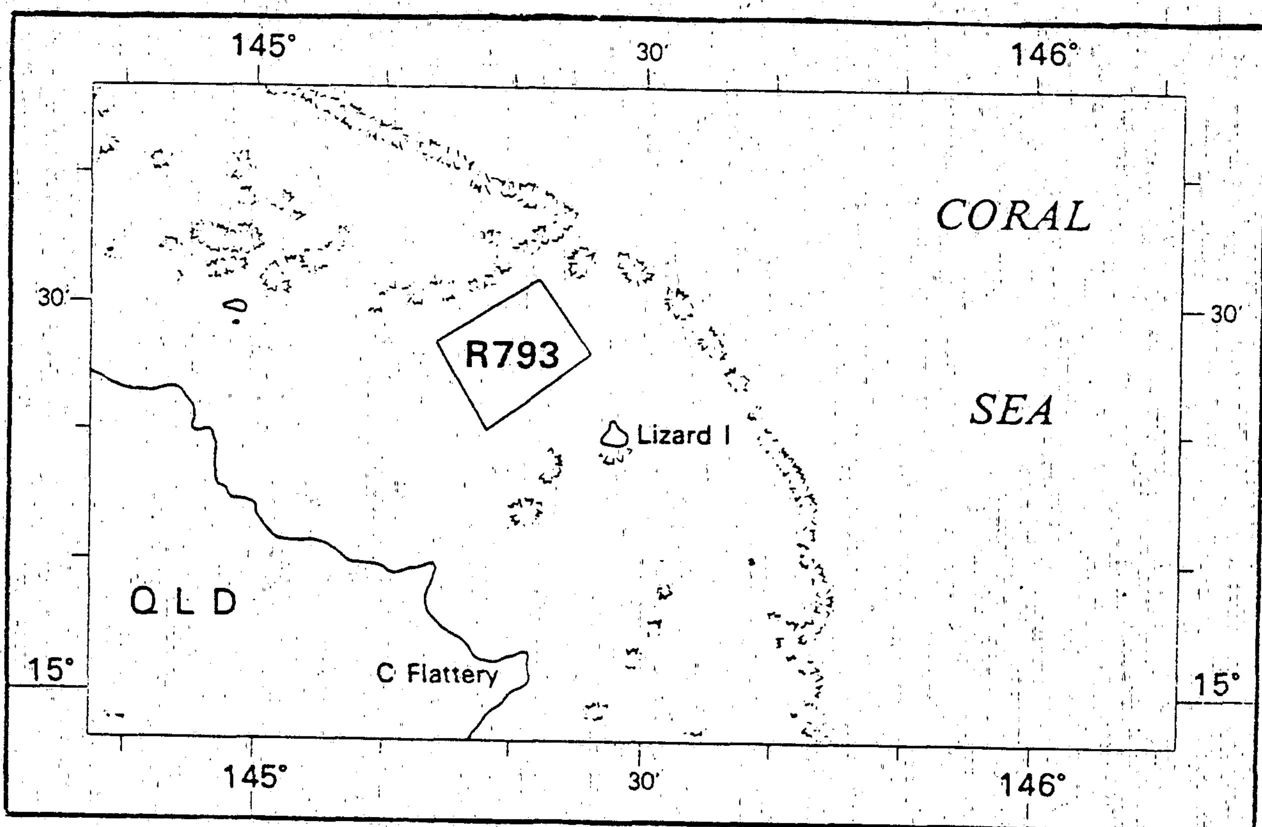
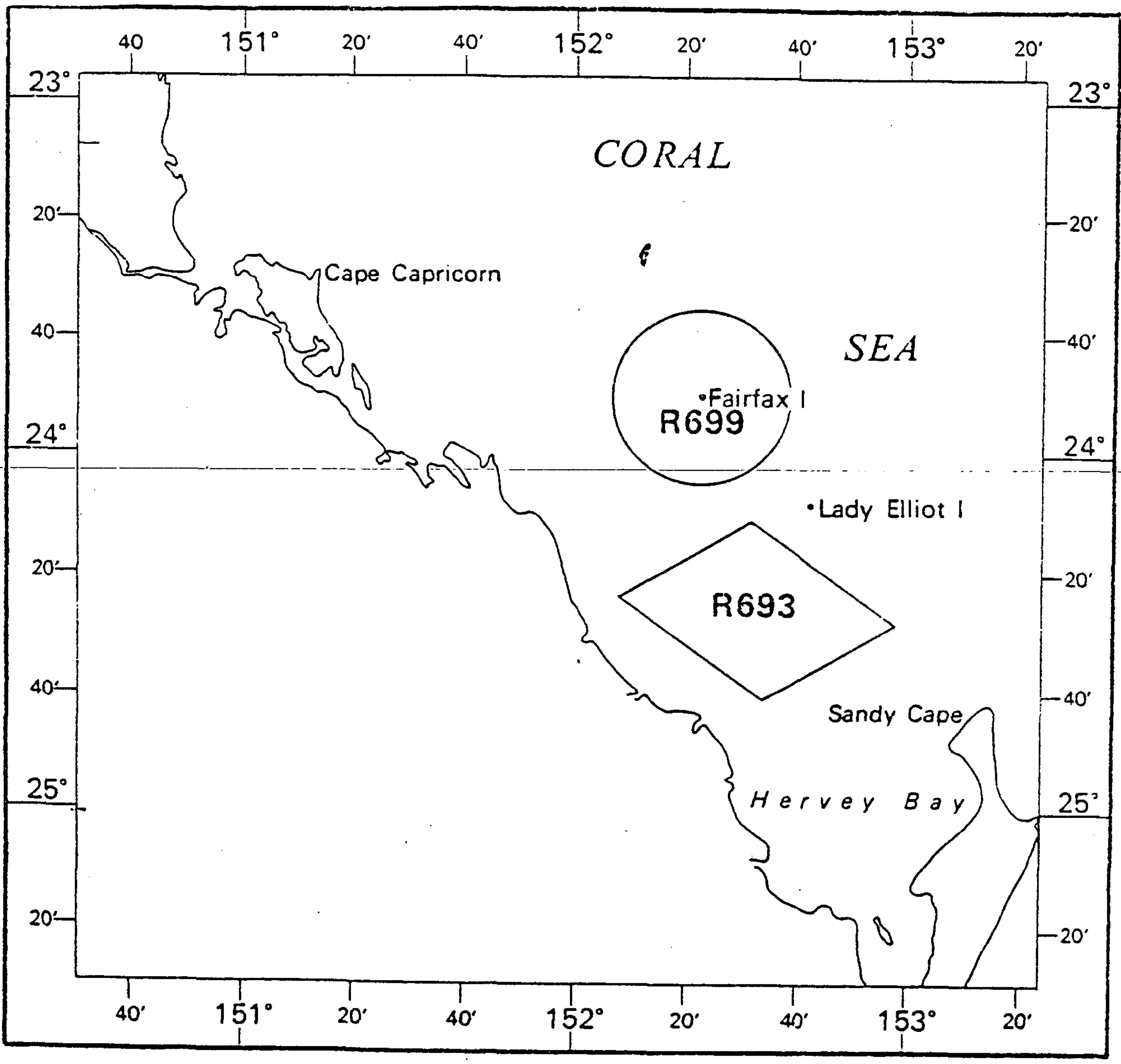
* Included in map, page 129
** Included in map, page 128


TOWNSVILLE
QUEENSLAND
CORAL SEA
R780
R784
Cowley Beach
A
B
Hinchinbrook I
Cordelia Rock
R771
Magnetic I
Townsville
145°
146°
147°
148°
18°
19°


14°
HOLMES REEFS
Holmes Reefs
Cairns
Townsville
Whitsunday Passage
QUEENSLAND
26°


30'
146°
30'
CORAL
SEA
R792
CAIRNS
17°
R791A
R791B
QUEENSLAND
30'
146°
30'


145°
30'
146°
CORAL
SEA
R793
Lizard I
QLD
15°
C Flattery
30'

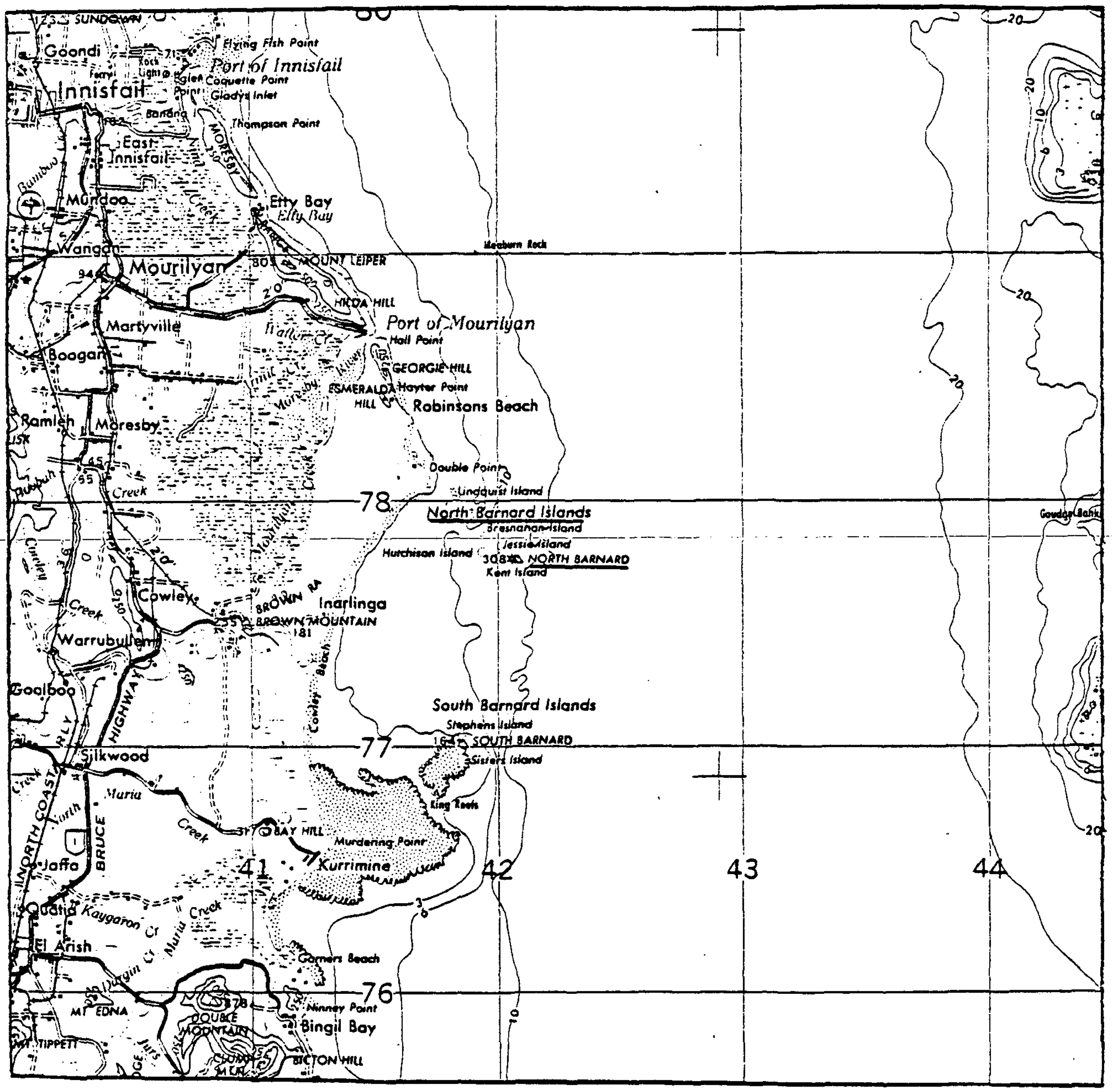

CORAL
SEA
Cape Capricorn
Fairfax I
R699
Lady Elliot I
R693
Sandy Cape
Hervey Bay
40
151°
20′
40′
152°
20′
40′
153°
20′
23°
20′
40
24°
20′
40′
25°
20′

was taken to ensure that the reef itself was not within the impact area. This trial was the first activation of the range in over two years and no further trials are planned at present. The range serves a unique purpose, and it is important that it should be retained.

All other Defence activities in the Great Barrier Reef area fall into the category of research. Most have no significant environmental impact at all; some may be positively beneficial to the environment. These include Naval assistance to the Department of Science in surveys of Crown of Thorns Starfish in the area, and could be repeated in several years' time, and continuing hydrographic survey work by means of which charts are made available to other bodies, including the Marine Park Authority.

We intend establishing a permanent Patrol Boat Base in Cairns. (You are no doubt aware of the contract to build new longer range patrol boats.) Thus our capacity to interdict intruders into the Great Barrier Reef area will be improved. Further, we plan to station hydrographic ships at Cairns. We are hopeful that the Australian Defence Science developed airborne laser depth sounder will prove to be successful. If it is, it will be peculiarly suited to reef waters and will greatly increase our capability to chart the reef.

Materials Research Laboratories have a tropical marine site at North Barnard Island, where research has been conducted to determine the effect of nutrient availability and seawater quality on marine fouling severity, as part of a project to develop anti-fouling paints. This facility has also been employed to evaluate life-rafts and life-jackets for the Services. Investigations have been carried out to characterise the chemistry and biology of the North Barnard Island site and a further site at Clump Point, and it is expected that operations at one of these sites will cease in the near future. Further trials to evaluate materials under tropical immersion conditions will continue at the remaining site. Such studies are useful in the gathering of oceanographic data in the area.


Goondi
Port of Innisfail
Flying Fish Point
Innisfail
Coquette Point
Gladys Inlet
Thompson Point
East Innisfail
Mundoo
Etty Bay
Wangan
Mourilyan
MOUNT LEIPER
HIGDA HILL
Port of Mourilyan
Hall Point
Martyville
Boogan
GEORGIE HILL
ESMERALDA HILL
Hayter Point
Robinsons Beach
Ramleh
Moresby
Double Point
Lindquist Island
78
North Barnard Islands
Bresnahan Island
Jessie Island
Hutchison Island
NORTH BARNARD
Kent Island
Cowley
Inarlinga
BROWN MOUNTAIN
Warrubullen
Goolboo
South Barnard Islands
Stephens Island
SOUTH BARNARD
Sisters Island
77
Silkwood
King Reefs
BAY HILL
Murdering Point
Jaffa
Kurrimine
41
42
43
44
El Arish
Garners Beach
76
MT EDNA
Ninney Point
Bingil Bay
BICTON HILL
BRUCE HIGHWAY
Goudge Bank

As users of the Great Barrier Reef area, the Australian Defence Force and the Department of Defence are both concerned and responsible. The need to continue military training activity in the area demands that care be taken in controlling and monitoring such activities. Further control and guidance is imposed by the need to comply with Federal legislation to protect the environment.

In summary. Defence has vital interests in the reef though overt activity is confined to a few small areas over which it exercises control in the interests of minimising adverse environmental impact.

SHIPPING AND TRANSPORT

GREAT BARRIER REEF INNER ROUTE & TORRES STRAIT

by Captain Bruce Whiteman

Shipping channels through the Torres are comprised of:-

(1) Booby Island through Gannet, Prince of Wales, Adolphus and the inner coastal passage via Gubbins Reef to Cairns and southern ports.

(2) Booby Island via Prince of Wales and Great North East channels to the Gulf of Papua via Bramble Cay or Bligh Passage.

(3) Variations via several openings on the East coast such as Cooks Passage Raine Island Entrance, Euston Reef at Grafton Passage and Palm Passage near Lucinda Point.

These passages (in Annex (A)) are classified as international waterways. The main channels of the East/West passages were originally noted by Luis Vais de Torres in 1605 and then more or less forgotten until the Cook era. It is possible that some were used by traders in the east but there is no firm record of this, despite rumours of Spanish Galleons wrecked on the reef. Spanish Traders did however use the East West Passage as many relics were recovered in this area.

Following settlement of N.S.W. and Victoria, Traders sought a quick route to India and Eastern Ports and records indicate constant use of the outer passage from N.S.W., entering the Torres via Raine Island, some 70 miles South East of Cape York.

Navigation of this passage, particularly the locating of Raine Island from seawards was extremely difficult, due to incomplete charts, the probability of several days without sights, and lack of knowledge of current and tidal streams. Vessels finding themselves in the reef often were unable to beat off a lee shore due to the strong prevailing South East Trades which blow consistently from May until October. The large number of wrecks in the vicinity of Raine Island and the Great Detached Reef nearby bear witness to the hazards of this route. Cook's epic voyage up the uncharted east coast as far as Lizard Island and his efforts to make the open sea in this locality is one of the great sagas of maritime history.

Surveys by King and Blackwood were followed with detail work by Owen Stanley in "Rattlesnake" in 1848. Additional close surveys were completed by the vessels "Alert", "Lark", "Dart", "Penguin", "Waterwitch", and "Paluma". Despite the loss of "Quetta" which foundered on an uncharted rock in 1890, with a loss of 133 persons the popularity of the Inner Route increased yearly and has never looked back.

Nevertheless mariners persisted and eventually a survey of the inner passage enabled these vessels to use the entire inner route to Cape York with confidence.

The close section of the Inner Route commences at Gubbins Reef (an English mariners' term for a hotch potch of food) south of Cooktown and traverses over 400 nautical miles of narrow passages which are only ¾ mile wide in places and necessitate many very sharp turns.

With increasing reluctance to go south-about, via the Great Australian Bight with its constant head winds, mariners pressed for further survey and the introduction of navigational aids, together with a pilotage facility. Queensland argued for a quick and efficient mail service to the East and Europe.

Eventually a steam packet mail service was started by two vessels, the "Souchays" and "Hero", and these ships quickly proved the financial feasibility of the passage. One major drawback remained. Marine Insurers refused to lift their qualification 'Warranted not to proceed via the Torres Strait' despite extreme pressure from the Queensland Government.

Licensed pilots were already offering their services to vessels and it was not until the pilots formed an association which enabled them to run the service efficiently that insurance companies finally relaxed their conditions.
A particularly interesting facet of reef navigation in the few years before the turn of the century is that of 57 casualties occurring on the Australian coast only three happened on the Inner Route via Torres Strait.

The Queensland Government commenced installing navigation aids through the reef and eventually the passage could safely be traversed day and night. This facility was later taken over by the Commonwealth Government and today over 30 beacons and light buoys assist the vessels using the passage.

The Torres Strait and Coast Pilot Service today is managed by Secretaries and manned by over forty experienced pilots who are licensed by the Marine Board of Queensland.

Vessels drawing a maximum of 39 feet (11.9 metres) constantly use the Inner Route. There are no size limitations on ships. In 1977, 1410 vessels were piloted through the reef, and whilst this is rather less than average, the size of vessels has increased dramatically. Average size last year was 25,000 tonnes and a total rough estimate of throughput was estimated to be about 35,000,000 tonnes. The re-opening of the Suez Canal is expected to increase this traffic and should offset the loss of crude oil tankerage due to the Australian local production of this commodity. Approximately 5% of the total users are non-piloted, whilst 200 to 300 voyages are made by small local coastal vessels on regular trades servicing Thursday Island and the Gulf ports, together with some fishing vessels and cruise operators.

Main cargoes through the reef comprise large quantities of bauxite, sugar, and coal, whilst general and freezer cargoes are carried in an ever increasing number of container ships. Some tankers still bring crude oil to southern refineries and return in ballast through the passage. Silica sand traffic from extremely large deposits at Cape Flattery on the mainland near Lizard Island is expected to increase.

The very large bulk ships which load at Hay Point and Gladstone are unable to use the inner route owing to a draft in excess of 50 feet (15.3 metres) and are compelled to go south of the Barrier at Swain Reefs. There are firm indications of a passage through the reef east of Hay Point and south of the Whitsunday Islands following satellite photographs and personal investigations by Alan Schneider of Mackay. Further investigation is indeed warranted to enable these large ships, often in excess of 150,000 tons deadweight, to gain the open sea as quickly as possible and thus shorten their passage to destinations.

Pollution

The first major pollution incident occurred when "Oceanic Granduer" hit a rock east of Thursday Island, whilst bound for Brisbane with 50,000 tonnes of crude oil. Fortunately the main part of her cargo was able to be transhipped to another tanker whilst the weather remained calm. The leaking oil moved out over the reefs and was dissapated in the Coral Sea.

Undisciplined and indiscriminate use of dispersant proved impractical, as had previously happened in the case of "Torrey Canyon" and had little effect. Nature, in the form of photo synthesis and wave action finally dispersed the pollutant.

Modern booms, skimmers, and dispersant-application equipment, together with less toxic dispersants are now stockpiled in strategic parts of Australia under a National Plan, to tie in with International Pollution Convention of 1967 and 1973 in which Commonwealth, State and local authorities co-operate very closely in pollution incidents. Chemical dispersants are not allowed to be used in Queensland waters, except in cases where there is a risk to human life, or where a slick may threaten bird rookeries. Harbour use is permitted in particular locations, particularly in dredged channels which could be called marine deserts.

In his recent tests of the effects of oil on coral reefs, Ernest Grant has indications that certain corals recover quite rapidly following attack by oil. This however would probably not be the case if chronic pollution was allowed to continue.

Another major pollutant of the reef is ship oriented garbage, and evidence of this is always present on the remote beaches of the inner route. Control of pollution in this form is contained in an annex to the 1973 Convention, when masceration, incineration, or retention for shore disposal is mandatory. This Convention also contains details of sewage disposal.

Even then I would consider policing would be necessary to a limited extent. The presence of an authorised person on board vessels in the reef - possibly the pilot, would act as a deterrent.

Over 90% of reported oil slicks within the reef turn out to be what is commonly called "reef scum" or plankton. These prevalent heavy slicks, whilst predominantly light brown in colour, often are brilliantly coloured in orange and green and look almost exactly like oil slick.

Examination and tracking are most costly, and when samples are collected for analysis, the material is thick and not unlike degraded oil. On arrival in Brisbane and prior to analysis, however, the liquid becomes quite clear and is obviously not oil.

Several weeks ago, almost the entire coastline from Frazer Island to Ballina was polluted by a decayed petrolific material not unlike bitumen. Degradation was well advanced, and the small particles were semi-solid, whilst the large parts, sometimes over a metre in diameter, were crusty and solid on the outside, whilst semi liquid internally.

This pollutant could have come from hundreds of miles away in the Coral Sea. Clean-up was most difficult and involved the use of both manual and mechanical methods. Nature again came to our assistance and the pollutant gradually broke up into fine particles, degraded, and dispersed below the dry sand level, or blew away. In considering tanker traffic through the Inner Route, it should be remembered that many of the large ocean-going vessels are in effect tankers themselves, as they very often carry as much fuel as the tankers of the 1950's.

Shipwrecks.

Over 700 known wrecks exist in the Great Barrier Reef. Some have been located, but the majority have only been vaguely reported, particularly those occurring in the early days of our nation in the sailing ship era. The recent discovery of the wreck of HMS "Pandora" in the detached Reefs near Raine Island, led to proclamation of the vessel under "The Historic Shipwreck Act". This Act was enacted originally to protect the looting of known Dutch wrecks on the West Australian North Western coast.

"Pandora" struck the reef and slid into deep water whilst transporting some of the "Bounty" mutineers from Tahiti to the United Kingdom. She missed the Raine Island entrance and became entangled in the notorious conglonerate of reefs some miles to the north. Some 17 other vessels lie in the vicinity but have yet to be fully identified.

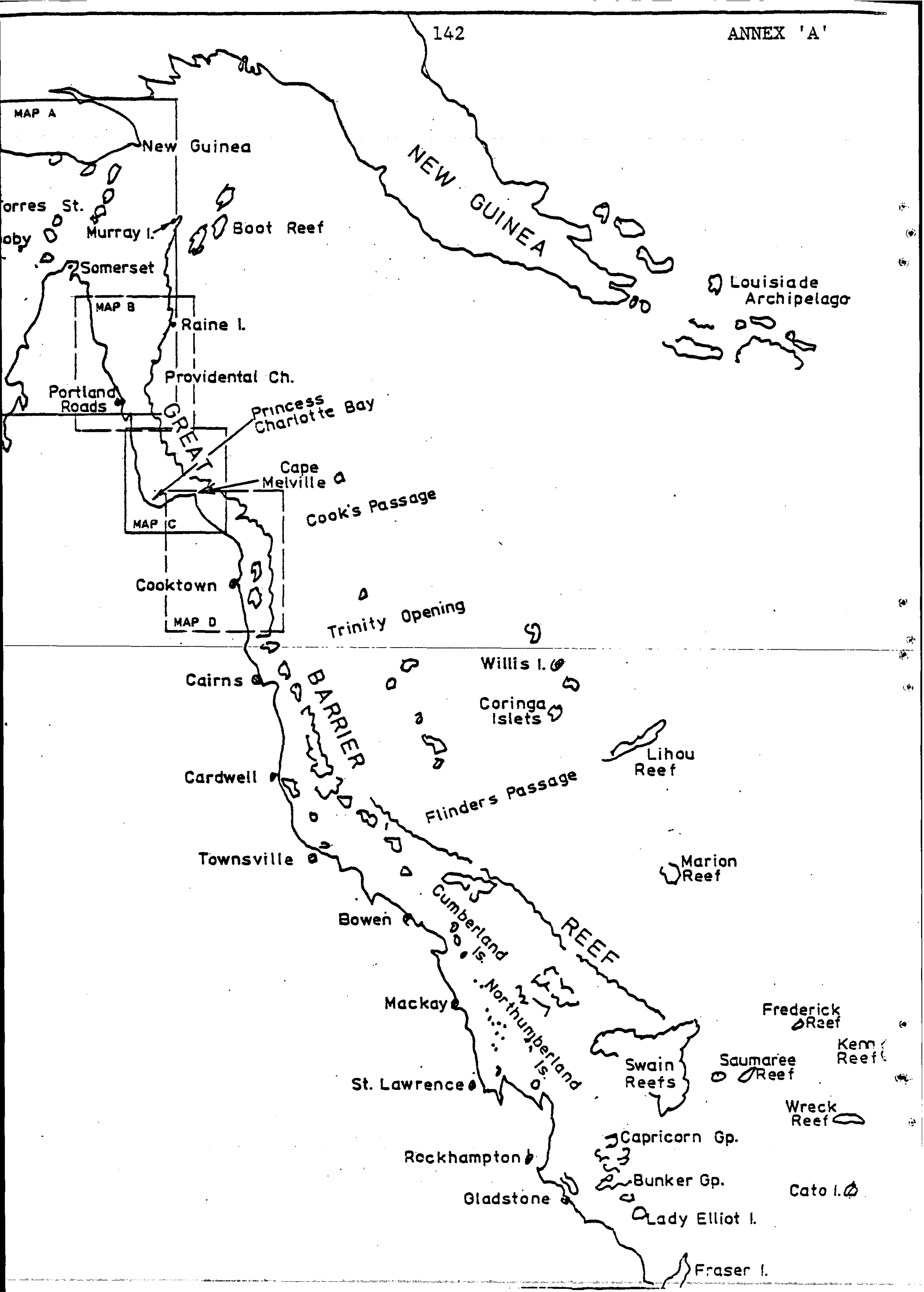
I am sure that we all agree that these wrecks should be protected from the itinerant plunderer. Historic relics and artifacts are known to exist in some of these vessels and when recovered should be restored for posterity.

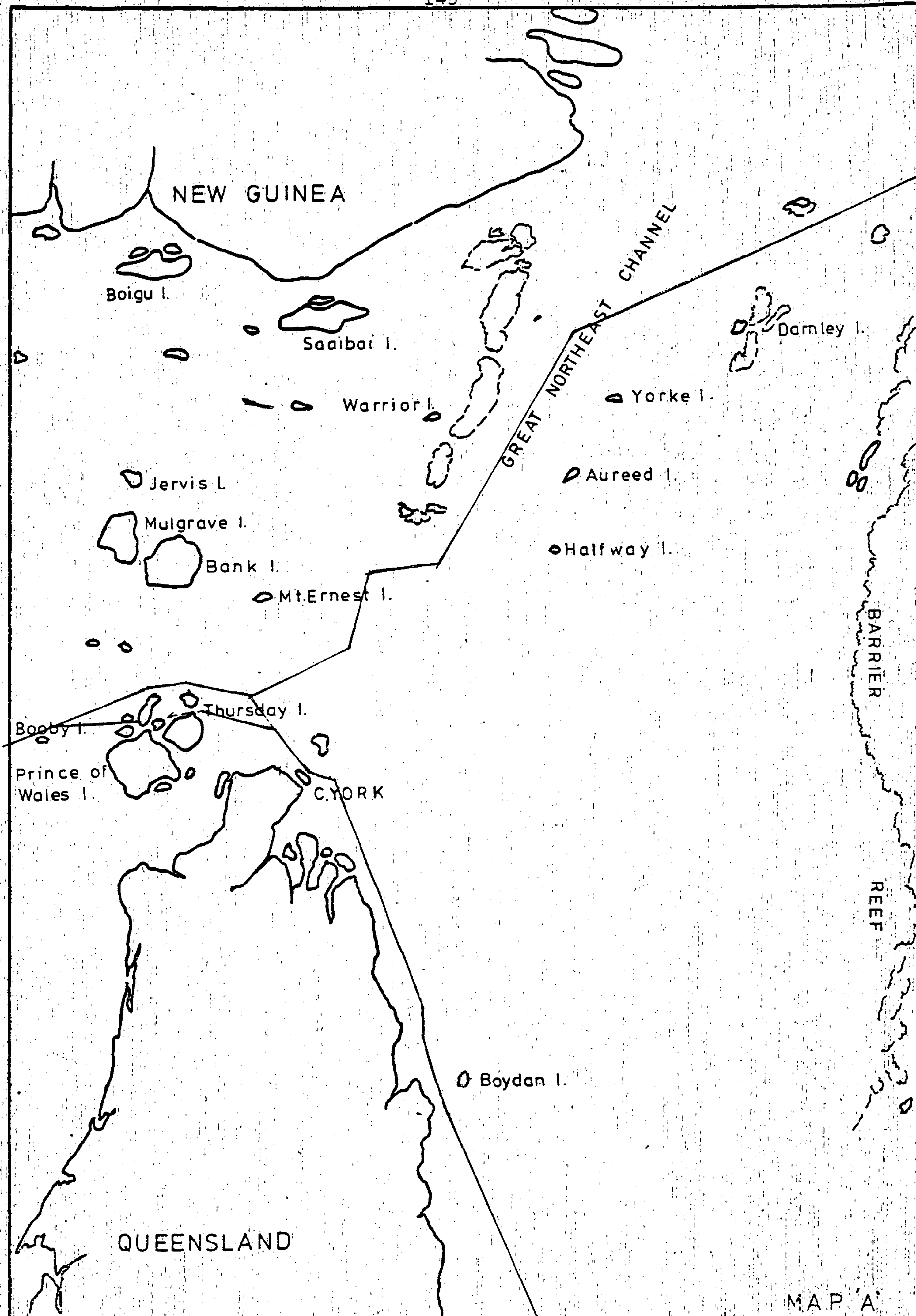
The Queensland Maritime Museum Association together with the Queensland Museum proposes to list these wrecks, and the materials collected will be restored and made available for viewing to the public throughout Australia. This will be a long and arduous task but certainly rewarding.

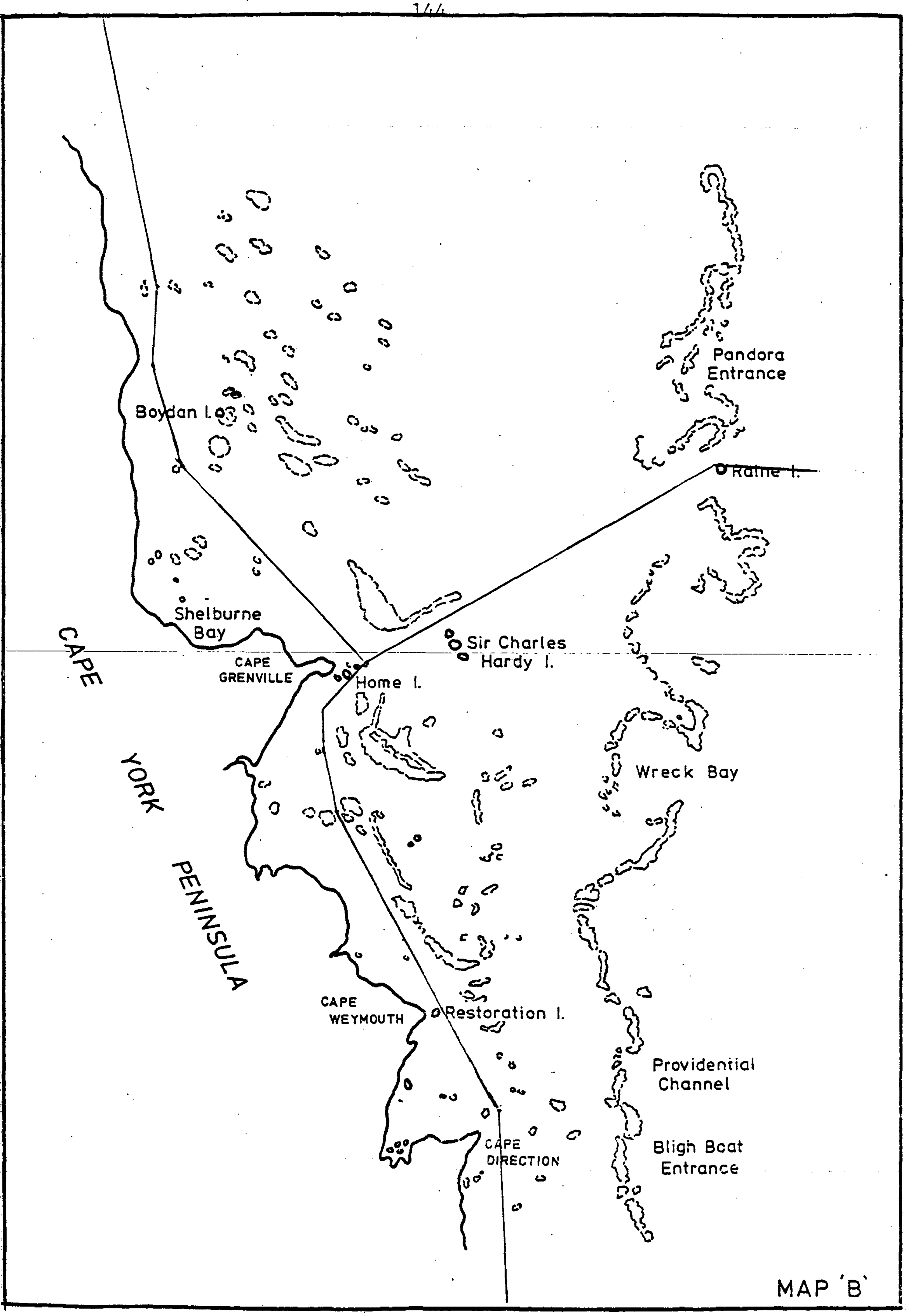
Perhaps fortunately, in the case of "Pandora", her position at the outer extremities of the reef and in dangerous and deep waters will prevent only the authorised professionals from working on the wreck.

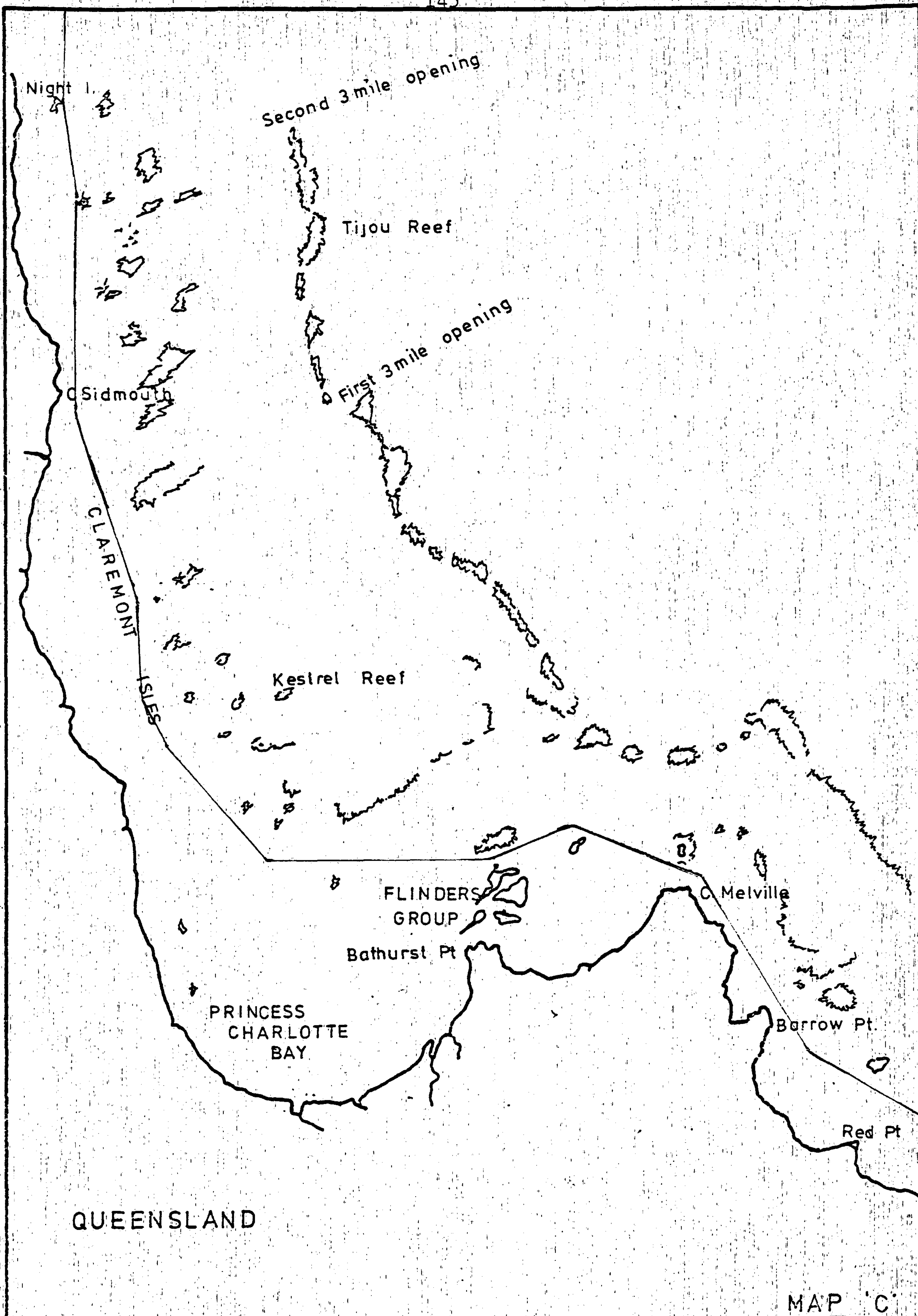
Surveillance by coastal air and sea patrols already engaged in anti-poaching patrols will act as a deterrent.

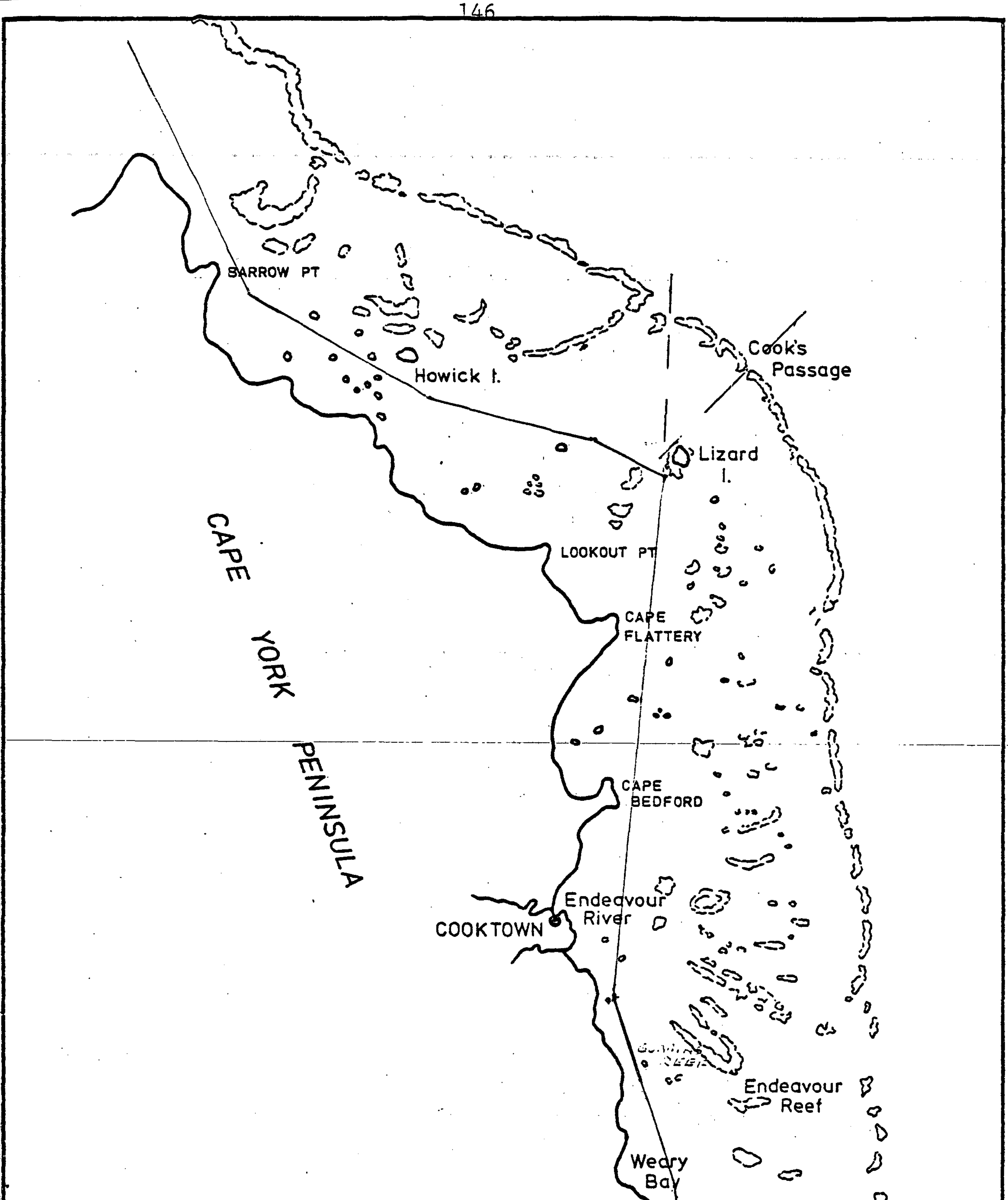
It is, I'm sure, the wish of all here and particularly those members of the Great Barrier Reef Marine Park Authority to protect not only the reef, but so much of our heritage which lies within it.


MAP A
New Guinea
orres St.
oby
Murray I.
Boot Reef
Somerset
MAP B
Raine I.
Providental Ch.
Portland Roads
Princess Charlotte Bay
GREAT
BARRIER
REEF
Cape Melville
Cook's Passage
MAP C
Cooktown
MAP D
Trinity Opening
NEW GUINEA
Louisiade Archipelago
Willis I.
Coringa Islets
Lihou Reef
Cairns
Cardwell
Flinders Passage
Townsville
Marion Reef
Bowen
Cumberland Is.
Northumberland Is.
Mackay
Frederick Reef
Kenn Reef
Saumarez Reef
Swain Reefs
St. Lawrence
Wreck Reef
Capricorn Gp.
Rockhampton
Bunker Gp.
Gladstone
Cato I.
Lady Elliot I.
Fraser I.


NEW GUINEA
Boigu I.
Saaibai I.
Warrior I.
GREAT NORTHEAST CHANNEL
Darnley I.
Yorke I.
Aureed I.
Jervis I.
Mulgrave I.
Bank I.
Halfway I.
Mt.Ernest I.
BARRIER
REEF
Thursday I.
Booby I.
Prince of
Wales I.
C.YORK
Boydan I.
QUEENSLAND
MAP A


Pandora
Entrance
Boydan I.
Raine I.
Shelburne
Bay
CAPE
Sir Charles
Hardy I.
CAPE
GRENVILLE
Home I.
YORK
Wreck Bay
PENINSULA
CAPE
WEYMOUTH
Restoration I.
Providential
Channel
CAPE
DIRECTION
Bligh Boat
Entrance
MAP 'B'


Night I.
Second 3 mile opening
Tijou Reef
First 3 mile opening
C Sidmouth
CLAREMONT ISLES
Kestrel Reef
FLINDERS GROUP
Bathurst Pt
C Melville
PRINCESS CHARLOTTE BAY
Barrow Pt.
Red Pt
QUEENSLAND
MAP 'C'


BARROW PT
Howick I.
Cook's Passage
Lizard I.
LOOKOUT PT
CAPE YORK PENINSULA
CAPE FLATTERY
CAPE BEDFORD
Endeavour River
COOKTOWN
Endeavour Reef
Weary Bay
MAP 'D'

ANNEX B

GLOSSARY OF RELEVANT NAMES

RAINE ISLAND	Capt. Thomas Raine. Early colonial Mariner
BRAMBLE CAY	HMS "Bramble". Survey cutter for Capt. Blackwood
FLY RIVER (P.N.G.)	Survey vessel attached to "Bramble"
PROVIDENTIAL CHANNEL	Matthew Flinders travelled to Australia as Midshipman in HMS "Providence" with Bligh
ENDEAVOUR REEF	Cook's grounding took place here
HEATH REEF	Queensland Portmaster
HERALD PRONGS	HMS "Herald" survey ship
SLASHERS REEF	Regiment en route in convoy to India stranded and refloated on this reef
FLINDERS GROUP	Matthew Flinders (Princess Charlotte Bay)
BLACKWOOD CHANNEL (RAINE IS)	Capt Blackwood surveyor. ("Bramble")
KING ISLAND (Prin. Charlotte Bay)	Surveyor. Commanded HMS "Mermaid"
SUNDAY ISLAND (PALUMA PASSAGE)	Bligh reported attempted mutiny on this day
PALUMA PASSAGE (CAPE GRENVILLE)	Queensland Government Gunboat and survey vessel. Located "Quetta" Rock
PANDORA	HMS wrecked near Raine Island (Blackwood Channel)
BLIGH ENTRANCE	Great North East Channel (Bligh's second voyage)

TOURIST & RECREATION ACTIVITY IN THE NORTHERN SECTION OF THE GREAT BARRIER REEF

BY J. WILSON

DIRECTOR-GENERAL OF TOURIST SERVICES

This paper presents a resume of current tourist and recreational activities in the northern section of the Great Barrier Reef Region, and considers briefly their impact on the region and future trends.

North Queensland is an area which is rapidly becoming recognised for its tourist potential. The Commonwealth Bureau of Statistics' quarterly 'Survey of Tourist Accommodation Establishments' shows a 5.2% increase in the number of room nights spent in far north Queensland (Cardwell north) during the second half of 1976 compared with the same period in 1975; while the rest of Queensland showed no growth and Australia as a whole showed a decline. Much of this tourist appeal is attributable to the Great Barrier Reef, and it might be expected that this Northern Section would have considerable tourist attraction.

Present activity in the area under discussion can be divided into three major categories:

1. Activities centred around Lizard Island,
2. Activities carried out from charter boats, and
3. Private trips to the area.

LIZARD ISLAND RESORT

Lizard Island is the centre of the most important tourist activity in the northern section. It is the most northerly island resort in Queensland; lying approximately 95km North-East of Cooktown. The island is rugged, sparsely vegetated and covers 1,000 hectares. It has a number of natural features which make it a tourist attraction, including white sandy beaches, an unspoiled fringing reef, clear waters, proximity to the outer Barrier (16km) and a good anchorage. It also has a colourful history which includes its use by Aborigines as a ceremonial area (stone arrangements and middens still survive), a landing by Captain Cook in August 11, 1770 and its use as a headquarters for a beche-de-mer fishery. It was the site of Mary Watson's (the wife of a beche-de-mer fisherman) attempted escape from attack by Aborigines in an iron pot. The ruin of the Watson's Cottage still stands on the island.

The resort was opened in 1975 and is owned and operated by a consortium which includes Bush Pilot Airways. The resort operates on a lease of 60 hectares (most of the island is a National Park)and consists of a single lodge, modelled on a 'homestead' design, plus four small self contained units. The resort consists of nine accommodation units catering for a maximum of 20 visitors at any one time. The units average at 60% occupancy over the year, with a peak between August and November during the marlin season.

Communications with Lizard Island

Transport to the Island is by air. Bush Pilots Airways run scheduled flights to the Island five times a week, except between December and March when there are only three flights per week. Bush Pilots also organise a Cooktown/Lizard Island day tour. The combination of these two services means that there are a large number of visitors to the Island on a daily basis. A total of 2,005 passengers were carried on the day tour in 1977. (Table 1) For the months in which comparable figures are available, there was a 160% increase in passengers carried between 1976 and 1977 and a 300% increase between 1975 and 1977. Scheduled flights also take day visitors to the Island. Seating capacity of the plane is 17 persons and approximately 20-25% of these passengers are connected with the Research Station. It is estimated that approximately 1,000 people may visit the Island as day visitors on these flights.

It is possible to camp on the Island if one has a permit issued by Queensland National Parks and Wildlife Service (Bush Pilots will not carry passengers intending to stay overnight if they do not carry such a permit). National Parks records (Table 2) show that in 1977, twenty permits were issued covering 61 persons.

Recreational activities of visitors to the island include big game fishing, fishing, snorkelling and spearfishing, coral viewing from a glass-bottom boat, hiking, birdwatching and general relaxation.

The management of the Lizard Island resort have projected an image of exclusiveness, catering for a limited number of persons, in an area of unspoilt beauty. They have a keen interest in maintaining the area in a condition as near to pristine as possible, and encourage guests and day visitors to undertake non-disturbing activities, and to keep both beaches and seafloor free of litter. For example, guests are asked to catch no more fish than can be used at the table.

In this endeavour, they appear to have been fairly successful. Their control of course only covers the 60 hectares within the lease, and there has been some criticism of campers on the Island following problems of litter and excessive fishing.

Overall, activities on the Island are probably not having a significant effect on the fringing reefs (in contrast with, for example, Green or Heron Islands), and very few visitors would use other nearby reefs. This situation is likely to continue, at least in the near future, as the syndicate operating the resort has no plans for expansion.

CHARTER BOAT ACTIVITES

Two types of charter vessels predominate in the Cairns area; the game fishing boats and larger, slower charter boats that mainly take large numbers of persons on day-trips to inshore reefs.

Game Fishing

The game fishing season runs from the beginning of August through to mid-December. Boats using the northern area operate out of Cairns during this period. It has been estimated that thirty boats operated out of Cairns during 1977 and the numbers have been rising steadily since 1965. (Table 3) The game fishing activity has become an important factor in the economy of the Cairns district, with boat hire alone generating an income of nearly $500,000 in 1974.

Most vessels operate between Cairns and Lizard Island and the heaviest fishing is concentrated in the outer Ribbon reefs. Estimates by gameboat operators suggest that up to ten game boats may go beyond Lizard to the Jewell reef area and perhaps three to four may continue to Princess Charlotte Bay. The emphasis in the last category is on pleasure cruising.

Boats may use Lizard Island as a base, flying their owners/charterers to that point. From the Island, they can fish the outer reef during the day and return each evening.

Alternatively, boats may use a 'mother ship' which will shelter from the south-westerlies in the lee of the outer reefs, and provide food, fuel and weighing facilities, allowing the boats to stay on the outer reef for extended periods up to several days. Fishermen are often flown to the location by float plane.

While game fishing is increasingly important in more southern areas, it does not extend greatly into the area under question. However, it is probable that there will be a steady increase in numbers of boats using Lizard Island facilities as the Cairns gamefishing area becomes better known internationally. The movement of big game fish is not fully understood, and it may be possible that fishes will be found further north earlier in the season, thus allowing the season to be extended.

It should be noted that game fishing occurs only outside the reef area, off the continental shelf, and as such may not have a direct impact on the Reef. Further, most fish caught are returned, and only those of particular significance are landed.

Other Charter Boats

Approximately nine charter boats (which are not game boats) operate out of Cairns and Port Douglas. These boats make day trips to the inner reef area around Cairns and Port Douglas for fishing, diving, shelling etc. and carry up to

30 people. Overnight fishing trips are also undertaken. Owning to the distances involved, this type of boat rarely goes beyond Lizard Island. However, a few extended charters are undertaken by most operators; Princess Charlotte Bay is the most common destination but trips may go through to Thursday Island. The type of charter varies, but includes purely pleasure cruises which may stop at a large number of reefs and islands on the way through; and scientific or filming expeditions with a specific destination. During the last few years, approximately twenty trips of this nature have been made each year, usually between one and six weeks in duration. The number of people on each trip rarely exceeds ten.

Private Trips to the Area

Small boat activity in the area is very low. It is too far away from Cairns or Cooktown to allow open boats to reach it with any safety and there are no major centres along the coast from which they could be launched. A few boats may go out from Iron Range.

Private yachts passing through the Reef are probably the most important users. The Torres Strait Pilot Service have estimated that an average of three such pleasure craft pass northward each day. This figure is confirmed by charter boat operators. These yachts tend to stay within the shipping lane as most reefs in the area are poorly charted, and call briefly at Islands with water and/or good anchorages. Unexposed reefs are not often visited.

FUTURE TRENDS

The northern section of the Barrier Reef has obvious appeal as a destination for tourists. However, there are no immediate signs of growth in the industry in this area even though there is significant growth in areas further south. The operations of Lizard Island resort have no immediate plans for expansion. The resort will only start becoming profitable next year, and a larger resort would clash with its present image of exclusiveness. A continued increase in day trips would appear a likely development.

Charter boat operations are becoming increasingly costly owing to the long distances involved and the consequently high fuel costs. A minimum cost for a ten day charter is $3,000 and this is likely to curb future growth in this direction.

Game boat charters are in a somewhat different situation. Cairns is becoming increasingly famous internationally as perhaps the world's best Black Marlin ground and the number of boats operating out of Cairns has been increasing steadily (Table 1). Lizard Island will become more important as a base for big game boats. The number of 'mother ships' which use the outer reef near Lizard Island is also likely to increase, and, as suggested previously, it is possible that game fishing grounds may extend northwards. However, there is no indication that it would go beyond Princess Charlotte Bay.

Access to the reef for small boats is seriously restricted. This situation could only change if centres along the northern coast were developed, and this is not anticipated. If the road to the Cape was greatly upgraded it would probably still follow its present inland route. Beyond Lloyd Bay, the reef diverges from the coast, making access difficult for small boats.

There are no known plans for further resort-style accommodation in the northern area - the isolation factor weighs against the area because of the high cost of travel. However, the aesthetic potential is there and the possibility that such a resort could operate profitably cannot be entirely ruled out.

Private pleasure craft traffic may be expected to increase in time with the world wide boom. Those islands and cays with water or good anchorages near the main shipping channels (e.g. Hicks Island, Hannibal Island and the Flinders group) will probably be visited more frequently.

SUMMARY

The tourist activity in the northern sector of the Great Barrier Reef is not expected to expand very much within the next decade, although the more southern section around Lizard Island should see some increase. The impact of tourism and recreation activity on the reef is, at present, minimal.

1. The number of persons is fairly small;
2. Ships and boats on passage are confined to the main shipping channels owing to the problems of navigating in unchartered areas; and
3. Most people fall within the control of charter boat operators or the management of Lizard Island resort, both of whom take a generally responsible attitude towards reef use.

Table 1: Number of persons carried on Bush Pilots Airways Cooktown/Lizard Island day tour

	J	F	M	A	M	J	J	A	S	O	N	D
1977	72	0	47	138	209	326	209	384	338	231	142	38
1976	42	0	11	58	158	161	181	229				
1975	38	6	23	7	105	82						

Table 2: Camping permits issued by Queensland National Parks and Wildlife Service for Lizard Island

Permits Issued 1977	1978 (to June 1)	No. in Party
3		1
9	2	2
4		3
1	1	4
0	1	5
2		6
0		7
0		8
0		9
0		10
0		11
1		12

Table 3: Number of Game Boats operating out of Cairns during season 1965 through 1975

Year	No. of Boats
1965/66	1
1967	3
1968	6
1969	5
1970	7
1972	14
1973	16
1974	25
1975	25 (est)

BETWEEN LAND AND SEA: ABORIGINAL COASTAL GROUPS IN CAPE YORK PENINSULA

A.K. CHASE

School of Australian Environmental Studies,
Griffith University, Nathan, Queensland

CONTENTS

BETWEEN LAND AND SEA: ABORIGINAL COASTAL GROUPS IN CAPE YORK PENINSULA

A.K. CHASE

School of Australian Environmental Studies,
Griffith University, Nathan, Queensland

Ngana walinyana wantum waathangkana wantumu?
Pakay waathangkana Pilmumu-e kayinana
yaawalingkana taraku.

We have winched up the anchor, Which way are we going?
We are going down to Pilmuku (island).
We have anchored now and are rowing to the reef
(for trochus shell).
(Contact song from the lugger days, composed by Matty Ropeyarn)

INTRODUCTION

Aboriginal anthropology, in line with general trends elsewhere, has recently become more aware of variables associated with the physical environments within which Aboriginal people operated in pre-contact times, and in some cases still operate, Ecological analysis of man - habitat interactions for example is offering new insights into such problems as the meaning of "tribe" and "territory", "subsistence", and the nature of hunting and gathering as a way of life.

In this way, anthropologists have become interested in wider issues than kinship and marriage structures, ceremonies, grammars of languages and the like, and the way is open for multidisciplinary teamwork in understanding the dynamic interactions between socio-cultural man and his biophysical environment. This will hopefully integrate what has often been separate and fragmented areas of research.

Hunting and gathering groups as represented by Australian Aborigines have always been seen as having a special relationship with the land they occupy and use (see Bicchieri, 1972; Lee and DeVore, 1968) and this is partially based on the fact that for some 99% of the two million years man has been in existence, he has operated as a hunter and gatherer. Australian Aborigines in particular have long been of particular interest to theorists concerned with man's history, though often this interest has produced crude evolutionary frameworks which view them as frozen relics from past stages of man's "progress". In many cases such studies have failed to reveal the rich and complex interconnections between Aboriginal people and their environments.

In Australia, anthropology has been partly responsible for other stereotypes which have grown up concerning Aborigines. In the eyes of most Australians Aboriginal traditional culture has come to be associated with those groups from the arid and desert zones, and this reflects the heavy concentration of literature upon these inland environments. This is, of course, partly due to settlement patterns of the Australian mainland by Europeans - a process which rapidly displaced Aborigines who occupied the more fertile coastlands and river systems, and who formed the bulk of the Aboriginal population.

This disproportionate attention to Aborigines of arid zones has meant that coastal groups generally have not received the anthropological attention they deserve. Across the northern tropical coastline of Australia Aboriginal groups still exist, and despite their resettlement in missions and communities they still possess considerable knowledge of their traditional practices and have retained relationships with their lands, albeit on a part-time or sporadic basis.

Aboriginal Groups of Eastern Cape York

This paper takes as its focus those Aboriginal groups who prior to European contact, occupied the coastal strip from Cape Melville to Cape Direction. As will be outlined later, these groups operated within a highly complex mosaic of plant communities which formed the littoral dune system and its immediate hinterland, and most importantly, a similarly complex mosiac of marine environments which extended from the beachfront and estuarine margins outward to encompass sandbars, offshore islands and fringing reef systems.

This area of Cape York represents a unique area from a scientific viewpoint. The area is impressive with its wide range of environments suitable for human occupation and use, and these range from dense coastal scrubs and riverine vineforests, saltpans and mangrove communities to open woodlands, swamplands and rainforest-clad mountain slopes (see Pedley and Isbell, 1971; Harris, 1976).

The strongly marked seasonal variation produces an annual fluctuation from the heavy monsoonal rains of February to May, to the extreme dry of early December. This results in a cyclical pattern of large areas of inundation, flooded streams and strong vegetation growth followed by reduced surface waters, dry grasslands which were, and still are burned, and animal concentrations upon the few permanent waterholes.

Marine and island environments also alter with the seasonal cycle. Heavy stream discharge during and immediately after the wet season muddies the shallow coastal waters and appears to initiate various fish migrations associated with food chain processes. Rhythmic alterations to tide levels provide access to shellbeds at certain times of the year, and islands follow their own micro-processes across the seasons with migratory bird populations and series of plant fruitings.

The most detailed coverage of the traditional culture of Aborigines from this area of Cape York can be found in Hale and Tindale (1933-1934), Thomson (1933, 1934, 1956) and Chase and Sutton (1978 in press). In distinction to other coastal groups from the western side of Cape York Peninsula, these people possessed large outrigger canoes with single and double outriggers, which were capable of holding up to four adults. These canoes were paddled, and were used as a hunting platform as well as transport. Large detachable head harpoons were used in conjunction with the canoes to capture such large sea animals as dugong and green turtle.

These people threfore possessed an efficient means of marine mobility which allowed them to ply up and down the coastline, and as well outwards to offshore islands, reefs and sandbars. In this way such groups exploited environments ranging from the inner reef areas to the foothills of the coastal range system several miles inland from the beach. In the area from Port Stewart north, these people referred to themselves as pama malnkana ("men of the sandbeach") and this self classification reveals in part their occupational strategy. Locating their camps on the immediate beachfront right through the seasonal cycle allowed them to exploit both terrestrial and marine environments in the most efficent manner. Situated on the foredunes they were truly between land and water, and able to strike out in either direction when seasonal or accidental concentrations of animal and vegetable resources made their appearance.

Another factor in the occupational pattern of these beach peoples is the extreme (by inland standards) sedentism throughout the year (see Thomson, 1934; Chase and Sutton, 1978). Camps moved little more than a half-kilometre at a time in the normal situation, and reasons for such shifts are nearly always based on the need for a clean campsite or the occurrence of a particularly known seasonal abundance such as yams, crabs and the like. Larger gatherings were held at intervals of two to three years at well established sites to carry out ceremonial activities and initiations of young men. Particular individuals would have moved further afield, visiting the countries of their wives, looking for new social stimulation, and making various personal arrangements that feature in the lives of any human group.

An overall picture, in summary, is of a highly stabilised series of groups occupying small areas in a continuous series of strips along the coastline and possessing mobility across both their terrestrial and marine environments. They knew these environments intimately and were able to draw upon an extraordinarily rich diversity of resources for their subsistence.

Contact History

The first contacts for the area were by sea, notably the arrival of Bligh at the Australian mainland, the sea explorations of Captain King and various surveying ships. On land Kennedy was the first explorer followed some thirty years later in the 1870's by Robert Logan Jack. Soon after Jack's expeditions Japanese and European boats began heavy contact along the coastal area searching for trepang, pearlshell, Aboriginal women and cheap labour for the boat crews. From the many fragmented reports of this period there did not appear to be any general hositility between the lugger operators and the coastal people; rather the relationship seemed to be one of guarded exploitation by both sides. On the part of the Europeans and Japanese there was economic rationality in keeping relations on a reasonable footing not only for their survival, but in order that a continuing labour force could be tapped. On the Aboriginal side, the foreigners possessed what seemed to be unlimited potential supplies of steel tools, clothes, flour, tobacco and alcohol, and by the turn of the century all of these had become firmly entrenched in the Aboriginal economy. In the area from Cape Sidmouth to the Pascoe River an enduring relationship was maintained between the various Aboriginal groups and one European entrepreneur who gathered sandalwood as well as fishing for marine products.

While this mutual dependency had its obvious costs on the Aboriginal side (for example removal of young men from their obligations and roles in Aboriginal society) the lugger industry did however allow certain traditional factors to continue. It increased marine mobility among a people who were very much at home on the sea and allowed them to retain regular contact with their beach, reef and island sites along the coastline. Older men could educate the young men into the complexities of sacred and secular sites and their myths, and show them favoured traditional sources of food and materials. Ceremonies continued during this period with boat crews gathering at the many boat anchorages along the coast. This presents a remarkable parallel to cultural continuity occuring in the cattle industry where stockmen carried out a similar underground education of young men while doing cattle work.

Summarising this brief overview of contact history, it can be seen that there has been a considerable cultural continuity of knowledge particularly associated with marine and littoral environments and this has survived one hundred years of contact in the area. This, as I will discuss later, has implications for the development of marine and terrestrial parks.

Cultural Differentiation: Territories and Environmental Components

From the 16th parallel northwards there were about 45 distinct Aboriginal language clusters in the Peninsula before contact, and these consisted of several hundred dialects. The Carpentarian coast, the far northern tip and the Princess Charlotte Bay area were areas of concentrated linguistic diversity with some dialects restricted to a few score people. It was not unusual in these areas for major linguistic differences to occur within twenty kilometres. For the area under discussion there is a major cultural boundary in the vicinity of Port Stewart separating Princess Charlotte Bay people from the "sandbeach men" further north. Here there is a change from the scores of associated dialects of the Bay to a large area extending one hundred miles northward containing only three dialects. This boundary also separates major ceremonial complexes and seems to have acted as outer limits for marriage exchange. Certain technological features associated with canoe manufacture change dramatically at this point.

It is perhaps worthwhile pointing out that for this area names of the major languages have often been wrongly taken to mean "tribes", and this ignores other crosslinking social dimensions which can combine and separate Aboriginal groups across linguistic boundaries. The considerable anthropological argument which has developed over the notion of "tribe" in Australia can be pursued in Peterson (1976). For the purposes of this paper I shall concentrate upon the notion of local group territories: discrete areas (usually of about $20km^2$. land area) which small groups of kinsmen see as their primary estate. These groups, ranging perhaps from twenty to fifty individuals in traditional times, validated their claim to this estate by patrilineal descent, mythological sites, explanatory myth and associated ceremonies. Such an area is often referred to in the literature as a <u>clan territory</u>. They have clearly defined boundaries and confer primary rights to the resources within them upon the members.

In both the Princess Charlotte Bay area and the Nesbit region to its north, these territories extended beyond the land and across marine environments taking into their ambit the offshore islands, sandbars and reefs. Such marine locations commonly possess formal names, and can be mythological sites with restrictions placed upon their accessibility. Maps A and B show locations of territories and their boundaries for selected areas of Princess Charlotte Bay and the Nesbit region.

For the Flinders Island group and the mainland from Cape Melville to Bathurst Head it can be seen that these territories crosscut both the mainlands and islands, while in some cases they consist entirely of island and marine areas. In the Nesbit region there is a much more regularised division with the territories appearing as parallel segments each of which includes a complete strip of coastal flatland and an offshore component of islands reefs etc. Below are listed by way of example, some of the names of offshore reefs for one small segment of the coastline in the Night Island area.

pulatyi, thinityi maathuy	- reefs at the northern end of Night Island
kupanthaku	- reefs and cay at Binstead Island
wuypanamuyku	- reefs and Lowrie Island
thuypa	- Bobardt reefs
wukaka	- Bobardt reefs
ngalungun	- reef off Voaden Point
puunytyanuku	- Stork reef
kumutyi	- Treat reef

From these examples we can infer that formal names were associated with all major patches of inshore reef along the coastline. When these sites are added to the similarly prolific naming of sandbars, cays and islands in the marine environment, and these in turn added to the extensive naming of locations and features on the mainland coastal strip, there emerges a picture of a highly formalised and named landscape. This is part of a complex cognition of the total environment both physical and spiritual, and encompasses myth, ceremony, resource usage, camping locations and sacred sites.

Each territory can, in this way, be seen as a central universe containing its own explanation of existence, validating firstly for the clan members their own social existence, and secondly in conjunction with other territories a wider order of existence of humanity and nature.

Coral reefs have a descriptive environmental term in the languages so far worked with, and as well they have a generic term for coral as a substance. Several types of coral are recognised as well, though extensive linguistic work has not been carried out in this area. In order to illustrate some of the distinctions, the following examples are given from the Flinders Island language:

coral reef	-	thandhuula
coral (gen.)	-	arrnggan
rock coral	-	arrnggan abu
black tree coral - ("sea wood")	-	arrnggan wulpay

Often underwater features of reefs share environmental terms with land features, for example in the language of the Nesbit area <u>awi</u> refers to clear sand patches among the coral, cleared patches in vegetation, or open areas on the foredune, <u>uuntyi</u> refers to deep holes in the coral, holes in the surface of the ground and in trees etc., as well as orifices of the body.

Land and Marine resources

Resource usage of the reef areas must be seen within a wider system of exploitation strategies which Aborigines had at their disposal. For the purposes of explaining this wider framework it is convenient to visualise a series of environmental zones encompassing the total potentially usable land and seascape:

1. <u>Outer marine zone</u> - consisting of large coral reefs, offshore islands and sandbanks. This is the deepwater zone usually unaffected by the muddy stream discharges and coastal silts.

2. <u>Inner marine zone</u> - the area most affected by seasonal runoff and consisting of beaches, river and creek estuaries and mangrove zones, small offshore fringe reefs and sandbars.

3. <u>Coastal land zone</u> - containing coastal dune systems with associated swales, swamps, saltpans, littoral scrubs,

rainforest headlands etc. Movement in this area can be severely affected by inundation in the wet season.

4. Inland zone - the back country of the territories extending some five miles or so from the beachline and typified by open sclerophyll woodland, open grass plains, riverine vineforests and upland rainforest. Mobility in this area is generally less affected by the wet season.

Potential resources for each of these zones can be categorised as either seasonally specific or seasonally generalised, and brief examples for the terrestrial zones are as follows.

Specific	Generalised
many fruits and tubers	mammals e.g. wallabies kangaroo cuscus echidna
migratory bird populations and eggs.	certain bird species e.g. emu, cassowary, scrubfowl
certain freshwater fishes and tortoises.	certain plants e.g. palms, for food.
certain plant products for technology	certain plants for technology

Reefs form part of both the inner and outer marine zones, and their products fall almost entirely into the category of generalised resources. Aborigines therefore see reefs as forming part of the area of exploitation which can provide a relatively certain supply of foods irrespective of the time of the year and particular seasonal fluctuations. In this way reefs contribute to a certainty factor in their yearly round, When the fringing reefs of the inner marine zone are difficult to exploit through muddy water, they possess the mobility with their canoes to move to the larger reefs of the outer zone. In this way the outer reefs become a standby area for food gathering.

The most important reef products were fishes and shellfish, and of course, the prolific crayfish. All of the species of these which occur on the reefs are classified and named extensively (so far over one hundred separate fish names have been recorded for the Nesbit groups), and there is considerable knowledge of their habitats, foods, behaviours and edible qualities. Examples of reef fishes particularly sought are cods (thathila), groper (puy-a), coral trout (wukuturu), "snappers" or emperors (takula) parrotfish (wurungkala) and crayfish (puku). These were hunted traditionally by spearing either from a canoe or standing on a reef, or by diving with a spear.

Large shellfish such as bailer, helmetshell and trumpetshell were considered prime foods and gathered off reef areas by diving. Large and small clams were gathered for their meat, and clamshells and bailershells used for liquid containers and cooking pots. A variey of smaller shellfish from reef areas were also gathered and eaten, for example trochus and pearlshell, and pearlshell and cone shells used for making ornaments. In one area, clamshells were used for facemasks in ceremonies. Pieces of braincoral were gathered to be used as highly efficient scrapers to shred tubers (*Tacca leontopetaloides*, or wild arrowroot) prior to soaking and leaching.

The importance of reef shellfish in precontact times can still be seen by surface examination of the many shell middens which are to be found along the coast, and from my own observation the use of reef shells seems particularly heavy in the Flinders Island group where large reef formations extend right to the shoreline.

Reefs and the mythological System

Many of the reef names that have been gathered so far in fieldwork refer to associations with mythological beings who occupied the area before humanity. It is neither necessary nor politic to go into these in any great detail beyond noting that these also can be categorised. Reefs can be points where creator beings rested or passed through in their odysseys., such as wukala (reef heron) and maathuy (pelican) in the lists presented earlier. They can also be places where these beings carried out specific actions, as is the case with Blackwood Island in the Flinders group, and these actions are believed to have permanently affected the locality in terms of present humans. Finally they can be places where the creator beings finally stop and become metamorphosed into present natural forms, and the Clack Island reef area is an example of this. While this latter category is somewhat rarer than the others, such sites do occur along the coastline.

Such mythological sites form part of a larger mythological complex which often extends to mainland areas as well.

Discussion

This paper has attempted to outline a broad man - environment interaction for Aboriginal people who traditionally inhabited the eastern coastline of Cape York Peninsula. It has assumed (perhaps wrongly) that its readers are not familiar with this area of study, nor with the literature of Aboriginal anthropology in general and of Cape York anthropology in particular. Accordingly it has presented certain fundamental propositions which I believe are necessary for any appreciation of Aboriginal cutlure for the area. These are:

(1) that despite the preponderance of literature on Central Australia and Arnhem Land, there are significant variations in the nature of Aboriginal society and its operations across the continent. Tropical coastal people are difficult to see as uniform either in their sociocultural organisation or in their use of coastal environments. Presence and absence of coral reefs and offshore islands may be an important variable in this differentiation.

(2) Coastal groups from central-eastern Cape York responded to the highly differentiated marine and terrestrial environments they occupied by developing strategies of emploitation. These capitalised upon the extreme diversity of potential resources across the whole environmental range. A significant portion of this range were the ree environments inside the main barrier.

(3) Exploitation of particular segments such as reefs can only be understood in the context of <u>social</u> territories which are imposed upon the landscape and seascape, and the way these social divisions interact.

(4) Areas such as reefs are not only resource locations in terms of material products such as food and technological items, but are also a <u>cognitive</u> resource, providing part of the mythological charter.

(5) Human interference and use of at least part of the reef system was in existence well before European settlement and perhaps extends back as far as the beginnings of Aboriginal occupation.

To-day Aboriginal populations from the area of Cape Melville northward have been drastically reduced. To my knowledge there would be fewer than 100 knowledgeable adults associated with areas as far north as Cape Direction, and these are spread across a number of settlements and towns in Cape York. To what extent the existing knowledge that I have been recording over the last few years remains viable is a matter of conjecture, though I will add that anthropologists to-day are less willing than they were in the past to predict disappearance of cultural knowledge.

One hopeful sign that such cultural extinction will not take place has been the growing recognitition by Aborigines throughout Australia that their traditions are neither "backward" nor "primitive" or indeed undesirable. They along with Europeans are beginning to realise that living in Australia in the 1970s does not necessarily mean that their culture must disappear as a matter of course.

Cape York is no exception to this trend, and much of my research has been the results of active requests by older people to the Australian Institute of Aboriginal Studies to have their knowledge recorded for later generations. They have shown great interest in past writings and in museum collections for their areas. There is also evidence that they are fully aware of the need to transmit knowledge to their younter people (most of whom have not had the opportunity to visit their countries) by directly involving them with research and in return visits.

Such continuity of knowledge by direct enculturation allows Aboriginal culture to adopt its own dynamic patterns of change that has always been a feature of these people. In this way it adjusts and compensates to the new circumstances of their lives. It is perhaps worthwhile pointing out in this context that what I have chosen to refer to as "traditional" knowledge was not a static and frozen phenomenon, but was constantly changing up to the time of contact.

The Relevance of Aboriginal Culture to Proposed Marine Parks

Included in the set of objectives for this workshop are the responsibilities of creating a Marine Park in the area I have been discussing, and I note that several of the papers listed emphasis the overall environmental system of which the reef complexes are part. My emphasis in this paper has been to present Aboriginal cultural phenomena as they apply to reefs as part of a similar complex. As pointed out earlier, mythological sties on reefs and islands are part of a larger system which only becomes meaningful in its totality. Whether the Authority chooses to consider Aboriginal elements in its deliberations or not, the reality of this knowledge for present day Aborigines still remains. On the assumption that the Authority may consider Aboriginal dimensions, I make the following suggestions.

Firstly we can consider those locations which possess evidence in a material sense of past Aboriginal history and beliefs. The most important area from this viewpoint is the Flinders Islands Group and Cliff Island in Princess Charlotte Bay, and the coastal mainland from Cape Melville to Bathurst Head. All of this area contains many galleries of rock paintings and there are spectacular examples at Bathurst Head, Stanley Island, Clack Island and Cliff Island. Associated with these are very large occupation sites of immense importance to the few remaining people of the area, because of the burials located there. The future archaeological importance of the many middens and occupation sites goes without further elaboration. It is very difficult to conceive of this area as separate units of islands, mainland etc., and my first suggestion is that the complete area as outlined above be incorporated into whatever

Park is introduced to the area. Whether this forms part of a Marine Park or a National Park I am not in a position to judge. Further to the north there are no paintings, but there are a number of burials of Aborigines, Islanders and others, on the small islands and sandcays. These usually date back to the lugger days, and the Aboriginal sites have acquired their own sacredness in the eyes of relatives alive today. These do not appear to be identified in any formal sense and they will presumably become a consideration for any Park Authority which controls the islands.

With regard to mythological sites either on islands or reefs, there is of course adequate protection from an Aboriginal viewpoint if a Marine Park Authority prevents disturbance in that form of drilling, blasting and other forms of progress. All that would be needed in my opinion would be adequate advice to Aborigines that such Parks come into existence.

My suggestions above are based on current State political attitudes towards Aboriginal traditional land claims in Queensland. Whether such attitudes remain constant over future years remains to be seen, and it is possible (if highly improbable) that at some future time legislation similar to that introduced by the Commonwealth in the Northern Territory may apply in Queensland. If this does come about there is no doubt that identifiable Aboriginal groups can establish links to areas of Cape York mainland as their territories, and possibly some of the larger island areas.

This problem is not one for a future Marine Park Authority alone, but has implications for National Parks created in the Cape. I do not see this issue as necessarily a conflictual one between State Authorities and Aborigines, but one which is very possibly negotiable to the satisfaction of both sides. My point is simply that, given the possibility of future legislative change, Park Authorities need to consider at least what the Aboriginal cultural involvement is with the areas they administer.

Finally, removing my anthropological cap, I would like to make one further suggestion with regard to points (ii) and (iv) of the Workshop's objectives. From my own work and interest in Cape York, I see a very great need for a detailed and comprehensive history of man's involvement with the Great Barrier Reef and the associated coastline. For some seventy to eighty years the reef was fished extensively by luggers and formed an important economic resource. What effects did this involvement have upon those reef areas which were major sources for trepang, pearlshell and trochus? What places of historical importance are there in the reef area which need recognition and preservation? The colourful and diverse history of the Reef surely needs some attention, and forms part of the history of this country. Perhaps with this historical information available we might gain some insights into resilience and fragility of reef environments. A large part of that history is preserved in the recollections of older Aborigines and Islanders who spent many years crewing the luggers, and it needs to be systematically collected before it is lost.

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NOTES

1. An archaeologist (J.M. Beaton) carried out a rapid archaeological survey of continental and reef islands south of Princess Charlotte Bay. The article is most useful for its discussion of the prehistory of the reef area, and the summary statements which deal with important questions which can be used archaeologically about the area. The reference list is also useful.

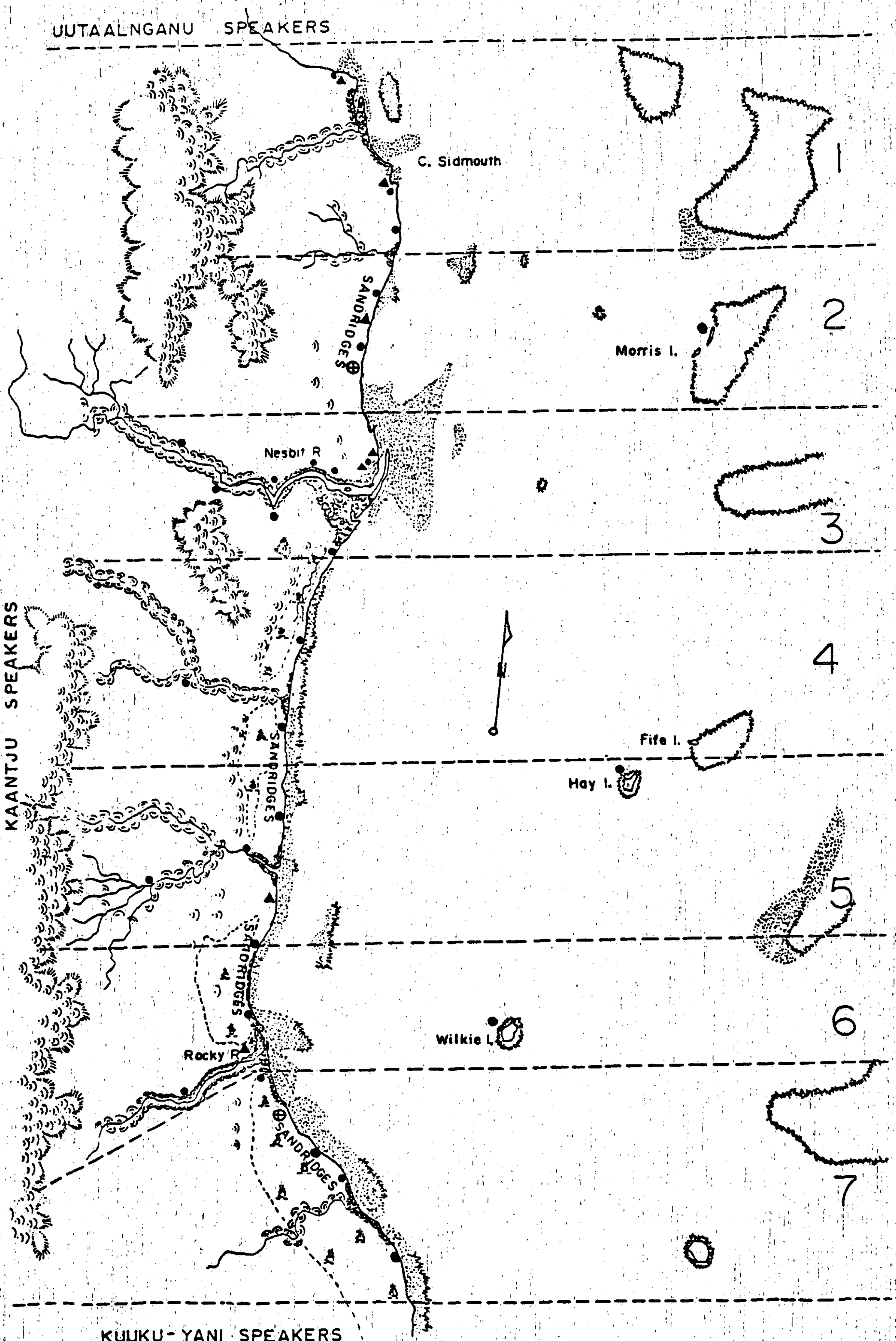
   John M. Beaton: A report on the archaelogical findings, The Royal Society and Universities of Queensland Expedition to the Great Barrier Reef Phase II, 1973

   Issued from the Dept. of Prehistory, Research School of Pacific Studies, A.N.U.

2. For a brief history from an Aboriginal viewpoint of the Cape Melville area, see tape extracts printed as:

   Flinders Islands Expedition, Australian Institute of of Aboriginal Studies Newsletter, N.S.3, 34 - 37

   This extract discusses the personal history of Mr. Bob Flinders of Hopevale Mission, and his views on Aboriginal sites in the area.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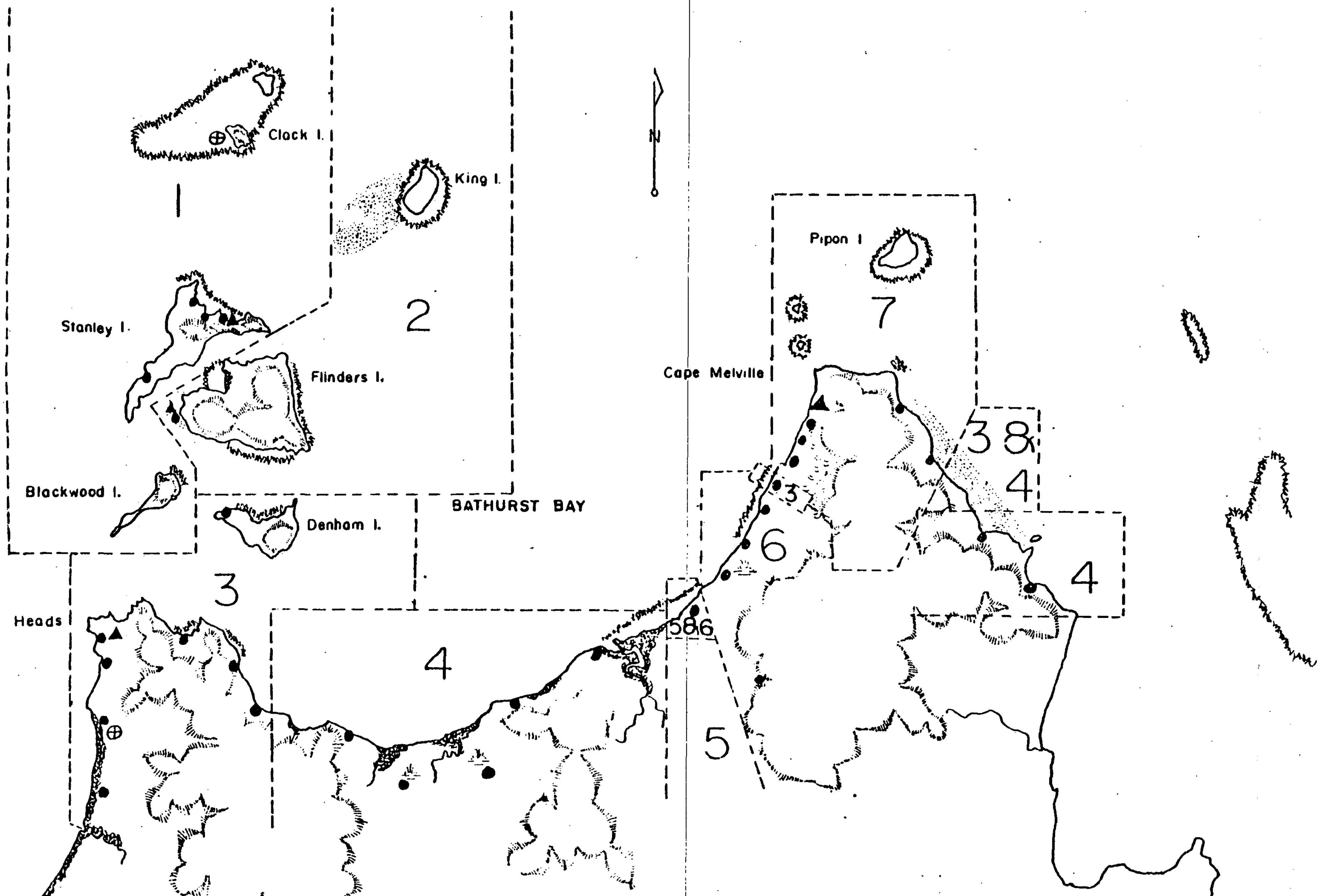


MAP "A" Local Group or Clan Territories for Flinders Island Region

MINERAL AND PETROLEUM RESOURCES OF OFFSHORE QUEENSLAND BETWEEN LIZARD ISLAND AND TORRES STRAIT

By J. T. Woods

Department of Mines, Brisbane

ABSTRACT

Details of the mineral resources of the area are essentially unknown, because of the lack of offshore exploration.

Sedimentary basins, namely the offshore portion of the Laura Basin in the south and the Peninsula Trough extending from the Papuan Basin in the north, may be prospective for petroleum, but no drilling has been carried out.

The only mining that has occurred is minor production of guano at Raine Island during the last century. Coral detritus from the Great Barrier Reef has a potential for use as limestone, while deposits of silica sand occur along and adjacent to the coastline.

HISTORY

Very little is known of the geology of the continental shelf in this area, and still less of the mineral and petroleum resources because of the virtual absence of exploration in the area.

The only area where any mining has taken place is Raine Island, where a deposit of guano was worked in the last century.

The development dates from 22nd August, 1865, when the Governor of New South Wales granted a lease of the island to Mr. W. L. Crowther of Tasmania for a period of seven years, for the purpose of working the guano deposits. The lease was afterwards transferred to the Anglo-Australian Guano Company. This appears to be the first record of economic mineral occurrence in the region.

Raine Island is unique in that it is the only island lying on the outer barrier of the reef complex. Historically, it was visited in 1843 by Captain Blackwood in H. M. S. "Fly", who in the following year placed on it a circular navigational tower 64 feet high built of stone quarried on the island - built in fact of phosphate rock. The excavations for this and later mining were reported to be still identifiable in 1967 when a lease was again applied for. This and later applications for a mining lease were rejected and the island is now proposed as a Queensland National Park.

The northern part of the area has been held under exploration permit for petroleum, but no drilling has been carried out.

The waters of the region under review provide the principal means of access to the eastern coastal strip of the northern half of Cape York Peninsula in which a variety of mineral wealth has been located.

GEOLOGY AND MINERAL RESOURCES

In the absence of details of the submarine geology of the area, the geology of the adjacent coastal parts of Cape York Peninsula has some relevance.

North to Cape Melville Silurian - Devonian rocks of the Hodgkinson Formation outcrop in the northern continuation of the Hodgkinson Basin. These are intruded by granites which are also exposed in some of the continental islands of the Howick Group and on Lizard Island.

South of Princess Charlotte Bay Jurassic and Cretaceous sediments occur in the Laura Basin. Jurassic sediments also outcrop offshore in the Flinders Group.

To the west, a spine of Precambrian metamorphic rocks, forming the Coen Inlier, extends north to the coast at Weymouth Bay. These are also intruded by old granite rocks.

Carboniferous rocks occur at the Pascoe River and also outcrop at Cape Grenville.

The northern part of Cape York Peninsula comprises Jurassic and Cretaceous sedimentary rocks of the Carpentaria Basin.

Dune sands and other Quaternary sediments are widespread along the coast. The Great Barrier Reef represents a complex of reef structures and associated sediments, also of Quat ernary age. These are the subject of a separate paper.

Mineral deposits are widely distributed in the older rocks.

<u>Gold</u> With the gradual exhaustion of the rich alluvial gold deposits of the Palmer River, prospectors moved northwards, following the belt of metamorphic and granite rocks with which mineralisation is associated. During the next thirty years, numerous finds were made, firstly alluvial gold and later reef. The more important were Coen (alluvial 1876, reef 1893), Rocky River (alluvial 1893, reef 1896), Batavia (Wenlock (1892), Ebagoola (1900), and other centres on the Hamilton field and Hayes Creek (1907). In 1910 an aboriginal prospector, Pluto, located a large lead at the base of Mesozoic sediments at Wenlock. As recently as 1933, gold was discovered at Iron Range, Scrubby Creek and Packers Creek, and at Blue Mountains, 40 km north of Coen. In most cases the numerous reefs were small, but carried rich shoots.

Tin Alluvial tin has been worked at Granite or Tin Creek, a tributary of the Archer River, and in northern tributaries running into the lower reaches of the Pascoe River.

Tungsten Wolfram was discovered in 1892 in quartz lodes adjacent to a granite-mica schist contract at Bowden, 30km west of Iron Range. A small reef was worked for wolfram on Rocky Island near Portland Roads, and also north of the Pascoe River mouth. It also occurs with molybdenite in a small lode 10 km east of Coen.

Another occurrence of considerable interest is on Noble Island in the South of the area.

Molybdenum Minor production resulted from the lode mentioned above.

Antimony Stibnite has been worked at Cocoa Creek and occurs also in association with gold reefs on the Starcke goldfield.

Coal Thin seams of coal occur in measures along the Pascoe River, but to date investigations have failed to locate a workable deposit.

Iron and manganese Deposits at Iron Range were investigated by the Broken Hill Proprietary Co. Ltd. in the period from 1957 to 1968. The ore varies from magnetite quartzite containing manganese at Black Hill in the north to hematite quartz-schist at Lamond Hill in the south. Indicated reserves amount to one million tonnes and inferred reserves 300 000 tonnes.

Mineral sands Small deposits generally rich in ilmenite occur near the mouths of the Nesbit and Pascoe Rivers. High rutile-zircon concentrates have been located on Shelburne Bay; elsewhere sand is high in monazite.

Aluminium Bauxite deposits on Turtle Head Island and on the mainland in the Escape River area have been investigated by Comalco Ltd. They include a body of low-iron bauxite valuable as a potentially strategic source of refractory raw material. This has been placed under reservation.

Silica Sand dunes cover extensive areas along the southern shores of Shelburne Bay and between Cape Grenville and the Olive River. At the former locality over 6 million tonnes of high grade sand with silica content in excess of 99 per cent occur in coastal dunes to a depth of 12 m.

White sand dunes extend at intervals along the coast between Shelburne Bay and Newcastle Bay, between Cape Direction and Second Red Rocky Point, at Bolt Head and Cape Griffith, and on the northern shore of Newcastle Bay.

Limestone While conservation interests may preclude any exploitation of the coral reefs and associated calcareous sediments in this part of the Great Barrier Reef Region, no paper on the mineral resources of the area would be complete without drawing attention to the vast quantities of limestone and lime sands involved. Subject to the availability of onshore limestone resources, it is possible that consideration will need to be given at some future date for the working of the detrital deposits especially, in areas of lesser ecological significance.

It is to be noted that, while the peak of mining in the region based on gold has long since passed, interest in further possibilities continues, as evidence by some thirty Authorities to Prospect granted in the past thirteen years to cover most of the near coastal area.

PETROLEUM PROSPECTS

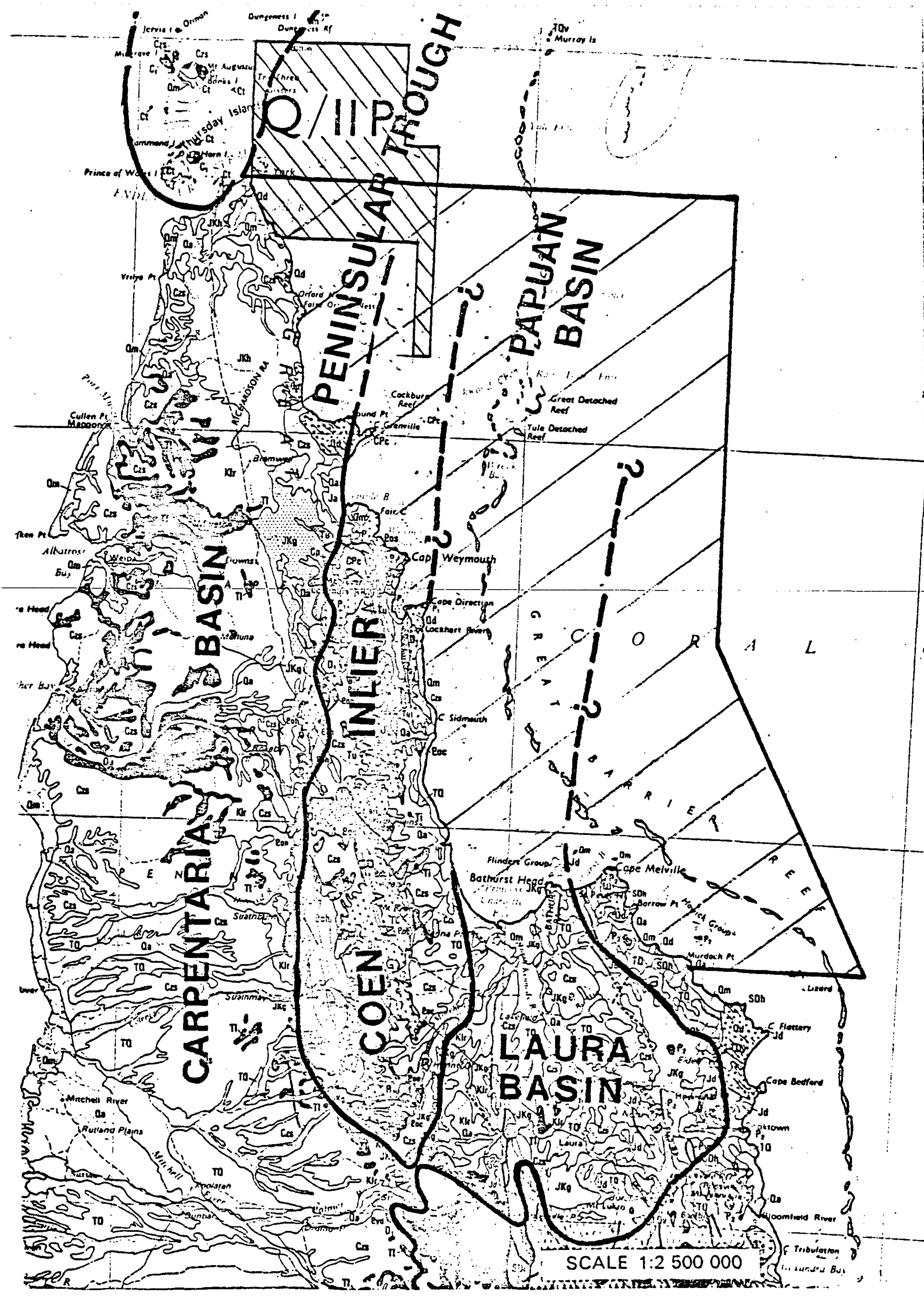
The region covers three sedimentary basins, the Laura Basin in the south and the Papuan Basin and Peninsula Trough in the north. The Laura Basin developed mainly as an onshore basin, but from geophysical evidence is known to extend and thicken for some distance offshore. Its maximum thickness has been estimated at 2100 m. It may be continuous northwards with the Papuan Basin, but there is no firm evidence for this. The Papuan Basin is a complex Jurassic to Quaternary basin extending from onshore Papua southwards under the Gulf of Papua into Queensland waters where the thickness of sediments reaches 4000 m. The Peninsula Trough lies to the west of the southern part of the Papuan Basin and east of a line from Cape York to Daru. It is continuous with the Papuan Basin in the north, but is believed to be separated from it by the offshore extension of the Coen Inlier in the south that is; within the subject region. The sediments of the Peninsula Trough are thought to range in age from Jurassic to Quaternary.

There has been little exploration for petroleum in the region. Three wells, all onshore, have been drilled in the Laura Basin. There has been no drilling in the Peninsula Trough, but one well (Tenneco-Signal Anchor Cay 1) was drilled to the north in the Queensland portion of the Papuan Basin. None of these wells met any occurrences of petroleum. The region has been covered almost entirely by aeromagnetic surveys, and partly by seismic surveys, but at reconnaissance scale only.

The prospects of finding petroleum in the Laura Basin are considered to be poor onshore, but possibly better in the thicker sequence offshore. The Papuan Basin offers better prospects, as several discoveries of gas have been made in Papuan waters. The prospects of the Peninsula Trough are possibly fair by analogy with the Papuan Basin, but our knowledge of this feature is very limited.

Only one petroleum exploration title is held over part of the area under consideration. This is Q/11P, held by Gulf Interstate Overseas Ltd., which extends into the northernmost part of it. An application for its renewal is currently under consideration by the Commonwealth and Queensland Governments.

MINERAL RESOURCES OF NORTH QUEENSLAND



The Commercial Trawl Fishery in the Lizard Island to Cape York Peninsula area : Its present and future prospects

E.A. Purnell-Webb
Department of Primary Industry, Canberra

Abstract

Despite the apparent remoteness of this area, the commercial trawl catch taken forms a very important component of the total trawl catch landings through the ports of Cooktown, Port Douglas and Cairns. The fishery concentrates principally on the tiger prawn resource in the Princess Charlotte Bay area, however known smaller grounds are fished along most of the entire coast. Some 112 prawn trawlers are licensed out of Innisfail, Cairns and Port Douglas, many of whom are partially and some totally dependent on the trawl fishery in this general area for their livelihood.

Introduction

Although the Australian prawning industry started about 150 years ago, it has only obtained national importance and attracted general interest in the past decade following the development of several new fisheries and the expansion of the export trade. The industry grew rapidly in the 1950's following the development of offshore prawning in New South Wales and Queensland, and Australian Fisheries Newsletter devoted its February 1956 issue to articles on this important subject. Twelve years later, after the development of new fisheries in the Gulf of Carpentaria, Western Australia and South Australia, the January issue was a special edition dealing with prawns and this new era in the prawning industry. Today, prawns are the most important sector in the Australian fishing industry in terms of landings and value. The historical development of the prawning industry in Australia has been reviewed in detail by Ruello (1975).

Historical Review of the Development of Prawning in the Lizard Island to Cape York area

Ruello (1975) suggests that the commercial prawn fishery in Queensland commenced in the 1840's. The fishery developed around the estuarine resources associated with rivers entering Moreton Bay, then gradually diversified in the 1900's with the use of seine nets, stripe nets, pocket nets and beam trawls, extending into many of the southern Queensland river mouths. Development of the offshore fishery however, was relatively slow in Queensland, and never really got underway until 1950 when otter trawling was officially permitted in State waters.

Although not directed toward trawl species, the Queensland Government in 1948 carried out the first commercial fish resource study in Princess Charlotte Bay area. The Department of Harbours and Marine, Annual Report for 1949 (page 14), states that the purpose of the investigation and survey was to determine the species of fish inhabiting each area and to assess the quantities available. "A 80-foot vessel was chartered and the survey took place over the three-month period July to September 1948 .... The survey revealed that many commercial fish inhabited this area and are in good quantities". The Department of Harbours and Marine, Annual Report for 1950 (page 15), stated that as a consequence of this survey, one fisherman in 1949, installed, "the most up-to-date snap-freezing plant on his boat", for use in Princess Charlotte Bay. This probably represents the commencement of commercial fish exploitation in the area.

The Department of Harbours and Marine, *Annual Report for 1956* (page 11), reports that following representations by the Queensland Government, the Commonwealth Government through its Fisheries Office, agreed to undertake a survey of the prawn resources on the Queensland coast. The purpose of the survey, which later became commonly referred to as the "Challenge" survey (L.F.B. "Challenge"), were:-

(i) to locate commercial quantities of prawns, in particular banana prawns, outside the present known prawn trawling grounds,

(ii) to define, where possible, the limits of good prawn fishing areas in relation to the seabed,

(iii) to obtain information for use in defining the fishing season in any particular area.

(iv) to carry out tests to compare the efficiency of various types of prawn trawl.

The "Challenge" survey played a significant role in the development of the offshore prawn fishery in Queensland. Trawling gradually extended up the coast resulting in prawn fisheries being established off Gladstone, Keppel Bay, Sarina, Mackay, Proserpine, Bowen, Townsville and Cairns.

In the area between Barrow Island and Princess Charlotte Bay, the L.F.B. "Challenge", between 1957 and 1958, made a total of 45 trawls. Whilst the survey did not produce results sufficient to precipitate a "gold rush", the survey did demonstrate that prawn trawl grounds existed. Further, the survey demonstrated that the principal prawn species present included:-

Penaeus semisulcatus	-	Northern or green tiger prawn
Penaeus esculentus	-	Southern or common tiger prawn
Penaeus merguiensis	-	Banana prawn
Penaeus latisulcatus	-	Western or blue-legged king prawn
Penaeus longistylus	-	Red-spotted king prawn
Metapenaeus endeavouri	-	Endeavour prawn
Parapeneopsis cornuta	-	Coral prawn

In addition to prawns, the trawl catches included beche-de-mer, starfish, shells, crabs, small fish, scallops, Moreton Bay bugs, squid, sea snakes and weed (Fisheries Division, Department of Primary Industry, *Exploratory Prawn Trawling in Eastern Australian Waters*, no date).

While the commercial development of the trawl fishery in the Lizard Island to Cape York area has not been documented since the initial "Challenge" survey in 1957-58, it is suggested that development is almost certain to have proceeded along with the development of the Gulf prawn fishery after 1963. Such early commercial activity, it is suggested, was transient in nature, being carried out by S.E. Queensland trawlers on their way to and from the Gulf fishery.

Status of the Present Day Trawl Fishery

In considering the status of the present day trawl fishery in the Lizard Island to Cape York area, it is important to bear in mind that this area is subjected to cyclonic depressions from January to May and receives monsoonal rains from December to March. Further, as discussed by Haysom (1967: Australian Fisheries Development Conference, AFD/67/MP/4), development in this relatively remote area must be hampered to a greater or lesser extent by:-

"(i) The distance from established grounds which could provide alternative working areas;
(ii) The distance from major centres of population;
(iii) The limitations of existing knowledge and/or experience of the area;
(iv) The difference in techniques required by a fishery in such an area compared with established fisheries elsewhere;
(v) The limited knowledge of the economics involved."

As suggested previously, the development of a commercial trawl fishery in the Lizard Island to Cape York area accompanied the development of the Gulf prawn fishery. It is suggested further, that vessels engaged in the initial stages originated from S.E. Queensland ports as the Department of Harbours and Marine, Annual Report for 1967, 1968 and 1969 show that their were only a limited number of trawlers licenced in the ports of Townsville and Cairns:-

	Townsville	Cairns
1966	12	2
1967	12	3
1968	20	15

Following the rapid expansion of the Gulf prawn fishery in the early 1970's, and because of the remoteness of the area being worked, a number of important changes took place in respect of the commercial trawler fleet. The traditional small Queensland east coast brine trawler (wet boat) which was limited in its operations by its capacity to preserve the catch, has been gradually replaced by larger steel, dry-refrigerated, double-rigged prawn trawlers fitted with sophisticated electronic fish-finding and navigational aids, the vessels being specially designed to operate in remote areas. Such developments have greatly extended the operational range of the vessels enabling better use to be made of resources previously unexploited or under-exploited. Today there is in the order of 112 prawn trawlers operating out of the ports of Innisfail, Cairns and Port Douglas.

Whilst the trawl fishery in the Lizard Island to Cape York area, based almost entirely on prawns, is not of the same magnitude as the Gulf prawn fishery, it nevertheless forms an important component in the already well established Queensland N.E. coast fishing regime. The present day fishery, is centred around the inshore prawn resources in Princess Charlotte Bay, Cape Melville and Lloyd Bay and the numerous other "pockets" of inshore prawn right throughout the area (illustrated in Figure 1). Subject to weather conditions, these resources are fished from January to mid-March each year by trawlers temporarily/permanently based in Cairns, Port Douglas and Cooktown, before the Gulf banana prawn season opens, and again by these vessels on their return from the Gulf around May. For the remainder of the year (May through to December) the resource is fished by Townsville, Cairns and Port Douglas resident trawlers. The catch landed from these areas for the period May to March, forms a very important component of the total landings in Cairns during this period. Table 1 illustrates some of the fishing activity reported from this area by the Northern Fisheries Unit (Fisheries Division, Department of Primary Industry), Cairns.

No precise landing figures are available for the prawns taken in the Lizard Island to Cape York area. The difficulty of acheiving such without a comprehensive log-book system is well illustrated in Table 1, where product taken is landed both in Cairns (and other southern Queensland ports) and at Thursday Island (and more than likely other Gulf ports). Whilst acknowledging that there are several prawn processing plants located in Cairns through which prawns taken from the Lizard Island to Cape York area pass, it has not been possible in this paper to collate all available landings data. Thus, prawn landing through the Cairns Fish Board for the period 1962 to 1975 have been selected for the purpose of illustrating the trends and species composition that could be expected from the area under consideration. Table 2 illustrates the total prawn intake by year through the Cairns Fish Board, while Figure 2 illustrates the composition of the prawn intake by principal species for the same period.

Prospects for further development in the area

It is suggested that whilst the inshore prawn trawl fishery has become firmly established around Princess Charlotte Bay, Cape Melville and Lloyd Bay, there still exists a potential for expansion of this inshore fishery northwards eventually joining up with the established tiger prawn fishery in the Torres Strait. Further, little attention has been given to the potential for red spot king prawn resources being located out on the coral bottom adjacent to the outer barrier reef.

In addition to prawns, little attention has been directed at this point in time to the potential for development of scallop, squid and Moreton Bay bug resources as indicated by the "Challenge" survey.

Table 1: Extracts from Northern Fisheries Unit Reports (Fisheries Division, Department of Primary Industry, Cairns) on fishing activity in the Princess Charlotte Bay area during the period 1969-1977

Date	Comment
6 August 1969	One carrier vessel plus six trawlers; trawlers averaging more than 90.9 kg/vessel/night; 6,818.2 kg/wet landed to date.
12-19 August 1969	Two carrier vessels anchored in Stokes Bay, Stanley Island; more than ten trawlers working; trawlers averaging between 68.2-90.9 kg/vessel/night.
8 October 1969	One carrier vessel enroute to Cairns took on 9,545.5 kg prawn; trawlers averaging 68.2 - 90.9 kg/vessel/night.
14 October 1969	One carrier took on 18,182 kgs.
15 May 1970	Six trawlers working; trawlers averaging 318.2 kg/vessel/night.
28 May 1970	More than six trawlers working; trawler averaging 227.3 kg/vessel/night.
3 July 1970	One carrier vessel delivered to Cairns 6,363.6 kg prawns to date.
5 August 1970	Two carrier vessels in the area.
3-17 September 1970	Two motherships and nineteen trawlers working in the Grub and Heath Reef area; 363.7 kg/vessel/night maximum; single-rigged vessels averaging 204.6 - 227.3 kg/vessel/night.
6 October 1970	One mothership in area.
30 June 1971	One mothership operating; bad weather hampering trawlers.
29 July 1971	One mothership operating at Burkett Island with twelve trawlers supplying; initially 454.6 kg tiger prawns/vessel/night dropping to 272.7 - 318.2 kg tiger prawns/vessel/night; some king prawns landed.

20 June to 2 July 1972	One mothership in area.
10 July 1972	Two trawlers working in area.
17 August 1972	Two trawlers working; averaging between 181.8 - 545.5 kg/vessel/night.
17-27 June 1973	Trawlers averaging 272.7 kg/vessel/night.
16 August 1973	Three to four trawlers working over two days landed 7272.7 kg.
31 August 1973	Three trawlers working; averaging 227.3 kg/vessel/night.
4 June 1974	Three trawlers working.
22 July 1974	Trawlers averaging 454.6 kg/vessel/night.
27 July 1974	930.9 kg tiger prawn unloaded at Thursday Island from Princess Charlotte Bay; exceptionally good size and quality.
14 August 1975	Twenty to twenty-five trawlers working the area; averaging 181.8 kg/vessel/night; 90% catch is tiger prawn.
22 August 1975	Twenty-five to thirty trawlers working the area; averaging 318.2 kg/vessel/night; 66.6% catch is tiger prawn.
17 September 1975	13,636.3 kg landed by three trawlers over a three week period.
23 September 1975	24,545.4 kg landed by three trawlers over a ten week period.
18 October 1977	2,727.3 kg tiger prawn landed by one trawler over a three week period.

Table 2: Total intake of prawns through the Cairns Fish Board for the period 1962 to 1975

Year	Quantity (kgs)
1962	284.6
1963	264.6
1964	No record
1965	884.1
1966	1,290.9
1967	16,656.8
1968	18,864.5
1969	11,110.0
1970	9,472.3
1971	13,741.3
1972	34,306.3
1973	31,967.2
1974	63,665.9
1975	42,576.8

Figure 1. Location of the principal inshore prawn trawling grounds in the Lizard Island to Cape York area.

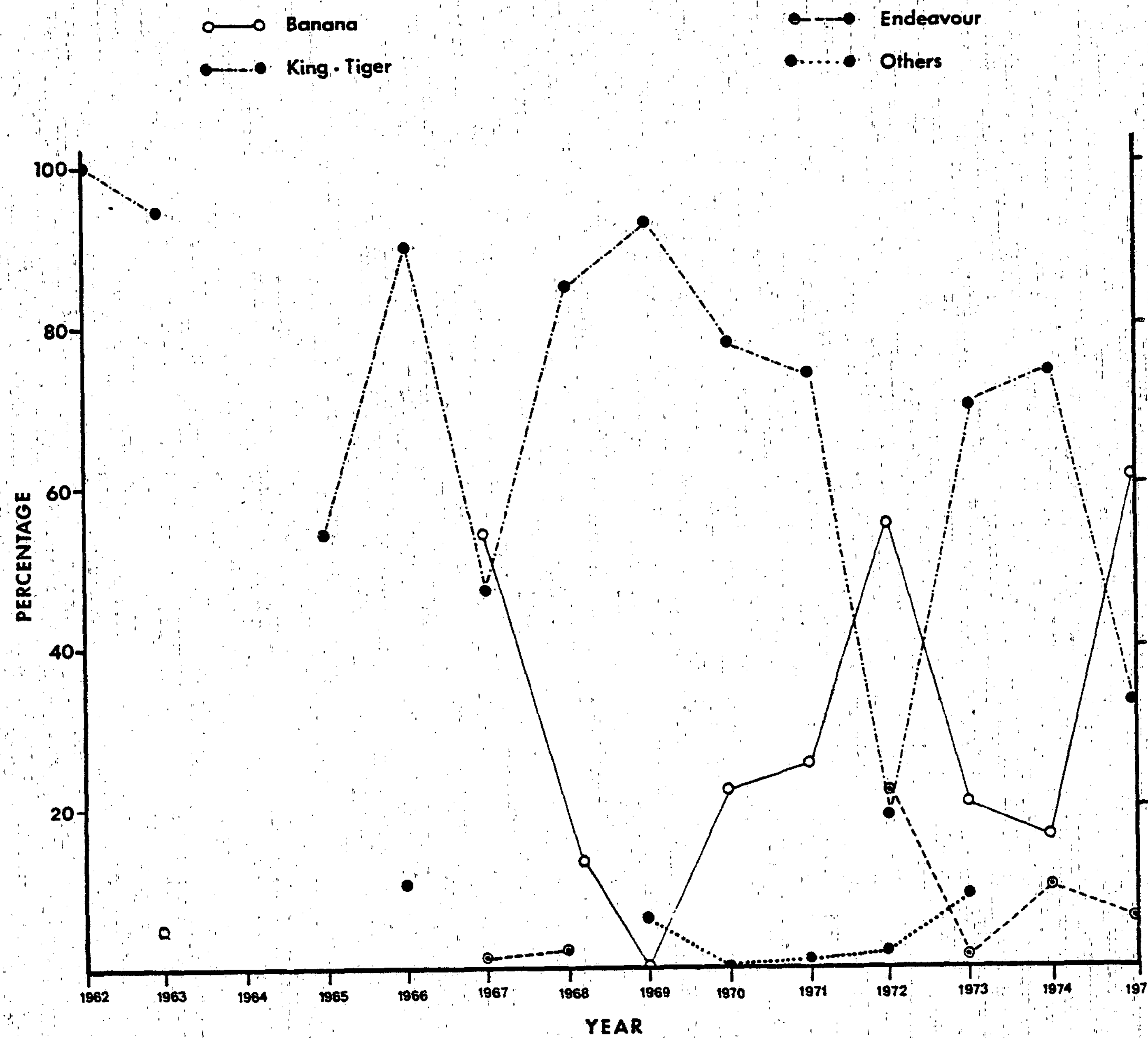


Figure 2. Composition of the prawn intake through the Cairns Fish Board by principal species for years 1962 to 1975.

GENERAL FISHERIES - LIZARD ISLAND TO CAPE YORK

N.M.Haysom and G. McPherson
(Queensland Fisheries Service)

INTRODUCTION

This paper deals with those fisheries (other than prawn trawling and rock-lobster fishing) which are either currently established in the waters between Lizard Island and the latitude of Cape York, or are likely in the foreseeable future to be established in those waters.

Not surprisingly, these fisheries are not well documented in terms of production, effort, or location of grounds, despite the fact that one of them is probably Australia's oldest export fishery. The tragic story of Mrs. Watson's attempted escape from Lizard Island in a rainwater tank is a well-known epic of Queensland's early history, but perhaps few people realise that she was on the island in the first place because of her husband's involvement in the beche-de-mer fishery.

TROLL-LINE FISHERY

The main commercial fishery in the area at present is the troll-line fishery. This is based principally on spanish mackerel, but other reef fish such as coral trout feature in the catch. A conservative estimate of the live-weight annual catch from the area would be of the order of 50,000 kg of spanish mackerel, 7,000 kg of coral trout and 40,000 kg of other assorted reef-fish. This catch would be taken in the main by some eight fishing vessels. For the operators of these eight boats, the area provides a substantial proportion of their total take for the year, and furthermore the production from this area, which is mainly concentrated in the period from March to August, is a valuable supplementary source of supply to the north Queensland fish markets at a time when landings from local grounds generally are at their lowest ebb.

PEARL-CULTURE INDUSTRY

Although no pearl-shell grounds are known in the area, four pearl culture farms exist just south of the northern boundary of the area under consideration in today's workship. One of the farms is at Albany Island and the other three are located near the mouth of the Escape River. They cover a combined area of a little over 1,000 hectares, which represents about 60% of the total area covered by pearl culture farms currently licensed in Queensland. I have been unable to assemble any figures on the value of production in recent years, but the Australian pearl culture production was worth $6.6 million in 1974, which suggests that potential production from within the area which this workshop is considering could be well in excess of $1 million.

Although most of the offshore reef areas are not suitable for pearl-culture farming, some interest has been shown by operators in the possible use of sheltered sites associated with some of the continental type islands between 14° and 15° south latitude.

TROCHUS FISHERY

The trochus fishery has been virtually non-existent in Queensland for at least fifteen years, but there have been recent signs of a revival of interest in this commodity, though the world market demand is expected to be relatively small, specialised and spasmodic. It can be expected that anyone fishing for trochus would be likely to take an interest in the reefs between Cape York and Lizard Island.

BECHE-DE-MER FISHERY

A similar revival of interest in beche-de-mer fishing has occurred, and discussions have taken place between the Queensland Fisheries Service, the Department of Primary Industry and the Great Barrier Reef Marine Park Authority with a view to formulating an interim management policy for such a fishery pending an assessment of the current status of the beche-de-mer stocks and their capacity to tolerate exploitation. At the time of writing, the policy being examined suggests a system of licence limitation but not exclusivity of licences, and freedom to operate only on specified parts of the region.

OTHER COMMERCIAL FISHERIES

The only other commercial fisheries conducted by our own nationals in the area are barramundi and mud crab fisheries, conducted on a small scale mainly in the vicinity of Princess Charlotte Bay. The units involved are generally land-based and operate within the internal waters of the mainland. The northern reefs are subject to illegal visits by Taiwanese clam-poachers. To date six such vessels have been apprehended in the area under discussion, with another three just to the south of but very close to Lizard Island. There is also a possibility that Japanese long-line tuna vessels may fish waters close to but outside the outer barrier.

SPORT FISHERIES

The region is generally too remote from centres of urbanisation for any large-scale use of the area by amateur fishermen. There would be some very localised fishing associated with the resort at Lizard Island, and occasional long-range pleasure cruisers, either private or chartered, may penetrate the area on an irregular basis. However the waters immediately outside the Barrier Reef within reasonable striking distance of Lizard Island are becoming ever-increasingly popular and famous with the game-fishing fraternity seeking thrills amongst the big marlin. It should be noted that this sport-fishery is not merely a recreational activity, but represents a livelihood for probably as many people as are fishing the area commercially. Moreover, the charter boats in the marlin fleet represent a not insignificant capital investment.

DISCUSSION SESSION II - USES OF THE AREA

CURRENT AND PROJECTED

CHAIRMAN: MR. H.J. HIGGS

Chairman: I think we have had a very good introduction to the use and resources of this northern sector. The major uses appear to be normal shipping movements and fishing activity. The rest of the resources of the area seem to be potential rather than actual at the moment, which does perhaps lend weight to the view that the area is largely pristine. However, that does in some way make it more difficult for us to make decisions about it. Against that sort of background, does anyone wish to probe any of the speakers more deeply on that particular topic?

J. Bunt: I would like to ask if there is any specific information about the amount of river and estuary fishing on that far northern coast. One suspects that it is substantial, but I am not aware of any real figures.

N. Haysom: Yes I agree with you. It is probably substantial in certain areas, it would be mostly by people with four-wheel drive vehicles and nets, and very likely without a licence. It is a very difficult area to patrol and to manage. But we are certainly concerned about the extent of traffic into the area of people with crab-pots and barramundi nets in the back of their vehicles.

P.L. Ellis: Mr. Buckham, from your Department's point of view would you agree that the Declaration of Marine Parks under the Authority's Act (1975) or indeed the regulation of fisheries along the lines you suggested would not be very significant, unless, simultaneously, some sort of coastal surveillance capability is developed at the Federal level? I would like to take it one step further - is there much point in drawing up zoning plans unless they can be policed?

M.W. Buckham: Mr. Chairman, I would like to agree with that publicly. Defence is on the periphery of this. The surveillance that we do for civilian purposes is co-ordinated by the Marine Operations Centre in Canberra. The Centre is run by the Department of Transport and is concerned with overall surveillance responsibilities. The monitoring of fishing activities is a far more specialised operation.

Chairman: Just to add to that point, I think we probably all recognise the enormous problems of surveillance and control of the reef area itself, let alone the 200 mile economic zone. However, that should not stop us from proceeding towards zoning plans which may be better policed in the future, and in some ways this is why possibly a little more time should be spent over the planning operations, rather than making some zoning arrangement which cannot be properly policed.

M.W. Buckham: Generally the Defence Force undertakes surveillance and regulation enforcement of foreign fishing activities. They are not involved in enforcement activities against our own nationals. If we are going to have any form of policing activities of Australian fishermen, it would best be undertaken by some organisation outside the Defence Force.

H. Jitts: I would like to add a little bit to the question of surveillance while not in any way wishing to diminish the problems involved in the question of surveillance of fishing activities for instance. I think it ought to be recognised that surveillance is not the only way of policing fishing operations, not only of Australian but also of foreign fishing operations. There are other ways, by co-operative agreements with the distant fishing nations, or with working through, for instance, the returns of fishing vessels within the Australian industry, and both of these in many ways are very much more effective than chasing them with patrol boats and overflying.

E. Hegerl: I would like to ask Captain Whiteman what percentage of ships using the Barrier Reef actually utilise the Blackwood Channel today and is it any safer today than previously in view of the twenty shipwrecks that you mentioned?

B.B. Whiteman: Nobody uses the Blackwood Channel these days.

A. Birtles: The long line-up on our panel this afternoon perhaps illustrates the diversity of interests involved in the Barrier Reef. One realises that the Marine Park Authority is dealing with quite an historical complexity of the usages and these have been illustrated today. But in setting up new projects, one hopes that with the Great Barrier Reef Marine Park Authority there will be encouragement for maximisation of information obtained from these projects. Hence I would like to direct a question to Mr. Haysom in relation to the beche-de-mer industry. While certain areas of the Reef have been excised from the proposal for collection, I wonder on what basis the other areas have been delineated and on what knowledge of the resource.

N. Haysom: This interim policy had to be brought into force very, very quickly. It resulted from a mixture of information from the industry in its heyday, consultations with Mr. Richard Kenchington and other workers, and our own people on their activities on particular reefs. We also felt we would like to space out activity along the reef rather than have it all concentrated in one place.

I might add, incidentally, that the beche-de-mer fishery is Australia's oldest industry. It dates back to about a hundred years before Captain Cook arrived, mostly up around the Northern Territory and the Gulf of Carpentaria and did not come on to the Queensland side until some time in the early nineteenth century. The early activities of the beche-de-mer fishery were very well documented. I have a book here on the history of the fishery in the Northern Territory, and in it are some excellent graphs produced from the data kept in those days, providing probably better sets of data on catch per unit effort than we have for most of our modern fisheries today.

D.W. Connell: Mr. Chase mentioned the need to conserve aboriginal relics, rock art, burial sites etc., and I was wondering if there are any traditional usages of the area by aboriginals that need to be taken into account in the development of any management plans for that region.

A.K. Chase: There are very few areas to which aboriginal people are actually returning on a full time basis. Although there has been some news recently of attempts to do this in the Aurukun area on the west coast, there is nothing similar on the east side. There have been a number of attempts by some of those people from the area from Pascoe River down to the Stuart River to return, largely to educate the young people in the names of places and the importance of places where families are aligned to in a biological sense. So people have attempted to carry on some sort of active education programme with regard to their own culture.

H. Marsh: Mr. Chase, I wonder whether you think that present day aboriginal hunting or fishing activities along that coast are likely to be affected by National Parks legislation?

A.K. Chase: An interesting question - I do not think so. I suppose that most of the issues that have occurred along the area that the Authority has been considering would be based at Lockhart. You would be dealing with a population of 300 people; men, women and children. They still take dugong and quite a quantity of fish. I think if the Authority's jurisdiction extends into the coastline, they should take some account of people pursuing these natural and traditional hunting techniques. I think you would want to look fairly seriously at the use of rifles, for example, for capturing dugong. I do not quite think that is playing cricket.

H. Marsh: How do you define traditional techniques - because I have seen dugong hunts at Lockhart River and although rifles were not used, speedboats certainly were? Do you call using speedboats and harpoons traditional techniques?

A.K. Chase: If it is run by Europeans, no. This often happens at Lockhart. I do not see anything wrong with pursuing dugong with dinghies which is mostly the case. I think I can be fairly certain that the dugong would not have a great deal to worry about from Lockhart inhabitants' outboard motors. Obviously we cannot expect the aboriginal people to return entirely to their original customs. An example of this happened at some of the National Parks in the Northern Territory recently, where a law was brought in prohibiting aborigines from hunting if they used guns or cars. This was revoked because it was pointed out that it is a bit ridiculous to expect aboriginal people today to chase kangaroos with a spear and a woomera when a .22 or a .303 rifle is quite effective. What is important is how many of these animals are taken. From my experience, few dugong are taken, maybe 40 or 50 over twelve months.

J. Baker: Mr. Chase, in your studies, have you come across any islands that currently have European names for which you feel Aboriginal names would be more appropriate; and, if so, have you submitted such names to be changed? It might be interesting if Mr. Wilson would comment on whether that would increase the attraction to tourists or not. Also, have you been able to initiate anything to ensure that what is still known of legends or the heritage of the aboriginals in the trochus shell gathering and other activities at the turn of the century, be preserved? Have you any recordings or are you accumulating data on that, or do you need any help on it?

A.K. Chase: Yes, all European names islands do have aboriginal names; that is, islands which are fairly close off the coast. Yes, personally I would like to see all of them have their aboriginal names. No, I would not like to see the names introduced only for the sake of tourism. Yes, a lot of the material is on paper and lodged at the Institute of Aboriginal Studies but it will take three years or so to work it up gainfully.

J. Wilson: From a tourist point of view only, I can see no problem at all in them carrying aboriginal names. In fact we would prefer it that way. However, what the practical aspects of changes of present names to Aboriginal names would incur, I could not answer.

G.E. Heinsohn: I just want to make a comment about tourism. Mr. Wilson's attitude towards tourism seems to be mainly concerned with money-making and caters mainly for well-to-do people. It is a matter of some concern to me that few Australians have an opportunity to see the Reef unless they are wealthy or are movie stars. I think that tourism should be extended so that every Australian has a reasonable opportunity to see the Reef other than at Heron, Green, Magnetic and Whitsunday Islands.

J. Wilson: If I could confine my comment to the coastal region generally, I should make the point that there is opportunity for Australians to see the Reef at Heron Island and Green Island, and thre is an opportunity to look at the Underwater Observatories at Green Island and Hook Island which is not the Reef itself, and I acknowledge that. I think one of the things we have to consider is that the present day operator's business is viable. Now I forecast a little time ago that the future was not bright and this is not a secret. However, the input of funds from P & O into Heron and Lindeman Islands and from T.A.A. into Dunk and Great Keppel Islands has revitalised them.

Now I cannot see a reason why I could support a recommendation that another island development should occur unless it is of an outstanding nature. I should also point out that there is a service which operates out of Happy Bay on Long Island via Whitsunday which takes people on Hardy Reef. There they can stay and wait for the airplane to return on that particular run: alternatively they can remain on a vessel which has been placed out there by the operator and spend one or two nights before returning to the Island or Shute Harbour. This gives them the opportunity to see as much reef as they wish to in that time.

P. Ogilvy: I would like to direct a question to Mr. Buckham about Defence Force shelling practice on the Great Barrier Reef. Fairfax Island is a national park and a fairly important seabird nesting colony. I would like to ask Mr. Buckham how his Department justifies both legally and morally continuing with that sort of activity on a national park?

M.W. Buckham: We are in the process of negotiating with the New South Wales Government who are running an area called Beecroft Range as a national park. Although it is not a national park, it is an area which is used for the purpose of an air-to-ground range and a sea-to-shore gunnery range, but we hope it becomes a national park to benefit more people than it does currently.

The use of any particular range tends to be infrequent and the amount of very serious damage is limited hopefully to a very small area around the impact area. However one has to designate a much larger area to cover all contingencies and thus reduce risks to levels which everyone could consider reasonable. This tends to mean that if you are managing it properly you are maintaining a wilderness area.

P. Ogilvy: We are talking about an island of about 15 acres, and this is a very small area.

R.A. Kenchington: Perhaps I could add a few peripheral details to that. My advice from the Naval Officer in charge in Queensland, is that the Fairfax Island range has been used for five years, and that they intend that all their firing and bombing would be done at the extended Townshed range. I believe that a proposal has gone through or will be shortly going through suggesting that R699 could be discontinued from the point of view of the Navy.

F. Talbot: I have a similar, immediate, emotional and quite irrational response to this matter, and although I take your point that perhaps damage is minimal, this is an area I would consider of supreme world importance and worthy of world heritage. If it is declared a World Heritage Area, which I think is likely, emotional reaction might be on a much larger scale. Perhaps to avoid this clash, other areas not as precious in the coral sense could be used, for example further off-shore islands in the Coral Sea.

M.W. Buckham: Mr. Chairman, all things are possible, it just costs money. Clearly you could organise an air-to-surface range by engaging a target which is moored in deep water, but in addition to the capital cost, the maintenance cost of ensuring that it has appropriate navigational beacons etc. is incurred. I think the answer is yes, and it is a question of resolution of national priorities.

P. Mather: This is a comment directed to Mr. Buckham and it relates to the use of live ammunition on targets in the Great Barrier Reef. The previous questioner referred only to Fairfax Island which is a national park under the Queensland Parks and Wildlife legislation. Is Townshend Island a coral cay or a continental island? Although I would, like Professor Talbot, feel emotionally opposed to the use of even a continental island as live ammunition target, I feel that the question becomes more profoundly concerning if it is a coral cay.

Anonymous: Townshend Island is a continental island.

G. Webb: My question is addressed to Mr. Haysom. Are there any rivers along the east coast of Cape York that are closed to netting? Do you feel confident that there is no netting going on?

N. Haysom: The answer to the second part of your question - no you cannot be confident. There is a whole string of rivers which are closed to or partially closed to netting just recently, and I just cannot remember whether any of these are located in the area with which we are concerned in this workshop.

G. Webb: Perhaps it would be possible for there to be one river with a resident officer to ensure protection from netting.

N. Haysom: I do not think there are any rivers closed in the area that we are talking about, except perhaps somewhere down around the Princess Charlotte Bay area. It is a little bit south of there, between Cooktown and Princess Charlotte Bay, where most of the netting is occurring.

A. Gilmour: Captain Whiteman, you mentioned hazardous cargoes moving through the inner passage and in this context I think particularly of tetraethyl lead. If we lost a barge of that around the reef, oil pollution might pale into insignificance. Have there been discussions with shipping authorities, the Department of Transport, the port authorities, on the matter of a national approach to the handling of hazardous cargo materials around the Australian coast?

B.B. Whiteman: The whole subject of hazardous cargoes is covered by certain I.M.C.O.* Conventions, and some of these Conventions are still not in effect as they have not been signed by the necessary percentage of nations. However, we are constantly in committee on the handling of hazardous cargoes through Australian Port Authorities Conference and the Marine and Port Council which is a Commonwealth oriented body in which all States are represented. These conferences take place on a regular basis, probably every six weeks, to upgrade the safety facilities required of ships. But overall, the control of hazardous cargoes sits with the Department of Transport under their legislation and that is particularly relevant when you take in the international conventions; the States do not have any international involvement in this area.

H. Jitts: If I might add to that, I would like to remind Dr. Gilmour that the Australian Environment Council has recently formed a National Advisory Committee to deal with environmentally hazardous chemicals and that this activity will cover many aspects. One of the more important of these will be the transport of chemicals, and this would be the complement to the sort of things that Captain Whiteman has been telling us. The I.M.C.O. * Conventions deal with the transport question from the shipping viewpoint, and they of course, also look at the environmental aspects of it.

Chairman: Well, I think, ladies and gentlemen, that we have had a very stimulating discussion and a good overview of the use and resources of the area, and on your behalf, I would like to thank all our speakers.

* International Maritime Consultative Organisation.

SESSION 111: NATURAL FEATURES

Reef corals of the Northern Region of the Great Barrier Reef

J.E.N. Veron

Abstract

A brief summary is given of the world-wide distribution of hematypic coral genera and the relationships of Great Barrier Reef corals to the Indo-Pacific centre of diversity. The distribution of corals within the Great Barrier Reef and the two principal factors which influence high diversity in the Northern Region (environmental diversity and ocean temperature) are discussed.

There are two regional centres of hermatypic (reef building) coral diversity:- the Caribbean and the central tropical Indo-Pacific including Indonesia, the Philippines, northern Niugini and the northern Great Barrier Reef (Fig. 1). The two regions have a completely different assemblage of species although many genera are common to both and most of the common Indo-Pacific genera now absent from the Caribbean have a fossil record there extending at least to the middle Tertiary.

There are at least 500 Indo-Pacific hermatypic species representing about 80 genera and subgenera. The majority of these are widely spread across the tropical Indian Ocean west to the Red Sea. Eastward from Niugini both species and generic diversity decrease rapidly, e.g. the Marshall Islands has approximately 20% of the diversity of the Great Barrier Reef.

To a very large extent, the corals of the Great Barrier Reef are geographically isolated. In the north-east, the inflow of fresh water from the Fly, Kikori and other major rivers into the northern Gulf of Papua forms a complete barrier to reef development and consequently there are many differences between the fauna of eastern Niugini[1] and that of the northern Great Barrier Reef. In the north west, the shallow, turbid waters of western Torres Strait and the eastern Arafura Sea also form a barrier where very little reef growth occurs and thus the fauna of eastern Indonesia has more in common with that of north west Australia[1] and the Philippines than with that of the Great Barrier Reef.

The distribution of reef coral genera along eastern Australia has been described by Wells (1955) who shows a progressive diminution from north to south as follows:-

South Latitude		Recorded Genera
9^{o} - 17^{o}	Great Barrier Reef	60 - 59
17^{o} - $20\frac{1}{2}^{o}$	Great Barrier Reef	59 - 53
$20\frac{1}{2}^{o}$ - $23\frac{1}{2}^{o}$	Great Barrier Reef	53 - 35
$23\frac{1}{2}^{o}$ - $24\frac{1}{2}^{o}$	Great Barrier Reef	35 - 25
$24\frac{1}{2}^{o}$ - $27\frac{1}{2}^{o}$	Moreton Bay	25 - 12
$27\frac{1}{2}^{o}$ - 34^{o}	Sydney	12 - 2

Although subsequent studies have added to, or changed, much of the data used by Wells, it can still be shown that this diminution does occur, both at a generic and species level.

There is also a longitudinal gradation of species within any Region of the Great Barrier Reef. This is more marked in the Northern Region than any other where there are markedly different fauna's associated with (a) the outer barrier, (b) the lagoonal reefs (c) islands (Fig. 2). These can be briefly described as follows:-

Footnote: 1. Evidence for some of these observations is, at best, superficial and awaits the confirmation of further study.

(a) The outer barrier or shelf edge reefs (Fig. 3). These are the ribbon, deltaic and dissected reefs described earlier in this volume. All these reefs are very strongly zoned (Fig. 4) with dense coral growth occurring on the outer slope and along the back reef margin. The depth to which major communities occur on the outer slope has yet to be studied in detail but certainly they regularly occur to greater depth than anywhere else in the Great Barrier Reef and can be expected to have faunal compositions which substantially differ from other communities. Maximal light penetration, turbulence and upwelling all contribute to creating an optimal environment for coral growth. On the upper outer slope coral zones change with increasing wave action. Coral cover remains dense until the surf zone is reached where a community of thickened stunted corals unique to very turbulent waters is replaced by flat, denuded limestone. Prolific coral growth occurs again along the back reef margin. These communities typically have a very large number of species and in this, as well as many other respects, are substantially different from those of the reef front.

(b) The lagoonal reefs. These typically have a greater generic diversity of corals than do the barrier reefs and, with the exception of *Acropora*, usually have many more species. However, very little is known of the myriad of lagoonal reefs of the far north of the Region or of the various coral communities associated with the east-west elongate reefs north of Princess Charlotte Bay.

(c) The islands. Islands, especially complex groups of high islands, provide the greatest diversity of marine habitats, and consequently the greatest diversity of benthic fauna, to be found in the Region. Markedly different communities occur in the various biotopes associated with the flat ocean floor, the fringing reefs, the intertidal and sub-intertidal mud flats and the zones of coral growths on the protected sides (western) of islands (Fig. 5).

There are thus north to south as well as west to east changes in coral abundance and diversity. The former effect may well be primarily a matter of temperature as the Northern Region has higher (Fig. 6) as well as more stable water temperatures. The latter effect is clearly a reflection of the variety of habitats available in the Northern Region, resulting from the diversity of reef types and abundance of islands contained in it.

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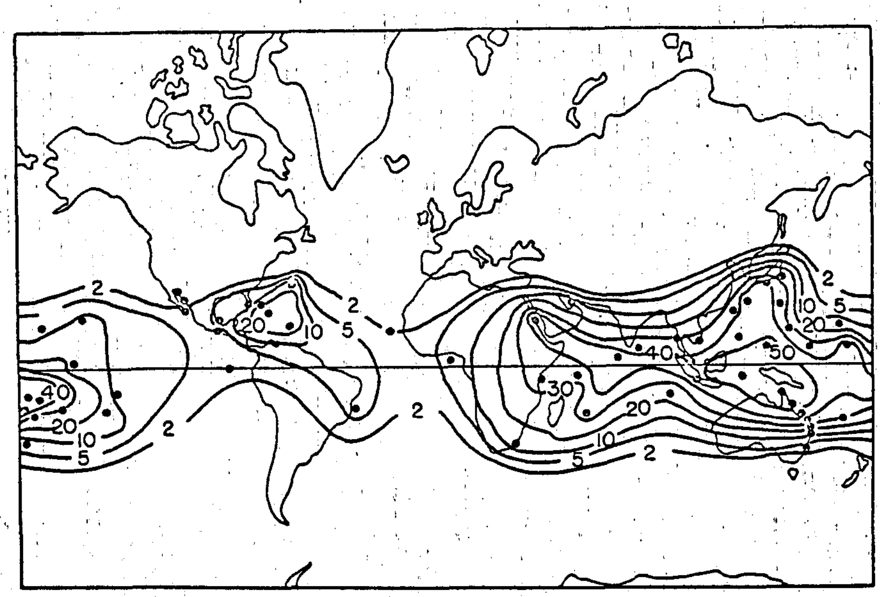

Fig. 1 Contoured data for generic diversity of Recent hermatypic corals (after Stehli, 1968).

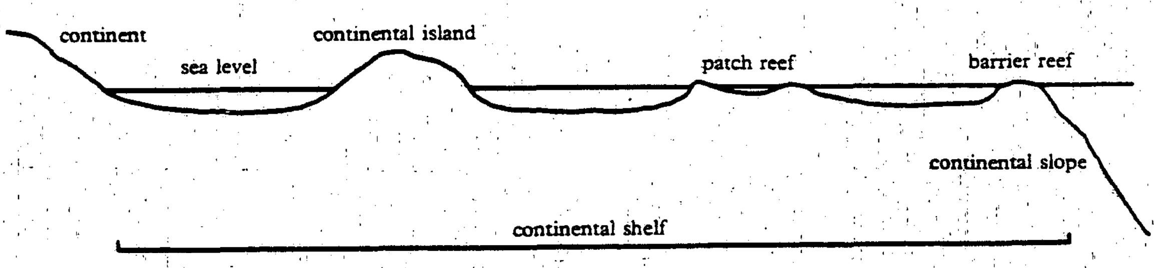

Fig. 2 Simplified diagrammatic profile of the northern Great Barrier Reef indicating the three principal cites of coral growth (after Veron & Pichon, 1976).

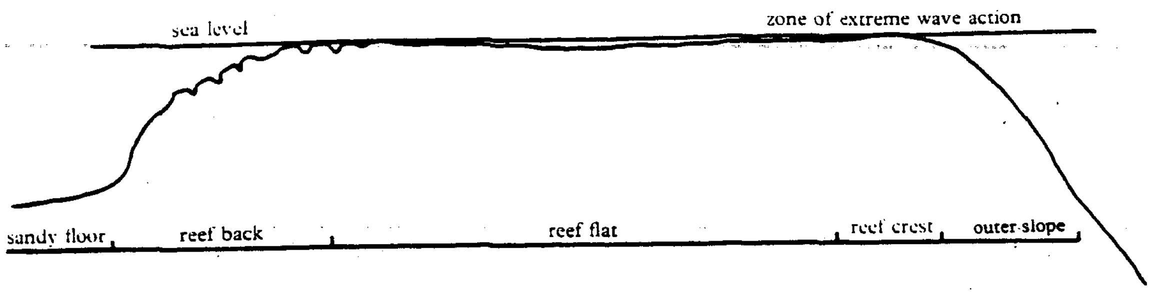

Fig. 3 Diagrammatic profile of a ribbon reef (after Veron & Pichon, 1976).

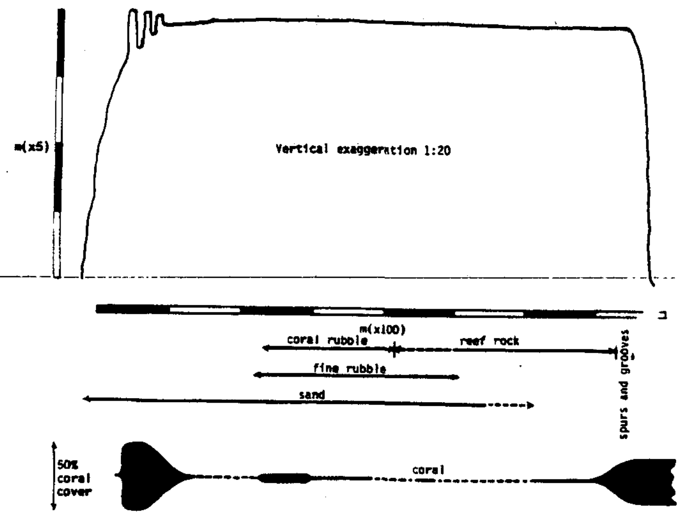

Fig. 4 Diagrammatic profile of the north end of Tijou Reef showing the position of the coral zones of the outer slope and back reef margin (after Veron & Hudson, <u>in press</u>).

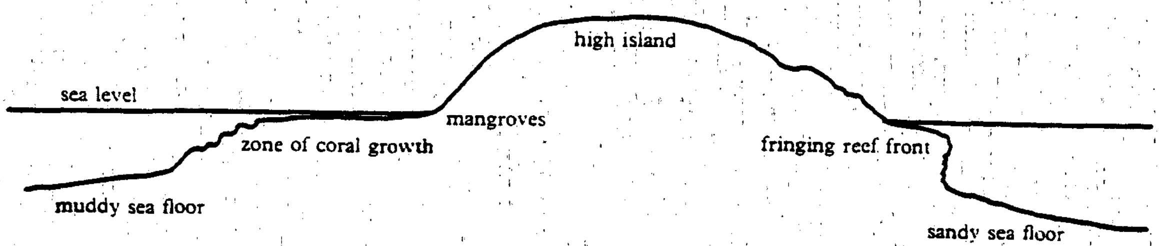

Fig. 5   Diagrammatic profile of a high island with associated reefs (after Veron & Pichon, 1976).

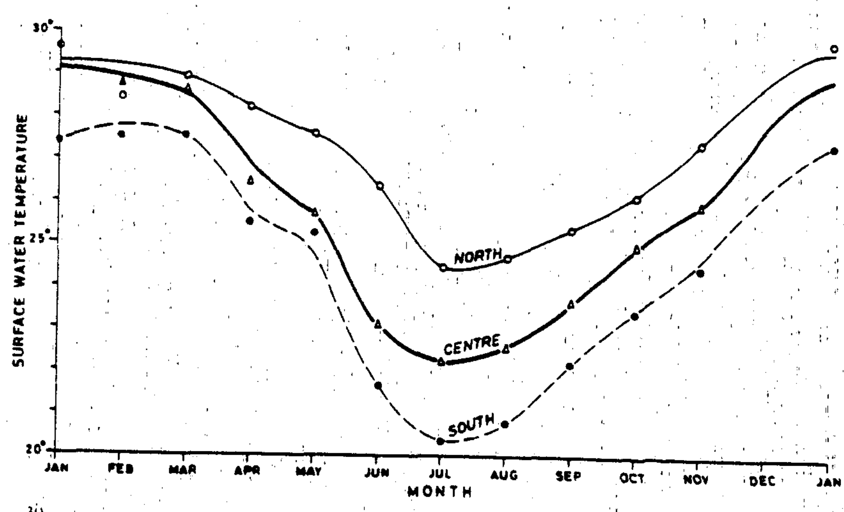

Fig. 6   Seasonal variation of surface water temperatures along the Great Barrier Reef, inshore stations (after Pickard, 1977; data from Brandon, 1973).

GEOMORPHOLOGY OF THE REEFS AND REEF ISLANDS

GREAT BARRIER REEF NORTH OF LIZARD ISLAND

David Hopley

Associate Professor

Department of Geography
James Cook University of North Queensland

Paper presented at the Great Barrier Reef Marine Park Authority meeting on the northern Great Barrier Reef, Townsville April 20-21, 1978

GEOMORPHOLOGY OF THE REEFS AND REEF ISLANDS, GREAT BARRIER REEF NORTH OF LIZARD ISLAND

David Hopley
Associate Professor

Department of Geography
James Cook Universityof North Queensland

This paper deals with the Great Barrier Reef from 15°00' South near Lizard Island to approximately 11°00' South (Fig. 1). It does not examine the distinctive reef province at the entrance to Torres Strait, but incorporates most of the morphologically uniform area of the northern Great Barrier Reef which commences at about 16°00' South near Cape Tribulation. The distinctive features of this reef province are largely the result of the narrow and shallow nature of the continental shelf, generally less than 50 m deep, and its box shape with steep shelf margins descending to over 1000 m within a kilometre of the outer reefs. Across this shelf it is possible to recognize six zones of reef and island development:

1. an inner zone of small low wooded island reefs and small reefs with sand cays generally within 20 km of the mainland coast.
2. a zone of reefs with vegetated or unvegetated sand cays. These are sometimes small reefs similar in size to the low wooded island reefs, or alternatively the westernmost parts of the much larger reefs of zone 3 where significant areas of reef flat have developed.
3. a mid shelf zone of massive reefs up to 25 km long and 125 km^2 in area, and with narrow intervening passages. Commonly these reefs have hard line margins and reef development only on their western sides facing the inner shipping channel. Towards the east they gradually descend and only isolated patches of reef flat are developed from a reef level which is generally 5 to 10 m below sea level.
4. a zone on the outer 30% of the shelf which is apparently devoid of reefs but in which there is a weathered limestone surface at depths between 20 m and 40 m.

5. a line of ribbon reefs, less than 600 m wide but individually up to 18 km long with narrow intervening passages situated at the outer edge of the continental shelf.
6. a zone of detached reefs rising from the deeper waters beyond the shelf edge.

Although remote from the major centres of population, there have been a number of significant contributions to the description and understanding of the geomorphology of the northern Great Barrier Reef. Observations made on the exploratory voyages of HMS Fly (1843-45) and HMS Rattlesnake (1846-50) on the northernmost reefs, including those of Torres Strait, suggested that raised reefs and raised beaches existed in this area (Jukes, 1847; MacGillivray, 1852), observations which were supported by later workers in the area (Rattray, 1869; Hadden, et al 1894; Mayer, 1918). Their evidence was quoted as recently as 1967 by Fairbridge. However, more recent work (Stoddart, et al 1978 in press) has shown that the raised reefs and beach rocks of the Raine Island area, at least, have been misinterpreted (see below). Alexander Agassiz in his voyage in the steamer "Croydon" in 1896 reached only the southernmost part of the area under discussion (Agassiz, 1898) and his views on the evolution of the Reef are now outmoded. Although the major part of the 1928 Royal Society Expedition to the Great Barrier Reef was spent on Low Isles, the geographical section comprising Steers, Spender and Moorhouse carried out a reconnaissance survey as far north as the Flinders Islands (Steers, 1929; Spender, 1930). A second geographical expedition in 1936 of Steers and Kemp extended the reconnaissance work as far north as Chapman Island (12°53'S). Most of the work on both these expeditions was concentrated on the low wooded islands, the salient features of which are described in detail, and discussion was generated about the origin of these features especially in relation to higher sea levels (Steers, 1937; 1938). Further reconnaissance level work on the northern reef was carried out by Fairbridge and Teichert during World War II and fitted into a picture of the total Great Barrier Reef (Fairbridge, 1950; 1967). More recently Maxwell (1968, 1973) has examined the sediments of the total reef region and Frankel (1974) the sediments of the Princess Charlotte Bay area. A major advance in knowledge of the area Lizard Island to Cape Melville occured in 1973 when this region formed part of the research area of the Royal Society-Universities of Queensland Expedition to the Northern Great Barrier Reef (Stoddart, et al 1978 in press). The third phase of this expedition involved a reconnaissance level survey of the inner reefs as far north as 11°42'S with extension of work out to the Great Detached Reef and Raine Island. Research carried out on this expedition forms the core of the present paper. Subsequent to 1973 the author and his postgraduate students have carried out further work of relevance to the interpretation of reef geomorphology in the Lizard Island area supported by ARGC funds (ARGC E75/15519).

DESCRIPTION OF THE GEOMORPHOLOGY OF THE REEFS AND ISLANDS

1. The Low Wooded Islands (Fig. 2)

Description

The low wooded island reefs are by far the best known of all the reef types of the Great Barrier Reef. The following description of the characteristic features is based on Stoddart, McLean and Hopley (1978 in press).

i) Windward reef flat

The windward reef flat, normally 60-100 m wide, usually dries at low water springs[1]. Its outer edge is formed of living corals the innermost zone of corals frequently being *Porites andrewsi*. This merges into a flat or gently sloping algal surface, drilling through which suggests that it overlies an older coral fringe, which has been infilled and veneered with encrusting coralline algae. Beyond this is a zone of rubble, mostly broken *Acropora* beneath which the algal surface may be continued.

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1 Throughout the northernmost Great Barrier Reef, tidal levels are very similar to those of Cairns, ie Mean High Water Springs (MHWS) 2.3 m; Mean High Water Neaps (MHWN) 1.6 m; Mean Sea Level (MSL) 1.40 m; Mean Low Water Neaps (MLWN) 1.2 m; Mean Low Water Springs (MLWS) 0.50 m.

ii) Ramparts

Ramparts are asymmetric ridges of coral shingle with steep inward face (up to 80^{o}) and gentle seaward slope of less than 10^{o}, which merges into the reef flat rubble zone. Tongues of shingle form extensions inwards over the reef flat from the ramparts which generally have a width of about 50 m. Mean heights of ramparts measured in 1973 was 1.8 m (Tidal Datum), but they may be as high as MHWS. Remnants of lithified rampart foreset beds forming projecting steeply dipping ridges known as basset edges occur on the reef flat where the uncemented upper rampart materials have been eroded. Ramparts may be colonised by a low scrub of *Aegialitis annulata* and *Avicennia marina*, whilst higher shingle sheets, may be covered by succulents (*Sesuvium* sp., *Salicornia* sp., *Arthrocnemum* sp and *Sueda australis*).

iii) Moat

Shallow ponds may be enclosed by the shingle ramparts on the inner reef flats. In these moats corals commonly in the form of micro-atolls grow to heights of 1.0 m (Tidal Datum) and, exceptionally, to MSL.

iv) Platforms or promenades

Conglomerate platforms of cemented coral shingle with horizontal upper surfaces often fringe the inner margins of moats and form the seaward edge of the land bodies of low wooded islands. Frequently the platforms overlie fossil micro-atolls. They appear to have resulted from basal cementation of old ramparts. The height of cementation varies considerably, and earlier workers, notably Steers and Spender identified an upper and lower platform, Steers (1938) in particular arguing that both features were the result of higher sea levels. However, the majority of "lower platforms" have elevations at or below MHWS, ie within the range of modern intertidal cementation. However "high" platforms may reach 3.5 m (TD) which may imply a higher relative sea level of up to 1.2 m at time of cementation. These platforms are commonly 30 to 40 m in width though erosion, often in the form of deep circular pot-holes, is severe on the outer edge.

v) Shingle Island

Platforms are frequently surmounted by a series of old shingle ridges, which may be older equivalents of the modern ramparts. Their maximum elevation is about 5 m (TD).

vi) Mangrove swamp

Mangrove areas vary from less than 1 ha to 125 ha on Bewick and even larger areas on the compound island (ie low wooded island cum high island) of Howick. Aegialitis annulata and Avicennia marina are characteristic of shingle ramparts and moats by Rhizophora stylosa is the main coloniser of reef tops with some Sonneratia alba. At higher levels, Rhizophora is replaced by Ceriops tagal, several species of Bruguiera and Xylocarpus and at the highest levels by Osbornia octodenta and Excoecaria agallocha. Within many of the mangrove swamps are fields of fossil micro-atolls in position of growth, which, within the Howicks especially, reach elevations of 1.35 m, 0.35 m higher than presently living moated corals.

vi Sand cay

Leeward sediment accumulations are characteristic of most low wooded islands but vary from discrete unvegetated sand cays to larger vegetated cays or sandy areas forming an integrated land area with windward platforms and shingle accumulation (eg the Turtle Group). Larger vegetated cays frequently comprise a low terrace around a central, higher and more extensive core. The higher terrace usually carries woodland or dense scrub, the lower a more open community of shrubs and herbs. Beach rock associated with erosion of the higher terrace is wider, more continuous and higher. Steers (1938) considered some of these higher beach rock outcrops to be raised features, associated with the lower platform at Bewick, Pipon and King Islands and with the higher platform at Nymph and Ingram. The vegetated discrete cays of low wooded islands investigated on the 1973 Expedition had a mean area of 12.0 ha almost exactly twice the area of isolated vegetated sand cays of the region.

viii) Boulder zone

A recurrent feature of the low wooded islands is a boulder zone up to 200 m long with boulders reaching 3-4 m in greatest dimension, occurring on the leeward reef edge. These storm deposits, frequently consisting of single coral colonies, are sometimes cemented into platform rocks or pass beneath sand cays (as on Sherrard Island).

Types of low wooded island

Great variation exists in the size and morphology of low wooded islands, both in size and the distribution, presence or absence of the features listed. The major types are:

i) Islands with mangroves of limited extent and separate sand cay.

The reef top is large and the cay and mangrove-shingle rampart-platform island are well separated. The reef flat may be completely sanded or have areas of moated micro-atolls. Typical are Lowrie and Pipon. Chapman, Binstead and Watson are similar but have only embryonic unvegetated sand cays. In contrast on Ingram-Beanley, Sherard and Piper the sand cay is well vegetated and substantially larger than the mangrove-shingle island.

ii) Islands with extensive mangroves forming shingle and sand cays.

Bewick has the most continuous mangrove cover but both Newton and Nymph have extensive mangroves, though with large enclosed lagoons. Houghton and Coquet have large distinct sand cays and extensive mangroves but the windward shingle is linked to the cay by a continuous belt of conglomerate platform and shingle ridges.

iii) Turtle type islands (Figs. 3 and 4)

These islands lack a central open flat and have the mangrove-shingle cay dominating and frequently enclosing the sand cay. The shingle ridges dominate the reef top, occasionally with a lower terrace surrounding a higher central area with old beach rock slabs on the slope between, similar to some sand cay morphology (eg Turtle VI).

2. Inner Reefs with Sand Cays

A further series of small reefs lies just outside the low wooded islands and on these are sand cays both vegetated and unvegetated. These reefs lack windward shingle ramparts although small tongues of shingle may be found in placed. The distinctive feature is the sanded surface of a very continuous reef flat over which there are few, if any living corals. However, dead corals usually in the form of planed-down micro-atolls may be seen where the sand cover is discontinuous. Very similar to this type of reef flat are the surfaces of the western ends of many of the very large reefs which lie to the east. These too have sanded reef flats and leeward cays, though all the cays are unvegetated. A boulder zone may be present on both types of sanded reef.

The cays of these reefs have been described by Stoddart, McLean and Hopley (1978 in press). They may be classified into vegetated and unvegetated types:

i) Unvegetated cays

These are generally small and also variable in form and size over time. Comparison of cays mapped both by Steers in 1936 and Stoddart in 1973 showed substantial changes, all cays having decreased in size since 1936. The amount of movement over short periods of a similar cay on Wheeler Reef near Townsville has been described by Hopley (1978 in press). Three sub-types of unvegetated cays have been recognized, which may represent a progression in their development:

1. Small ephemeral cays - intertidal sand patches possessing no beach rock. The majority of the cays on the western margins of the large reefs are of this type.
2. Large, generally oval islands up to 300 m long and 100 m wide. These have steep beaches and pronounced swash ridges.
3. Cays of more variable dimensions, surrounded by extensive beach rock. The present form and size of the cay may differ from that outlined by the beach rock, presumably as the result of cyclonic activity. Examples include Ashmore (Fig. 5) and Ellis cays.

ii) Vegetated cays (Figs. 5 and 6)

The 1973 Expedition found that vegetated cays were ten times the size of unvegetated cays. On the northern reef the orientation tends to be east-west to the south of Cape Melville and north-west to south-east to the north. Three sub-types were recognized by the 1973 Expedition:

1. Elongate narrow islands with steep beaches often surrounded by dunes to a maximum altitude of 7 m (TD). The vegetated area ranges from 10 to 66% of the total area of the cay. Numbers of plant species range from 2 to 11 for the smallest and up to 34 for the largest, consisting of herbs, grasses and low scrub. Included are Combe, Eagle, Kay and Stapleton.
2. A group of larger, oval islands, averaging 530 m in length, 200 m in width. The islands are flat topped though sometimes displaying an upper and lower terrace similar to those on the cays of the low wooded islands. Beach rock is extensive and superficial phosphatic cay sandstone may be found in the interior of the cay. Examples include Morris, Magra, Stainer and Saunders Islands.
3. Equidimensional islands, up to 500 m in maximum diameter. On the northern reef these generally maintain a vegetation of low scrub, herbs and grasses. Fife and Pelican are included in this group.

3. Mid-shelf massive reefs

Mid-shelf reefs of massive dimensions generally lying normal to the mainland are unique to this part of the Great Barrier Reefs. Only the large reefs lying between Bowen (Darley-Dingo Complex) and the hard line Pompey Complex off Mackay may be comparable in size although their morphology is quite distinct.

Several examples on the northern reef incorporate continental high islands and proximity of basement rocks to the surface of these reefs may be a factor in their size and development. Included in these reefs are the high islands of Quoin, Forbes, Sir Charles Hardy and Cockburn. Stoddart et al (1978 in press) suggest that it is possible that the large platform reefs on the Princess Charlotte Bay area are thin veneers on flat lying or gently dipping Mesozoic sedimentary rocks of the Laura Basin.

Morphology of these reefs varies. Immediately north-west of Lizard Island are the great crescentic loops of Waining and Parke Reefs and South Warden Reef. Although hard line development occurs only on their western and windward south-eastern sides, the perimeters enclose reef platform submerged to a depth of about 20 m. The reefs off Princes Charlotte Bay (Corbett, Grub, Hedge, Lytton, Magpie and Noddy Reefs) are relatively simple and consist of a higher sanded reef flat surface on their south-western extremities sloping gently seawards towards the north-east where they may terminate in submerged reef patches. Most continuous hard line development occurs on the windward south-eastern side. Narrow channels separating these elongate reefs have depths ranging from 25 to 30 m.

North of 13°30' South these reefs become smaller as the shelf narrows and break up into largely submerged reef patches up to 10 m below the surface. North of Restoration Island (12°37'S) the shelf widens and the large reefs again become prominent. Reef tops are sloping, with extensive reef flat development only on the landward sides, the remainder of the reef being submerged platform up to 18 m deep. Narrow passages 30 to 50 m deep separate and cut across these reefs in a dendritic pattern converging towards the east. North of Cockburn Reef, a further change occurs in the reef morphology. The shelf widens further here to over 100 km. The inner zone of small reefs is wider and the massive mid-shelf reefs although still present as large reefal shoals separated by a similar dendritic channel pattern to further south, reach the surface only occasionally, invariably on the western side.

Figure 7 is drawn from an echo sounding traverse across the entire width of the shelf off Cape Grenville. It includes Wreck Reef which even at this scale can be seen to slope eastwards. Little is known of the submerged eastern sides of these reefs, although it can be seen that Wreck Reef at least, after sloping down to about 17 m, drops off sharply on the eastern side to depths of over 60 m. Sediment constituents are also indicated in Figure 7. The inner channel sediments consist mainly of molluscan fragments together with up to 40% terrigenous materials. The sediments of Wreck Reef are more varied, coral, coralline algae, foraminifera (Marginopora) and molluscan fragments dominating. The terrigenous content is less than 12%, probably derived from the Sir Charles Hardy Islands. Molluscan fragments, coral and coralline algae dominate the sediments in the trench to the east, with terrigenous content less than 5%.

4. Outer shelf karst surface

Figure 7 shows that the trench east of the massive reefs is about 10 km wide. From it rise a number of small irregular reef patches (Middle Banks, Ashmore Banks). To the east, and occupying much of the outer shelf is a zone of reefal shoal between 20 and 40 m depth. The exact distribution of this shoal area, identified as a relict subaerially weathered karst surface, is difficult to assess. It clearly shows up on both echo sounding traverses (Figs. 7 and 8) and also occurs on a traverse south of Lizard Island near Lark Pass. Orme et al (1977, 1978 in press) have described a continuous seismic profile over this surface near Lizard Island (see below). The shoal area may be much more extensive. On aerial photographs of the Great Barrier Reef north of Princess Charlotte Bay, exceptionally good water penetration has permitted the mapping of the karst surface, together with much of its morphological detail over a relatively large area of shelf (Figs. 1 and 9). In places it can be seen to merge into the back reef areas of the outer ribbon reefs. Elsewhere, as off Carter Reef in the south (Fig. 1) there is a distinctive eastern edge to the zone. The surface consists of an apparently irregular series of enclosed depressions quite unlike normal reef constructional morphology. Individual depressions may be up to 200 m in diameter, but many are smaller than this. Details of the echo sounding traverse opposite Cape Grenville (Fig. 7) suggests the amplitude of relief on the surface is about 10 m near the margins of the "plateau" to less than 5 m near the centre. It must be pointed out that conclusive evidence of this surface being karst eroded is not available. However, the patterns as seen on the air photographs and dimensions from soundings are strongly suggestive of such an origin. A high degree of compatability exists between this surface and the undeniably karst eroded surfaces of, for example, Aldabra atoll in the Indian Ocean (see Stoddart et al 1971; Braithwaite et al, 1973). Even the thick mats of Halimeda and Halimeda derived sediments which are so distinctive of this surface, as previously noted by Orme et al (1978 in press) have apparently not been sufficient to mask the morphology of the underlying surface.

5. Outer ribbon reefs

Narrow linear or ribbon reefs are a distinctive feature of the Great Barrier Reef north of Cape Tribulation. Individual reefs north of Lizard Island vary from less than 2 km to over 18 km in length. Smaller oval plug reefs of Maxwell's (1968) terminology may occur within or just behind the passages between the ribbons. Width of these linear reefs is very constant, varying from about 400 to 600 m from the reef front to the back reef detrital slope. These reefs occur at or close to the edge of the continental shelf, with deep water of 500 m or more found within a few hundred metres of the reefs, and over 1000 m within a kilometre.

The reef front is steeply sloping in excess of 20^{o}, occasionally interrupted by minor terrace levels (eg at c 10 m on Carter Reef). The surf zone is one of prolific coral growth up to the level of tidal datum. At this level the reef top is reached and extends back from the reef front to a maximum level of approximately 0.4 m, apart from higher shingle banks and boulders. The outer flat is a planar surface of encrusting coralline algae with low flat lying corals, mainly Acropora sp. occurring only in gentle undulations on the surface. Approximately 200 m from the reef front the algal surface is covered by rubble with occasional Acropora shingle banks rising to c 0.8 m. It is in this zone that the reef flat surface reaches its highest elevation. At the rear of the zone the algal surfaces continue as narrow linear fingers overlying massive corals, separated by parallel channels up to 4 m deep. This morphology is continued into the aligned coral zone, which is identical apart from the lack of an algal crust. The lineaments are usually normal to the reef front or at a slight angle to it and appear to be determined by the pattern of refracted wave fronts. The back reef area consists of a steeply inclined sand ramp sloping into water depths of c 14 m from which rise isolated massive coral colonies.

In a few locations the orientation and width of the ribbon reefs are such that small unvegetated sand cays form. These are usually small and the majority are ephemeral (cf aerial photography with bathymetric charts). However, one at least, at Waterwitch Passage has had sufficient permanence for the formation of prominent bands of beach rock and aerial photography suggests that a low vegetation occurs on the cays on Derry and Ham Reefs ($13^{o}02'$S).

Shallow drilling has been carried out on Carter (Hopley, 1977) and Lark Pass Reefs, typical ribbon reefs of the Lizard Island area (Fig. 10). Radio-carbon dating of cores from these reefs suggests that they have developed from coral colonies first reaching modern sea level about 200 m from the reef front. From this area the reef has slowly widened by growth both towards the reef front largely by consolidation of debris by cementing coralline algae, and towards the rear of the reef by coral growth over which the coralline algae form a veneer.

6. Detached reefs

On the northernmost Great Barrier Reef north of $12^{o}35'$S are a series of small reefs detached from the main barrier and separated from the ribbons by deep water. Several (Southern Small Detached, Yule Detached and the reef west of the Great Detached Reef are ovoid platforms enclosing deep lagoons. Two, Northern Little Detached and Raine, are similar but with flat reef tops, Raine also possessing a vegetated cay. Great Detached Reef consists of a submerged platform with *Halimeda* banks submerged at a level of 35 m (Fig. 7) with a fringe of ribbon reefs on all but the western sides. All the detached reefs have extremely steep marginal slopes.

Only two of these reefs have been examined in any detail:

i) Great Detached Reef has a morphology analogous to that of the outer shelf reefs of the main barrier. Its ribbon reefs have similar morphology and zonation and the flat *Halimeda* platform is similar to the karst platforms already described, though the amount of relief is much less (2 to 3 m).

ii) Raine Reef and the cay are described in detail by Stoddart et al (in press). The reef is about 3.5 km long and 0.75 km wide, the cay being situated on its western side. The cay, 850 m long and 430 m wide, has a steep beach consisting largely of small pink foraminifera. Beach rock occurs intermittently around the island's margins. A continuous beach berm, 20-25 wide is overlooked by a low scarp (1 to 1.5 m high) of phosphatic cay sandstone misinterpreted in all previous literature as raised beach rock or raised reef (see, for example, Fairbridge, 1950). The outer edge of this cemented material stands at 6.0 m (TD). It is surmounted by a high ridge of uncemented sand rising to a maximum of 9.0 m. There is a central unvegetated flat with superficial guano cemented surface at 6 m, extensively modified by phosphate quarrying, mainly between 1890 and 1892.

EVOLUTION OF THE REEFS AND ISLANDS

Understanding of reef morphology has increased significantly over the last 10 years, from work carried out elsewhere in the world and on the Great Barrier Reef (eg see the Proceedings of International Coral Reef Symposia in Brisbane, 1973 and Miami, 1977). In most areas, present reefs have developed as veneers of Holocene growth over older Pleistocene foundations which were exposed to subaerial processes during the low sea levels of the late Pleistocene. The morphology of the Pleistocene foundation is dependent on both the original morphology of the earlier reef and the modifications during exposure which may develop a karst relief. In turn the degree to which this Pleistocene morphology influences modern reef morphology is a reflection of the depth of the antecedent platform, the nature of the rise of sea level over it, together with the response of reef building organisms and the sediments they produce to the prevailing environmental conditions including wave and tidal regimes.

1. The pre-Holocene surface

Seismic profiling by Orme et al (1977, 1978 in press) and by Harvey (1977 in press) together with drilling by Thom et al (1978 in press), all in the Lizard Island area, indicate that in this area at least the surface on which the Holocene reefs and sediments have been laid largely mimics an older pre-existing surface. Orme et al (1978 in press) report a major disconformity indicating marine regression and shelf emergence at a depth of about 45 m but with channels (now infilled) cut into it to depths of 69 m below present sea level. This irregular surface is particularly prominent beneath the Halimeda covered banks. The Halimeda deposits are indicated as having a maximum thickness of 18 m. The amount of relief on the banks surface is less than that of the karst platforms further north (including that shown on Figure 7 and it is suggested here that the cover of Holocene sediments on the northern karst surfaces is much thinner.

If the "karst surface" in the northern reef is correctly identified, two major problems of interpretation remain. First, the degree of relief displayed by the surface may be greater than that shown by last interglacial reefs which are now elevated above present sea level elsewhere (eg Barbados). As palaeo-climatic indicators for northern Queensland suggest that the last glacial period was one of reduced precipitation compared to the present, it is unlikely that karst processes were more rapid here than elsewhere. More likely is that this is a composite surface of greater age than the last interglacial and exposed to subaerial weathering more than once. If so then the problem still remains as to why this surface was not colonised by corals during the Holocene transgression. Fairbridge (1950) has suggested that reefless areas are ones with depths over which the Holocene transgression was most rapid, sea level far outstripping the role at which reefs could grow upwards. By the time the transgression rate had slowed, the surfaces were at depths not greatly conducive to coral growth. A further important factor noted by Adey et al (1977) off St Croix in the Caribbean as responsible for retardation of coral colonisation is turbidity derived from erosion of shelf regolith. This may have been particularly important in the sheltered waters behind the exposed limestone island chain of the pre-Holocene ribbon reefs (see below). Thus the final removal of the regolith, and its associated turbidity may not have taken place until modern sea level was being approached (c 6000 years BP) and the Pleistocene foundations of the ribbons were inundated, thus allowing stronger wave activity over the zone where the karst surfaces can now be seen.

Seismic refraction survey over reef flats by Harvey (1977) has shown that on Carter Reef a pre-Holocene rim lies beneath the algal surface of the ribbon reef at a depth of only 9.5 m, descending to 19.3 m in the aligned coral zone. In conjunction with the C14 dates (Fig. 10) it is clear that initial growth of Holocene corals on the ribbons has been over this high rim. On Nymph Island, the pre-Holocene surface has been identified at a maximum depth of 9.35 m. Drilling on Bewick, together with subsequent dating and geochemical analyses of the cores has identified the pre-Holocene surface at a depth of only 3 to 4 m below low water and a similar programme on Stapleton Island identified the unconformity at 14.6 m below the surface, although the drilling site is located on the back reef detrital slope and the unconformity may be higher elsewhere on this reef (Thom et al 1978 in press).

No information on the pre-Holocene surface is available for the reefs further north. However, conclusions drawn by Stoddart et al (in press 1978), Davies (1977) and Davies et al (1977) about the influence of the depth of the unconformity on present reef morphology are relevant. Where the pre-Holocene surface is deep, inundation during the Holocene transgression took place when the rate of sea level rise was rapid (up to 10 mm/year), probably twice the maximum rate of possible upward reef accretion. Thus reefs with pre-Holocene surfaces at c -20 m would have been inundated about 9500 years BP, and (based on upward growth rates of about 5 mm/year) reached modern sea level by 5500 years BP, probably 1000 years after modern sea level was actually achieved. Deeper surfaces would have reached present sea level later, leaving less time for reef flat development, whilst shallower surfaces would reach modern sea level relatively earlier, possibly growing upwards at the same rate as the latter part of the transgression at about 5 mm/year. Such reefs, like Bewick, would develop reef flats very early, allowing formation of cays, ramparts and mangrove swamps. As the degree of reef flat development and cover of sediments apparently decreases eastwards across the shelf from the low wooded islands, to the sandier reef tops, to the submerged reefs, the implications are that the pre-Holocene surfaces beneath reefs deepen seawards. This may be so although no evidence is yet available. Other factors which need to be acknowledged are variations in apparent sea level curves, and the influence of turbidity produced by removal of the pre-Holocene regolith, as discussed above.

2. Sea levels and tectonics

Controversies in the 1960s over the nature of the Holocene rise in sea level and the existence of evidence for higher sea levels has largely been resolved by the global and local shelf isostatic models of Bloom (1967), Walcott (1972) and Chappell (1974). These hydroisostatic movements have probably combined with or reinforced local tectonic patterns and shelf marginal subsidence. It is now accepted that modern sea level apparently has been only just achieved in the northern hemisphere, whilst in the southern hemisphere it was achieved as much as 6500 years ago. Further, according to the Chappell hydroisostatic model, subsidence on the outer shelf may give the impression of a much later achievement of modern sea level whilst a compensatory uplift of the inner shelf may give correspondingly older dates or even result in sea levels higher than present being achieved. In view of the relationship between reef accretion rates, depth of pre-Holocene platform and sea levels discussed in the previous section, the exact nature of the sea level rise will be of vital importance in determining the nature of present reef morphology. This will be especially so where the pre-Holocene surface is shallow and the upward growth of the reef will have closely followed the rise in sea level. All other factors being equal, reef flat development would be expected to be greater where modern sea level had been achieved earlier (ie on the inner reefs according to the Chappell model). Sufficient radiocarbon dates are available for the northern Great Barrier Reef to indicate the significance of the sea level factor.

Numerous dates from the inner shelf low wooded islands indicate that modern sea level was achieved here prior to 6000 years BP. Dates include:

ANU 1640	Fisher Island. Tridacna resting in fossil micro atoll field	6310 ± 90 yrs BP
ANU 1639	Stainer Reef. Favites abdita micro atoll in growth position.	4980 ± 80 yrs BP
ANU 1284	Bewick Reef. (Possibly Porites) Core material above the pre-Holocene surface	6920 ± 130 yrs BP

ANU 1287	Haughton Reef. Favid coral from micro atoll field	5850 ± 170 yrs BP
ANU 1286	Leggatt Reef. <u>Tridacna</u> in growth position from micro atoll field	5800 ± 130 yrs BP
ANU 1479	Turtle Island. Coral, <u>Cyphastrea</u>, from shingle beneath island	4910 ± 90 yrs BP

As all these dates relate to micro atolls or reef flat deposits, they suggest that the respective dates indicate periods of reef flat formation, ie subsequent to modern sea level being reached.

Also on the low wooded islands to the south of Cape Melville is evidence again with numerous radiometric dates for a sea level marginally higher than present (c + 1.0 m). Evidence comes in the form of:

i) the high terrace levels of the cays
ii) the level of the higher platform
iii) levels of fossil micro atolls
iv) levels and morphology of beach rock outcrops

The evidence has been discussed by McLean <u>et al</u> (1978 in press) who, within the limitations of the types of evidence used, conclude that on the low wooded islands,

i) modern sea level was achieved prior to 6000 years ago and was marginally higher than present by 5000 years ago
ii) by 4900 years sea level was even higher
iii) by 3000 years BP the outlines of leeside cays and windward ramparts were established. Much of the evidence for higher sea levels greater than 1.0 m above present give dates of 3200-3800 years BP.
iv) between 2000 and 3000 years BP sea level gradually fell
v) sea level has probably not varied greatly over the last 2000 years

Evidence of former sea levels on the outer reefs is generally lacking. A date of 1180 ± 65 yrs BP (ANU 1591) for a Tridacna incorporated in beach rock and overlain by phosphatic sandstone gives a minimal date for island and reef flat accumulation at modern sea level. More significant are dates from Carter Reef (Hopley, 1977) and from Lark Pass Reef (previously unpublished).

GaK-6477	Carter Reef	0.70 m	below reef top	5420 ± 130 yrs BP
GaK-6478	Carter Reef	1.40 m	below reef top	5750 ± 130 yrs BP
GaK-6479	Carter Reef	0.05 m	below reef top	3760 ± 100 yrs BP
GaK-6480	Carter Reef	0.55 m	below reef top	5800 ± 110 yrs BP
GaK-6481	Carter Reef	0.10 m	below reef top	4480 ± 100 yrs BP
GaK-6482	Carter Reef	0.50 m	below reef top	4870 ± 120 yrs BP
GaK-6681	Lark Pass Reef	0.08 m	below reef top	4940 ± 140 yrs BP
GaK-6682	Lark Pass Reef	0.50 m	below reef top	4040 ± 130 yrs BP
GaK-6683	Lark Pass Reef	0.14 m	below reef top	4910 ± 110 yrs BP
GaK-6684	Lark Pass Reef	1.30 m	below reef top	5720 ± 130 yrs BP

Clearly on the outer reef modern sea level had been achieved by or shortly after 6000 years BP, possibly only a few hundred years later than on inner reefs. Thus previous suggestions that higher sea level evidence on inner reefs was due to the very recent growth of the outer ribbons and their effects on tides (ie reducing tidal range) are no longer tenable. Shelf warping normal to the coastline appears to have been minimal although outer reefs bear no evidence of higher sea level evidence. Previously reported evidence on Raine Island and on the adjacent outer barrier has been proved incorrect (Stoddart, et al, 1978 in press) and it seems unlikely that had such evidence ever existed it should have been removed entirely from the whole of the 500 km of the outer barrier. Reasons for this lack of warping across the continental shelf may be related to the narrow and shallow nature of the shelf on the northern reef. Minor variation does exist parallel to the coast for the higher sea level evidence does not extend north from Princess Charlotte Bay. This location marks a major structural break along the Queensland coast, and, as previously hypothesised by Hopley (1974, 1975) Holocene hydroisostatic movements may have taken advantage of older structural weaknesses in the crust. In terms of the northern reef as a whole, however, it must be concluded that regional Holocene sea level variations have been minimal and that contrasts in the degree of reef flat development are due to other factors, most probably the depth to the pre-Holocene surface being the most influential.

3. Responses to prevailing environmental conditions

As modern sea level was achieved by 6000 years ago and has not varied significantly since (within 1 - 2 m), and as the majority of pre-Holocene reef platforms appear to be within 20 m of present sea level, the majority of reefs have had sufficient time to grow upwards and reach modern sea level, converting upward growth to vertical accretion and reef flat formation with infilling of central reef flat lagoons. Further, on the linear outer reefs it would appear that an equilibrium state has been achieved in the manner suggested by Kinsey and Davies (in press) in which, once a reef flat of c 400 m width has been achieved further widening of the flat is unlikely as production and loss of calcium carbonate are balanced. There is therefore an explanation for the more or less constant width of the reef flats of the ribbon reefs.

Of the prevailing environmental conditions to which the reef flats have responded, by far the most influential is the predominance of sediment moving waves from the south-eastern quarter. The reef organisms themselves have responded and it is mainly in the windward sides that "hard line" reef development is greatest. Coarser, less mobile sediments have accumulated on the windward reef margins in the form of ramparts, and shingle banks, whilst more mobile sediments have accumulated over the inner reef flats or as cays on the leeward edge at the point of intersection of refracted wave trains. Variation exists, however, in the intersection points of these waves and short term modifications to even vegetated cays are constantly taking place. From the results of the 1973 Expedition, long term changes in the cays appear to be towards a reduction in size.

Tropical cyclones, with their high wind speeds and higher than normal sea levels produced by storm surge are also influential in developing reef top features. Boulder zones and reef blocks are certainly deposited during cyclones whilst many of the high shingle accumulations are also initiated during such storms and only modified during normal south-easterly weather. Hopley and Harvey (1978 in press) indicate that both cyclone frequency and intensity and storm surge risk is low along the northern Great Barrier Reef and generally reduces northwards. Nevertheless extremely intense cyclones with high storm surges can be experienced. The 1899 Bathurst Bay cyclone (Whittingham, 1958) had a central pressure of 915 mb. Its reported 12.2 m surge is greatly exaggerated. The remnants of former cays, now seen as only outlines in beach rock as on Sherrard and Ellis Reefs, are adequate testimony to the effect which cyclones may have on reef islands.

CONCLUSIONS AND SOME IMPLICATIONS FOR MANAGEMENT

The zonation of reefs and islands noted at the start of this paper is the result of variations in the depth and nature of the pre-Holocene surface, the nature of the Holocene sea level rise and the response of the reefs and reef organisms to this rise and to prevailing environmental conditions. The low wooded islands result from generally shallow pre-Holocene platforms and a long period of sea level at or close to its present position. Slightly higher sea levels are also responsible for some features. An exposure factor, as discussed by Stoddart (1965) may also be involved. Declining reef tops to the east may represent deeper pre-Holocene platforms combined with the rapid rise of the Holocene transgression through the -35 to -15 m levels. High turbidity levels at time of initial submergence may be a related factor in the lack of development of mid shelf reefs and the complete lack of Holocene reef on the karstified surfaces of the outer shelf shoals. The ribbon reefs, and probably the detached reefs also, have developed on a pre-Holocene rim, which together with a comparatively long period of sea level stability (5000 years +) has allowed the reefs to develop in equilibrium with prevailing conditions.

A number of geomorphic factors have implications for management of the northern Great Barrier Reef.

1. Largely because of variations in the depth of the pre-Holocene surface, the reef tops display a series of different stages of development. Lack of corals in a reef top may not indicate the effects of

Acanthaster planci or man but result from a long period of reef flat development. However, other reefs just changing from essentially vertical to lateral accretion may be in a critical state of balance which will make them vulnerable to such influences.

2. Although the risk from cyclones and storm surges is much reduced on the northern reef, a certain degree of risk is still present. Cyclones may completely remove sand cays.
3. Sand cays are constantly undergoing modification in response to minor changes in wind and waves. Construction should take this into account and lower terrace levels especially avoided. The higher terrace is the most stable area of the cay. Unvegetated sand cays may migrate several hundred metres, and provide no permanent base for navigational or research platforms. It is notable that most cays over the last 50 years have been reducing in area.

Acknowledgement

I wish to acknowledge the Australian Research Grants Committee for support of much of the research reported here, and colleagues on the 1973 Royal Society-Universities of Queensland Expedition, especially Dr D.R. Stoddart, whose work is included in this paper. Thanks also go to Nick Harvey and Peter Davies for their help in making unpublished results of this work available.

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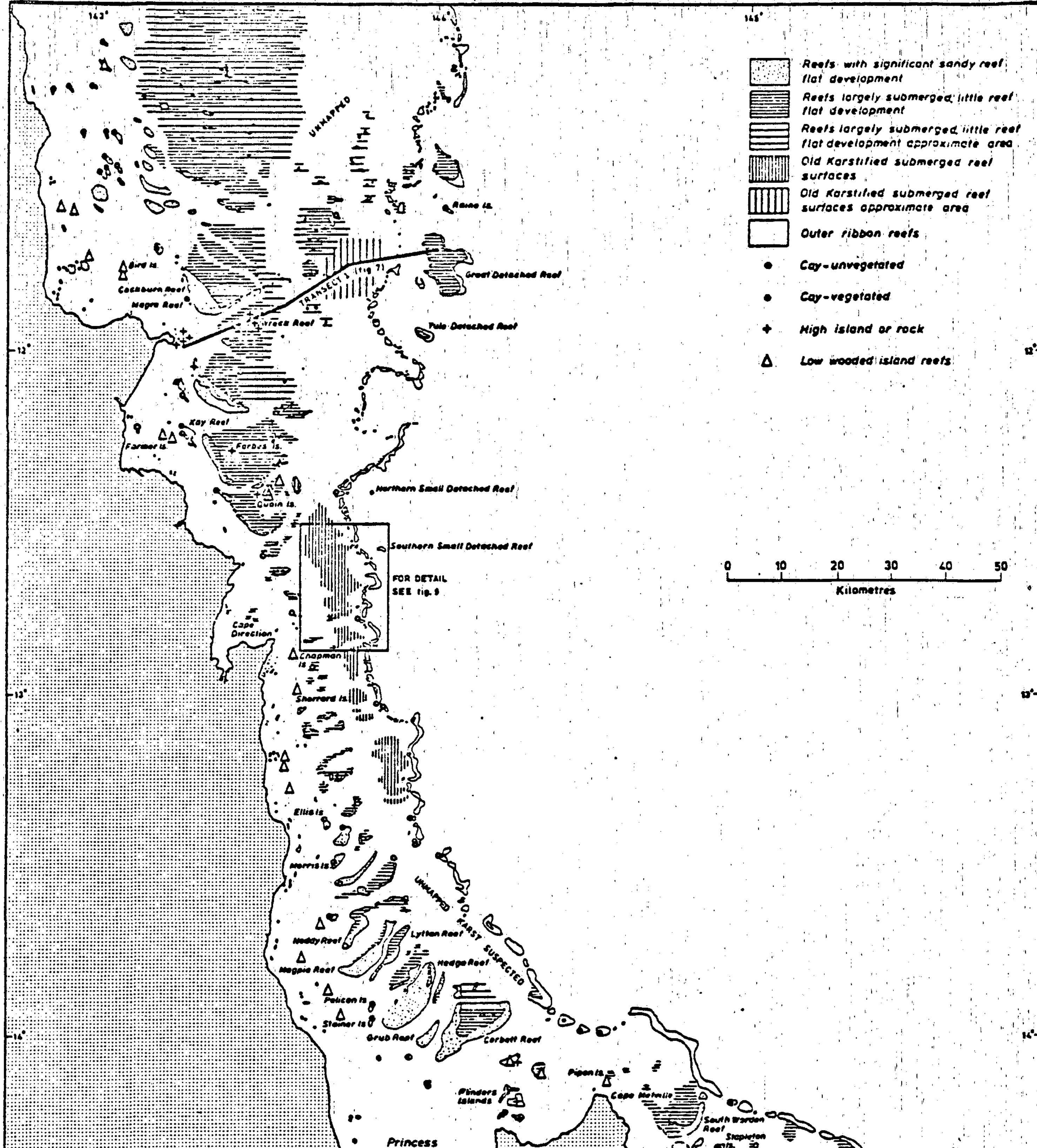
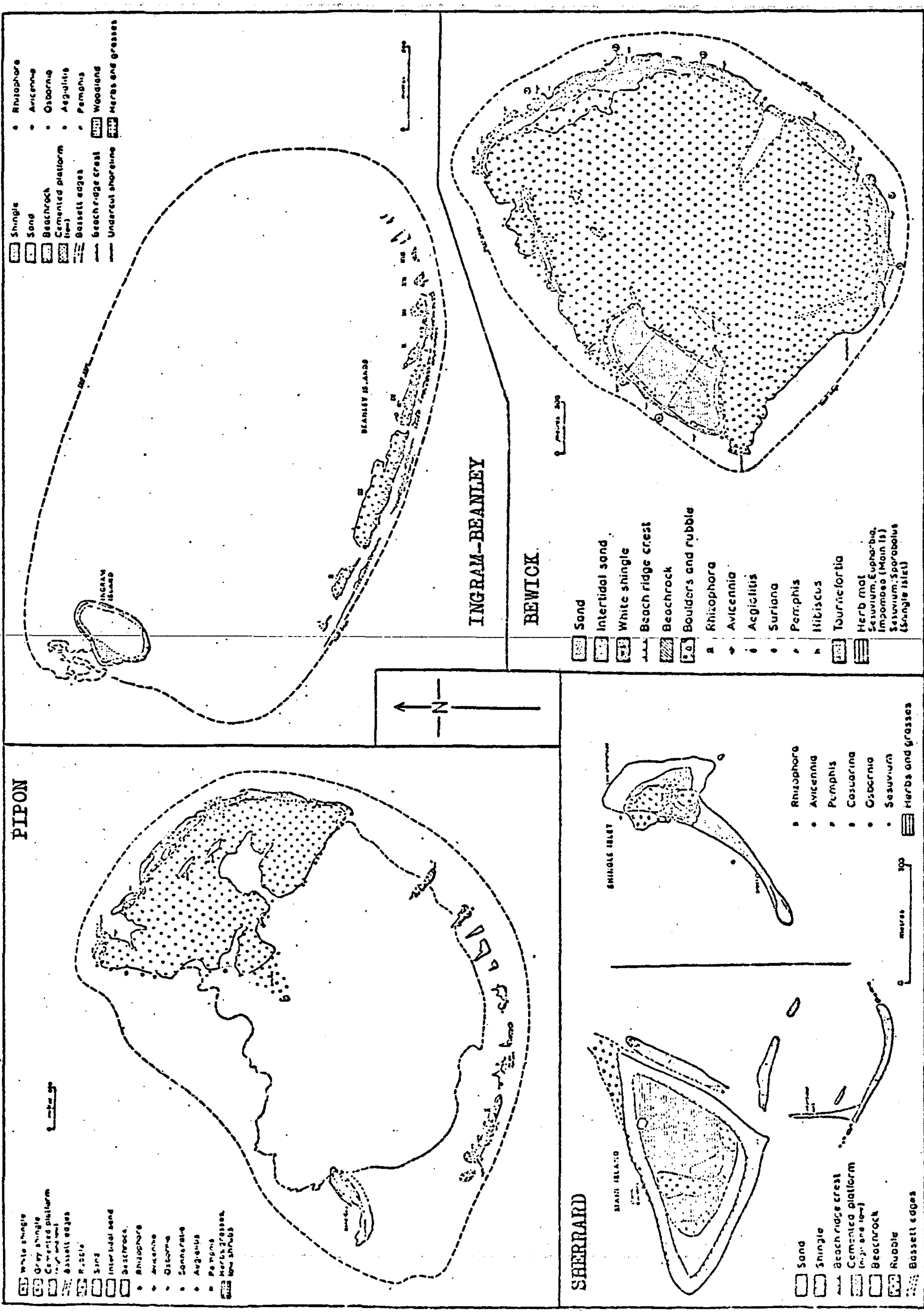


fig. 1 The Northern Great Barrier Reef

Fig. 2: Low Wooded Islands of the northern reef - examples
From surveys by D.R. Stoddart 1973



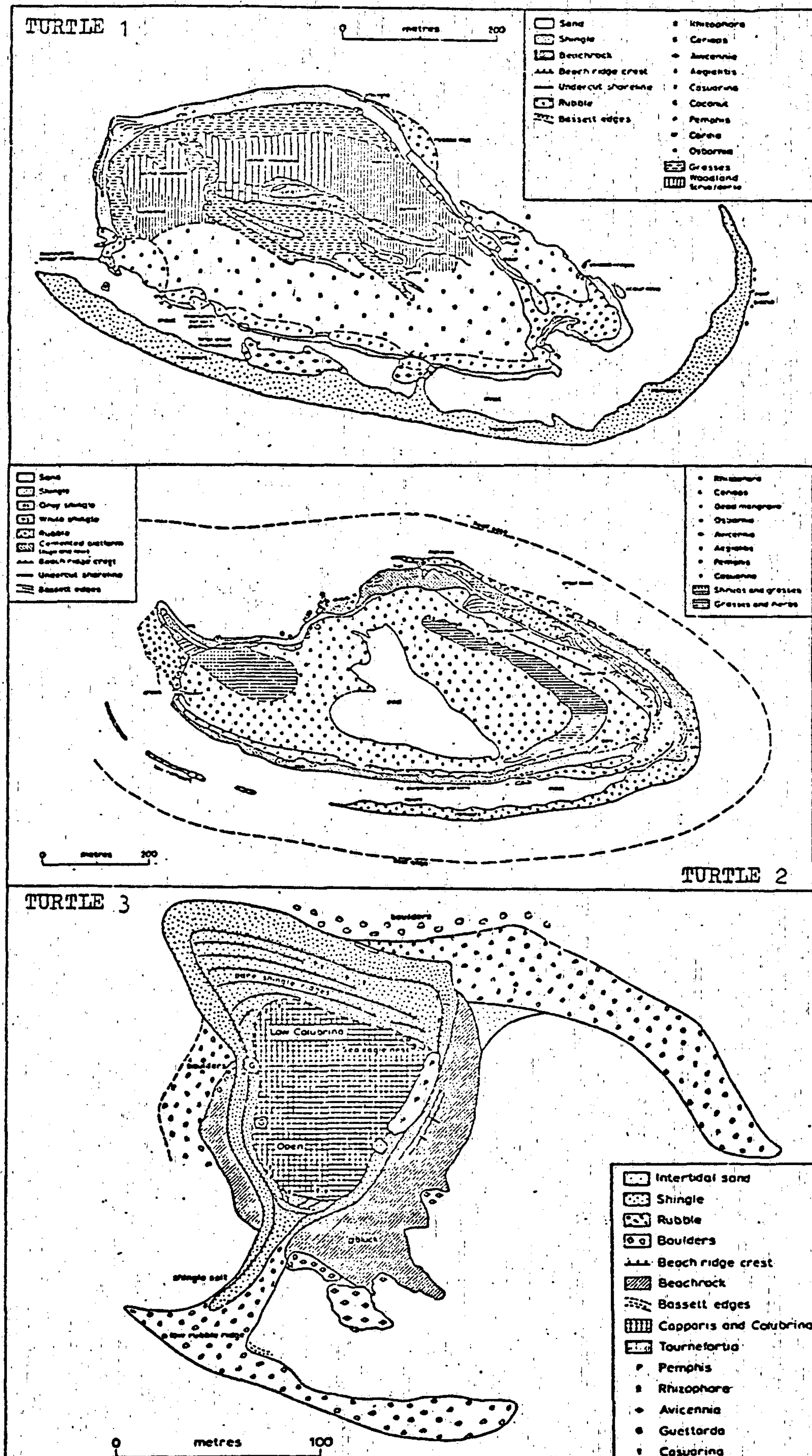


Fig. 3: TURTLE ISLANDS I, II, III
From surveys by D.R. Stoddart 1973

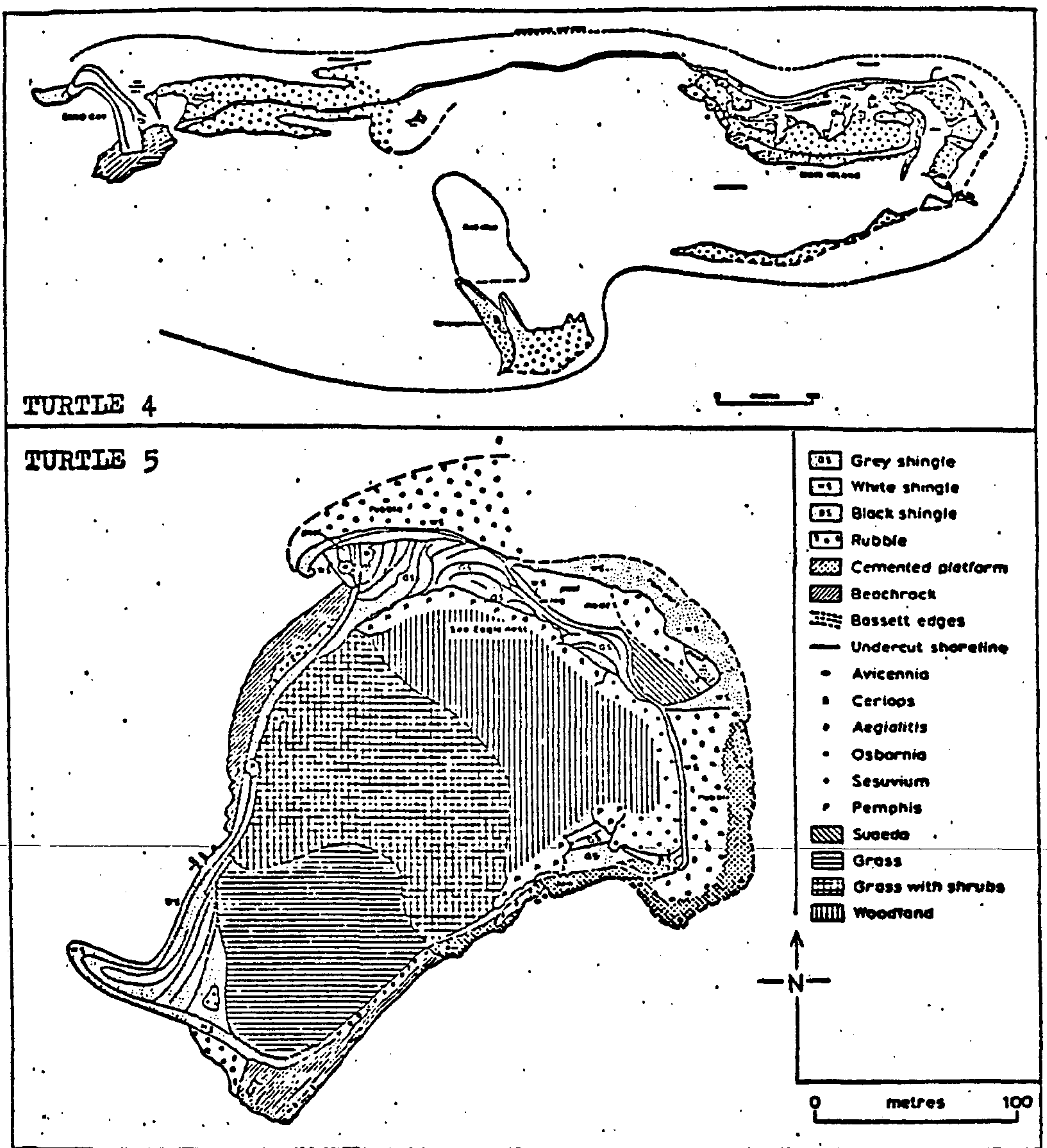


Fig. 4: TURTLE ISLANDS IV, V, VI
From surveys by D.R. Stoddart 1973

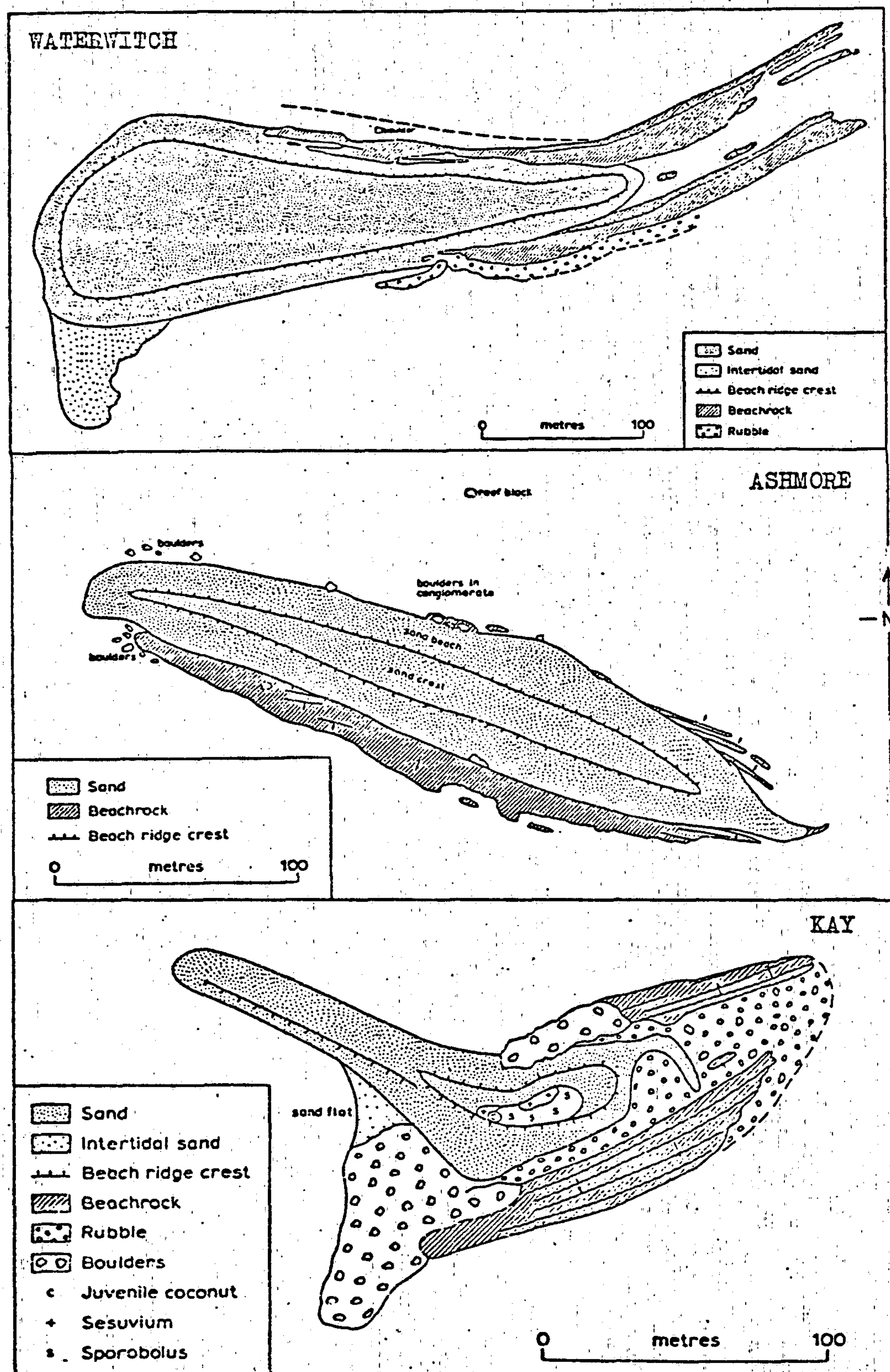


Fig. 5: Examples of small cays, northern reef
From surveys by D.R. Stoddart 1973

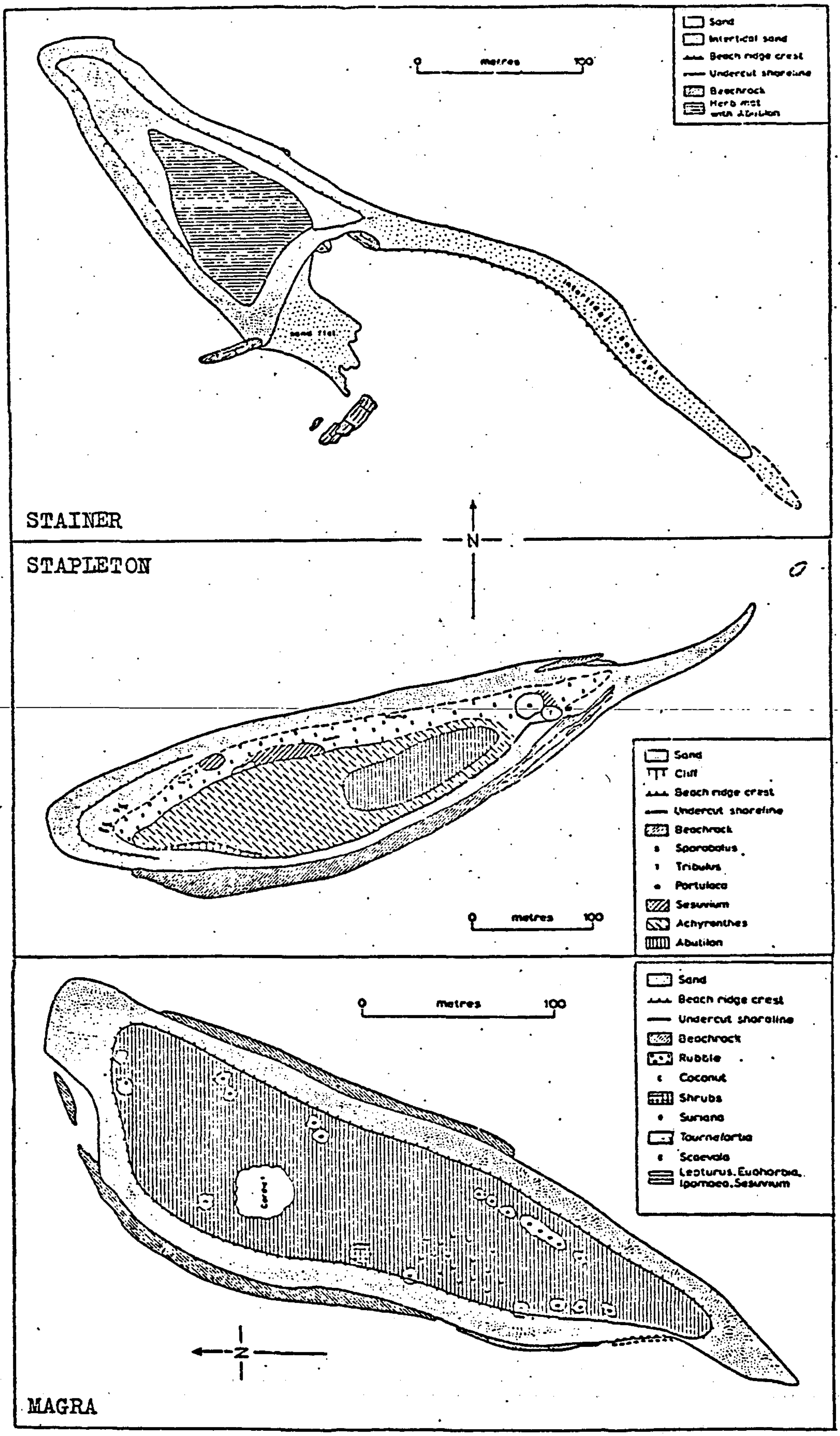
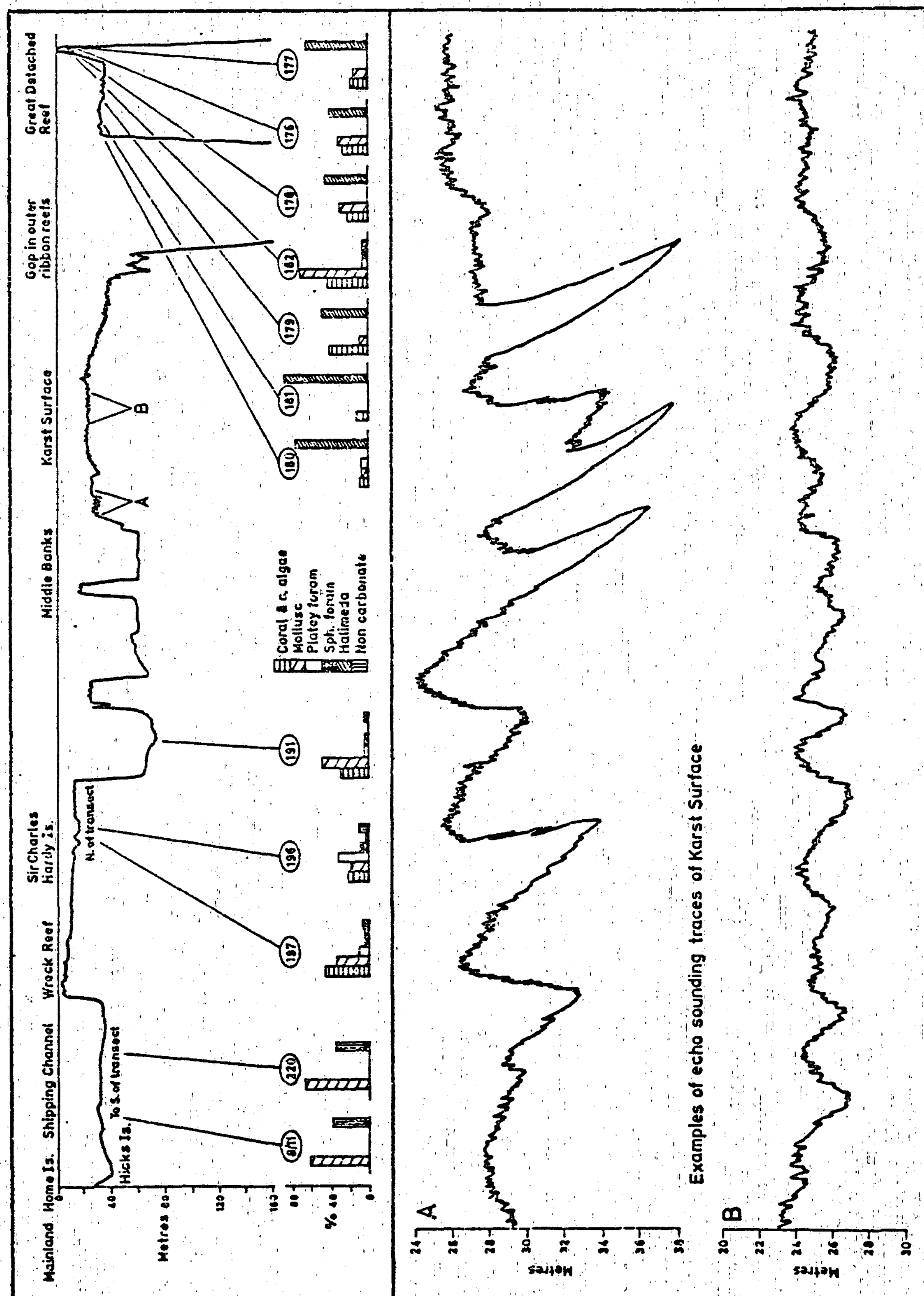


Fig. 6: Examples of larger cays, northern reef
From surveys by D.R. Stoddart 1973

Fig. 7: Transect across northern reef shelf from Cape Grenville



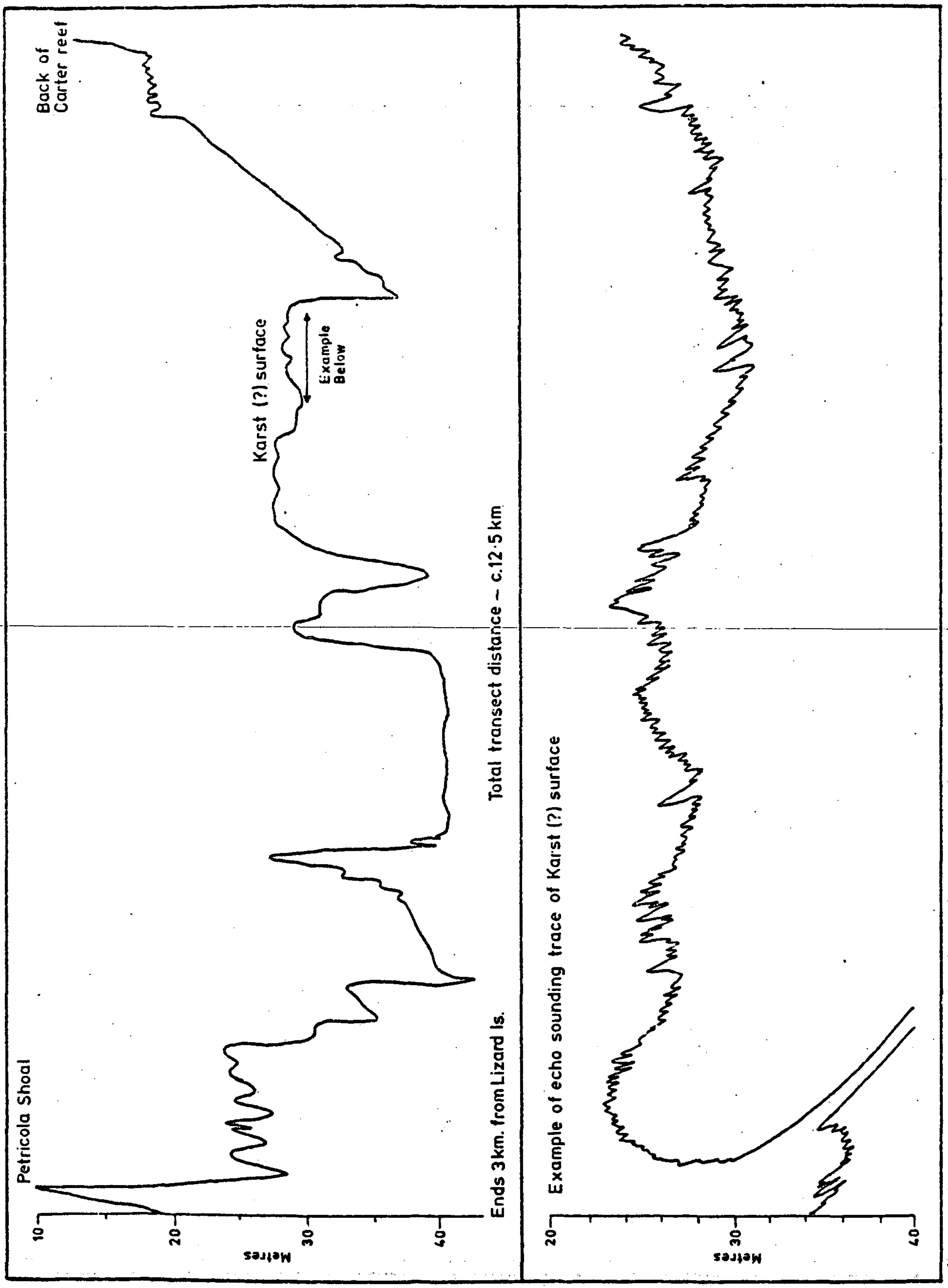


fig. 8 Echo sounding traverse, Lizard Island to Carter Reef

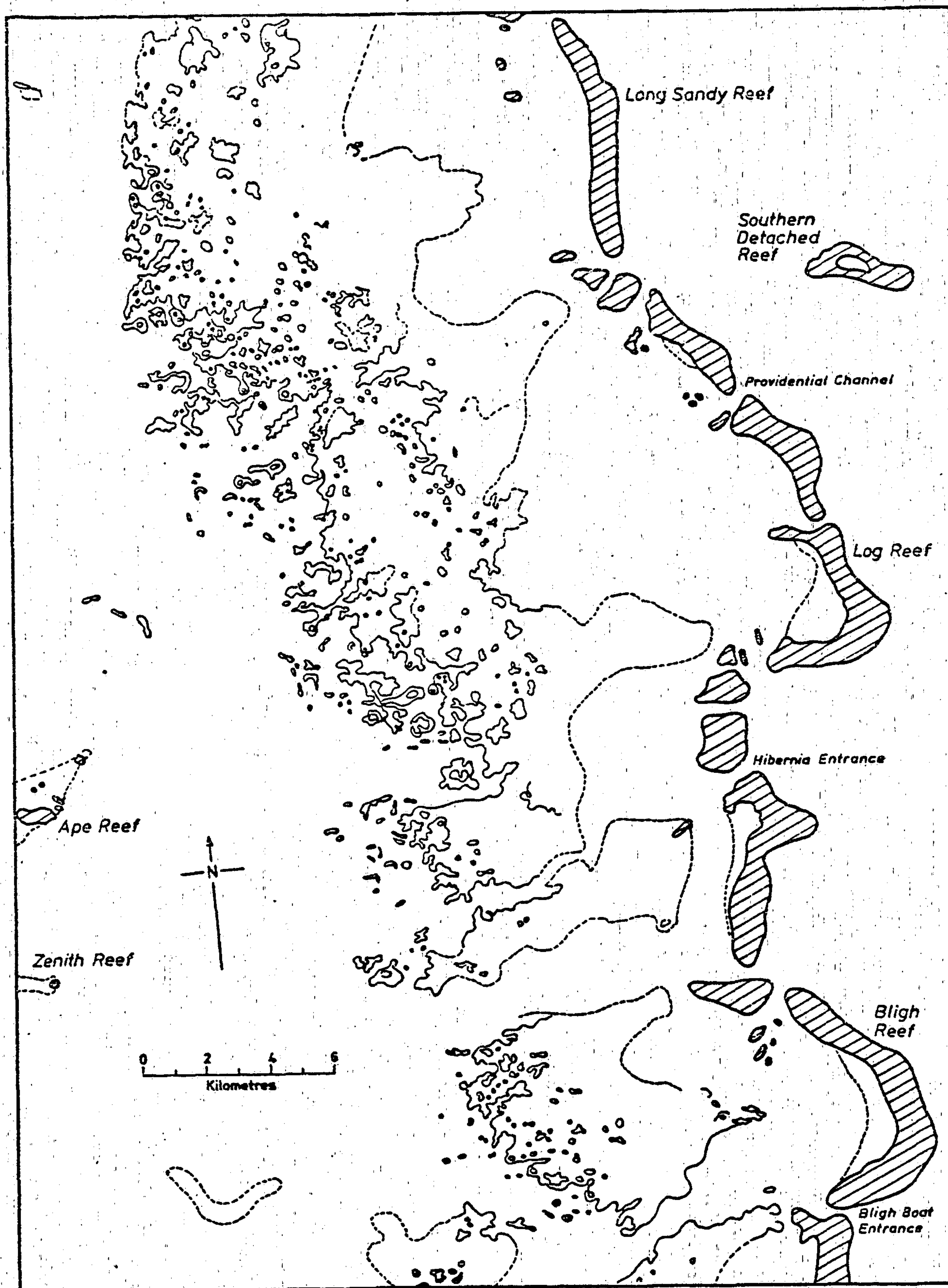


Fig. 9: Outer reef submerged karst surface at about 12°45' South

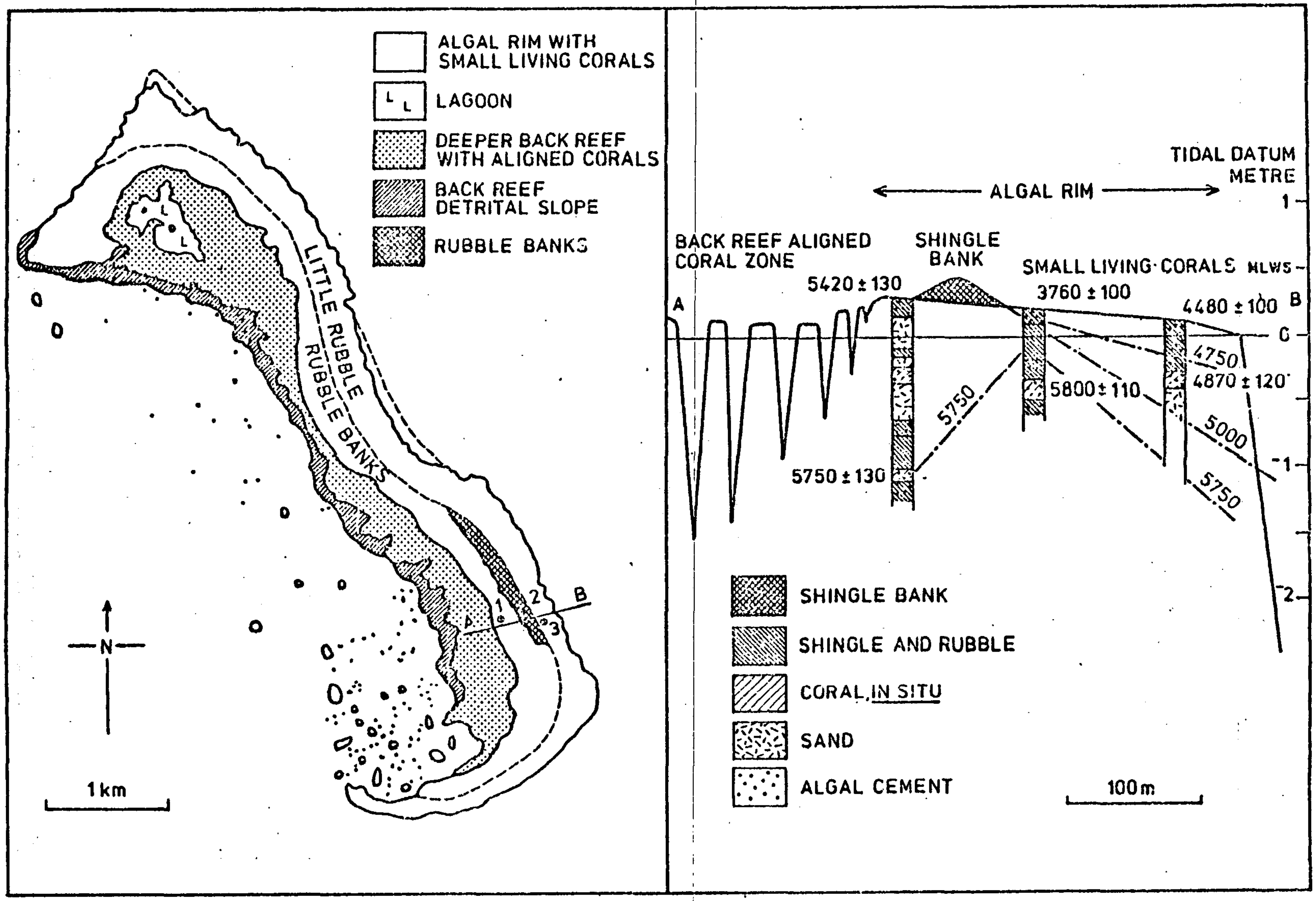


Fig. 10: Carter Reef, morphology and radiometric dates

THE MANGROVES OF THE EASTERN COAST OF CAPE YORK PENINSULA NORTH OF COOKTOWN

J.S. Bunt

Australian Institute of Marine Science

Introduction

Botanically, mangroves comprise an assemblage of trees and shrubs adapted to life within the intertidal zone. Several species are to be found growing with reasonable success well into temperate latitudes. Most, however, are restricted to the warmer subtropics and tropics where they dominate and characterize sheltered coastlines. The greatest diversity of species is encountered in South East Asia.

There has been a tendency, even until quite recently for western communities in the tropics, and sometimes their scientific advisors, to treat mangroves as wastelands best eradicated. The limitations of this viewpoint have now been recognized and, as a consequence, the urgency of developing a rigorous understanding of mangrove ecosystem character and function is fully apparent.

Along the eastern boundary of the Cape York Peninsula, the existence of the Great Barrier Reef has created shoreline conditions favourable to vigorous and extensive mangrove growth. The mangroves, in their turn, may well play an important role, either directly or indirectly, in assuring persistence of a living, active reef biota. It is clearly necessary that this possibility be investigated, and in advance of extensive land use development.

This paper outlines the limited background of information currently available on this subject and points to immediate research needs.

A Brief Perspective

The historical record indicates that Cape York Peninsula was first visited by European navigators in 1606 when Janszoon discovered the west coast. It was not until 1770 that Cook made the first landfalls along the east coast. Kennedy's ill-fated 1848 expedition initiated exploration by land. A more detailed account of these and latter developments has been given by Brass (1953) who also lists some of those involved in botanical exploration to 1944. Probably little interest was taken in the mangroves up to this time. Certainly, Brass (1953) paid them scant attention in his summary account of the Archbold Expedition. In fact, it would appear that the first extensive treatment of the eastern Australian mangrove communities is attributable to Macnae (1966) who, the title of his paper notwithstanding, concerned himself primarily with the coastline between Cairns and Townsville. Notes on the distribution of the eastern Australian mangrove species with keys to their identification suggests that Jones (1971) must have visited Cape York Peninsula although he did not make any reference to study areas or manner of data collection. Walsh (1974) took account of Macnae's observations in preparing a review of the mangroves on a global basis. Equally, Saenger, Specht, Specht and Chapman (1977) appear to have depended on the same source in considering Australasian mangal communities. It is not clear on what sources Chapman (1975) drew in an examination of mangrove phytosociology encompassing the Cape York region, save for the Macnae documentation. One is left with the conclusion that direct observation along the eastern coast of Australia north of Cooktown has been scant and superficial. Personnel from AIMS have only recently begun surveys with the object of filling this gap in knowledge.

General Background

The topographic environment

Jennings and Bird (1967) point out that very little work has been done on the geomorphology of Australian estuaries. As they explain, the subject is complex. Estuaries behind the Great Barrier Reef exhibit a greater degree of variation than elsewhere. North of Cooktown, furthermore, although not uniquely so, mangroves commonly are found in environments that are not classically estuarine. The spectrum of habitats ranges from small, sheltered bays on dry islands to the steep banks of rivers where the fresh water influence is marked and more or less constant throughout the year. In addition, one might list open beaches with or without substantial watersheds, small creeks or creek systems of intermittent flow to relatively large rivers with or without strong meanders and flood plains. Rivers may be either deltaic or non-deltaic and then not uncommonly occluded to some degree at the mouth through coastal duning. In such cases and where the topography allows, downstream mangrove areas may be quite extensive and perhaps lagoonal. In many cases, conditions near river and creek discharge points may be considered estuarine although inputs of fresh water may be strongly seasonal and intermittent and even markedly variable within single estuaries.

Some 22 mangrove centres have been indicated roughly in the accompanying map overlay. These might be grouped tentatively as follows:

1. Island sites: e.g. the Flinders Group and many others
2. Open coastal fronts: e.g. Cape Flattery to Lookout Point
3. Coastal flats with complex but not extensive creek drainage: e.g. Hunter Inlet
4. Small to large meandering rivers without extensive estuaries: e.g. Princess Charlotte Bay
5. Relatively directly flowing rivers within confined valleys: character of fresh water discharge variable: e.g. Nesbit and Pascoe Rivers
6. Rivers discharging to the sea via extensive estuaries: fresh water influence variable within the estuary and with season: e.g. Lockhart River, Jacky Jacky Creek.

Detailed study undoubtedly will lead to modification or further elaboration of this scheme. More detailed discussion seems unwarranted at this point.

Physical Oceanography at the coastal margin

To the best of my knowledge, fine scale studies on the temperature and salinity characteristics of the inshore waters have never been undertaken. Broad scale figures for temperature and salinity patterns based on CSIRO data have been presented by Pickard (1977). Particularly notable are year to year changes in salinity patterns in the northern sector along with seasonal fluctuations within single years. One might conjecture the significance of such variability for the mangrove ecosystems. The temperature regime is not unexpected.

Tidal data are published regularly only for Thursday Island and for Cairns where the maximal ranges approximate 3.5 m. Patterns along the intervening coast probably are similar although local tidal fluxes may be aberrent and of significance for mangrove development.

Hydrological data for the rivers

For the limited information on stream discharge volumes, periodicity of flow and related parameters, the reader is referred to the account of Isbell in this workshop.

Climate

July mean minimum temperatures along the coast north of Cooktown do not fall below 18 C and in January the mean minima and maxima range between 24 C and 31 C. Typically of northern Australia, rainfall is monsoonal and largely restricted to the summer season. Annual figures mostly range around 1800 mm although Princess Charlotte Bay receives a mean of only 1270 mm. As might be expected, rates of evaporation are high and approach 1500 mm annually. The entire region is subject to cyclones. Solar radiation ranges from 350-450 cal. cm^{-2}. day^{-1}. Sources of climatic data are available in standard State and Commonwealth publications, some of which have been listed by Saenger et al (1977). Unfortunately, there appears to have been no recording or observation of climate on a meso scale along northern Cape York Peninsula. Mangrove forest expression and the dependent ecology is likely to be heavily influenced by local weather patterns, especially in concert with tidal movements.

The mangrove flora

Jones (1971) has listed the following mangrove species occurring north of the Daintree River:

Acanthus ilicifolius L.
Aegialitis annulata R. Br.
Aegiceras corniculatum (L.) Blanco
Avicennia eucalyptifolia Zip. ex Miq.
Avicennia marina var. resinifera (Forst. f) Bakh.
Bruguiera cylindrica (L.) Bl.
Bruguiera exaristata Ding Hou
Bruguiera gymnorhiza (L.) Lam.
Bruguiera parviflora (Roxb.) Wight and Arn.
Camptostemon schultzii Masters
Ceriops decandra (Griff.) Ding Hou
Ceriops tagal var. australis C.T. White
Ceriops tagal var. tagal (Perr.) C.B. Rob.

Cynometra ramiflora var. bijuga (Spanoghe) Benth.
Excoecaria agallocha L.
Heritiera littoralis Ait.
Lumnitzera littorea (Jack.) Voight
Lumnitzera racemosa Willd.
Nypa fruticans Wurmb.
Osbornea octodonta F. Muell.
Rhizophora apiculata Bl.
Rhizophora mucronata Lam.
Rhizophora stylosa Griff.
Scyphiphora hydrophylacea Gaertn.
Sonneratia alba J.Sm.
Xylocarpus australasicum Ridl.
Xylocarpus granatum Koenig

In fact, B. cylindrica was noted only from the vicinity of Cape Sidmouth and Nypa fruticans only from the McIvor River. Current survey, the results of which have yet to be published, disclose B. cylindrica in the Lockhart River, the Hunter Inlet area and in Jacky Jacky Creek as well as at several points closer to the tip of Cape York. In addition to the McIvor (Morgan) River, Nypa has been found in the upper Lockhart, the Claudie and the Pascoe. Camptostemon, recorded by Jones (1971) only at Cape York, has now been found as far south as the Pascoe River although its distribution is not continuous. Sonneratia caseolaris (L.) Engl., overlooked by Jones (1971) but noted by van Steenis (1968) for locations further south, has been located in the Morgan River. Our records of species occurrences at various locations are shown in Table 1. Note that the listing includes also R. lamarckii which we encountered first on Hinchinbrook Island, the new record having been documented by Tomlinson and Womersley (1976). As the examination of botanical collections now in hand proceeds, further additions to the northern mangrove flora will be necessary.

The occurrences shown in Table 1 are not intended to be definitive in all cases. Some areas were explored extensively, others were examined only along water frontages. Species such as C. schultzii and B. exaristata can be missed sometimes under those circumstances. Also, although every effort was made to travel upstream to the mangrove limit, this was not always feasible. For other species such as C. tagal we find it impossible to distinguish the two varieties unless propagules are present and this was not always the case. On the other hand, the record for S. alba and similar key species such as H. littoralis is probably reliable and relevant in consideration of forest character.

The character of the tidal forest

The basically zoned appearance of mangrove forests is inescapable to the most casual observer and it has been usual practise to base descriptions on this characteristic. At the same time, detailed observation reveals a considerably greater complexity with substantial variation from location to location and site to site, reflecting responses to an involved spectrum of interacting edaphic factors. This is certainly true of the mangroves along the eastern coast of Cape York Peninsula. With some 800 sites and around 85 penetration transects now logged, the Inshore Productivity group at AIMS feels itself in a position to examine more critically present concepts of mangrove vegetational character in north eastern Australia. Data analysis, however, remains to be completed at the time of this workshop. Therefore, it proves most convenient to couch a description in terms of Macnae's (1966) observations for the forests between Cairns and Townsville, offering comments only where these appear essential.

Macnae recognized the following zones in gradients from land to open water:

1. The landward fringe and 1a. the landward Avicennia zone
2. Ceriops thickets
3. Bruguiera forests
4. Rhizophora forests
5. The seaward fringe

The landward fringe

Macnae recognized that the inner mangrove may lie adjacent to a variety of terrestrial vegatation types including rain forest, wet to dry eucalypt scrub, bands of sedges backed by Melaleuca spp or simply sparsely vegetated to completely bare salt flats. In such situations, he indicated, would be found the greatest diversity of mangrove species including some with marginal mangrove affinities. Whether or not this fringe expresses itself clearly in floristic terms depends on local conditions. It is most obviously distinct in dry areas e.g. near Townsville. However, there exist many circumstances in which the "fringe" species may be found well out into the mangrove proper. Equally, the character of the margin itself varies substantially from place to

TABLE I

Occurrences of mangrove species at various locations north of Cooktown

Species	Morgan R.	Normanby R.	Lockhart R.	Claudie R.	Kangaroo R.	Macmillan R.	Jacky Jacky Creek
Acanthus	x	x	x				x
Aegilitis	x	x				x	x
Aegiceras	x	x	x	x	x		x
Avicennia*	x	x	x	x	x	x	x
B. cylindrica			x		x		x
B. exaristata						x	x
B. gymnorhiza	x	x	x	x	x	x	x
B. parviflora	x	x	x	x			x
Camptostemon						x	x
C. decandra	x		x	x	x	x	x
C. t. tagal	x	x	x	x	x	x	x
C. t. australis		x					x
Cynometra	x	x	x	x	x		x
Excoecaria	x	x	x	x	x	x	x
Heritiera	x	x	x	x	x		x
L. littorea	x	x	x		x		x
L. racemosa	x						x
Nypa	x		x	x			
Osbornia	x	x			x	x	x
R. apiculata	x		x	x	x	x	x
R. mucronata	x	x	x				x
R. stylosa	x	x	x	x	x	x	x
R. lamarckii	x		x			x	x
Scyphiphora			x		x	x	x
Sonn. alba	x					x	x
X. australasicum	x	x	x	x	x	x	x
X. granatum	x	x	x	x	x	x	x
Acrostichum fern	x		x	x	x		x

* We have experienced difficulties with this genus and have not distinguished the two species listed by Jones (1971).

place and often over quite short distances. This is true for Cape York Peninsula and can lead to floristically complex situations as in the Claudie and Pascoe Rivers as well as others such as the Morgan/McIvor. It is rather beyond the interests of this meeting to explore the matter in specific detail although the fact that wide variability exists is important to note.

Macnae gave a separate listing for the landward *Avicennia* zone, however various other species demand at least as much emphasis and distinction. One should also, perhaps, draw attention to the fact, not only that floristic variability exists close to the land but also that the degree of development by individual species varies remarkably with extremes between pronounced dwarfing and veritable giantism. *H. littoralis* and *L. littorea* are good examples.

Ceriops thickets

In most characteristic form, the *Ceriops* thickets exist as densely packed extensive stands of stunted trees and saplings 1-3 m in height. Such dwarf forests are common on the central Queensland coast. Further north, however, the physical expression within this zone becomes much more variable and the presence of associated species far more common. Nonetheless, Macnae's description of the zone has general validity for the north although it deserves some elaboration.

Under favourable conditions *C. tagal tagal* commonly reaches heights of 10 m or more, especially as a vigorous understory in pure or mixed stands of *Bruguiera* and *Rhizophora* spp. In such situations, furthermore, it is most usual to encounter *C. decandra*. We have never found the latter species in pure stands. Macnae's account of *C. tagal australia* is misleading. This variety has been found invariably in the more landward parts of the *Ceriops* zone, appearing most able to withstand the severe conditions approaching and bordering highly saline bare mud flats. There, along with usually stunted *Avicennia*, it is also sometimes associated, as in parts of Jacky Jacky Creek, with *A. annulata*. It is not possible to agree with Macnae that *C. tagal australia* does not occur north of Townsville. Its distribution to Cape York is complete.

Bruguiera forests

Macnae's interpretation of the several species of *Bruguiera* taken together is inadequate and somewhat misleading. He recognized *B. exaristata* separately but considered the species simply as an occasional associate of C. tagal. While this is true to a point, there are situations where B. exaristata develops in virtually pure and extensive stands, especially in the inner mangrove. Its requirements are not yet entirely clear although its importance under appropriate conditions is unquestionable on Cape York Peninsula.

North of Cooktown, clear zonation of B. parviflora, as described by Macnae, is less apparent. Certainly the trees not uncommonly develop to heights of 30 m or more. However, they tend to lose their identity as pure stands within the Rhizophora zone. This is widely apparent in Jacky Jacky Creek.

It is not common to find pure stands of B. gymnorhiza except in rather localized pockets. The species more generally occurs as a subdominant or as isolated individuals and then under a wide range of conditions. It appears to develop most vigorously in locations of fresh water influence although this factor alone seems not to be determinant for success. Very large B. gymnorhiza are also common well within the Rhizophora zone.

Rhizophora forests

These are ubiquitous on the north eastern coast and one would agree with Macnae that R. stylosa probably is the most abundant species. His remarks for R. mucronata, however, are not acceptable. This species is an unmistakable element of the Rhizophora forests at least northward from Hinchinbrook Island although it is not particularly common and tends to be favoured by sheltered upstream situations. R. lamarckii, a previously overlooked species, by distinction, although capable of developing with considerable success close to full sea water, is most extensive in somewhat stunted form in the inner part of the Rhizophora zone commonly along with C. tagal tagal or in pure stands. R. apiculata is frequently associated with R. stylosa at the mangrove front although it is also to be found as pure stands, generally, however, appearing to be rather less tolerant of environmental extremes than R. stylosa and R. lamarckii over their respective ranges. The conditions which favour each of the four Rhizophoras remain to be fully defined. All four are present in the northern zone, frequently developed into massive forests. The stands in the Lockhart River and in Jacky Jacky Creek rival any to be seen in the high rainfall areas between Innisfail and Tully.

The seaward fringe

Where Rhizophora forests do not themselves form a direct front to the sea or to open water in estuaries, it is common to find either Avicennia or Sonneratia alba as narrow leading fringes. The absences of either species are as perplexing as their presence. Equally, it is not clear, at least to this writer, what conditions favour each species to the exclusion of the other. Where it occurs, S. alba is most common closest to the direct influence of the sea. Avicennia develops in rather similar circumstances although its penetration of estuarine water fronts is deeper and it is found not infrequently growing with obvious success on leading river meanders well upstream e.g. in the Normanby River. Of the two species, Avicennia is probably the more abundant along the north-eastern coast although both must be considered of significant importance as frontal colonizers. Aegiceras is a common associate, especially of S. alba. Isolated very large individuals of both Avicennia and S. alba sometimes persist within the Rhizophora zone.

The shortcomings of the type of zonal classification followed by Macnae become most apparent in consideration of the mangrove forests in complex estuaries such as Jacky Jacky Creek or of long tidal rivers such as the Normanby where it is not feasible to view the tidal forest as a simple topographic gradient between high and low water. Under these circumstances, particularly, species of the so-called landward fringe complicate analysis within that frame and lead one to seek other, more generally applicable approaches. These difficulties apply as much along the high rainfall coast between the Daintree River and Tully as further north. With the exception of several added species and perhaps a wider diversity of expression, the northern mangrove forests, therefore, are compatible in general character with those immediately to the south.

In the regional sense, it would be reasonable to view the mangroves of eastern Australia as vegetational outliers of those in the Gulf of Papua, with climatic and other conditions tending to become more and more marginal and restrictive with increasing latitude, the harshness of low rainfall and high evaporation rates gradually leading to the predominance of tidal salt flats and marshes.

The mangrove faunal assemblage

In his overview, Macnae devoted considerable attention to a description of the mangrove fauna, notably those elements associated directly with the substratum. Many of his observations presumably could be applied to the far northern coast. In this connection, Saenger et al (1977) have prepared a useful check list of the known species of many of the animal groups inhabiting the mangrove environment. It is not likely that much of the collecting has been from the sector from Cooktown north. Tentatively, however, one might expect to find at least the following:

molluscs	59 species
crustaceans	42 species
annelids	8 species
fish	14 species
birds	186 species (including a number of "visitors")

With the exception of the birds, it is virtually certain that these groups have been inadequately explored and that others have been neglected altogether. Note further that Saenger et al (1977) have not included any mention of the highly diverse arthropod fauna and do not include the reptile crocodiles, snakes and lizards or the bats and native rats among the mammals.

Except in the broadest terms, the biology, ecology and character of the inter-relationships of this complex assemblage are little understood. The importance of this neglect scarcely requires emphasis.

Environmental Significance of the Mangroves

Productivity and dependent food webs

There is very little information, worldwide, on the productivity of tidal forests. Most attention has been paid to the simple mangrove ecosystems of Florida and Puerto Rico from which Lugo and Snedaker (1974) report values for net primary productivity based on short term gas exchange measurements ranging from 1.3 - 7.5 g $C.m^{-2}.day^{-1}$ which are substantial. In Puerto Rico, Golley, Odum and Wilson (1962) reported leaf fall as 1.3 $g.m^{-2}.day^{-1}$, a level exceeded slightly in South Florida at 1.4 - 1.7 $g.m^{-2}.day^{-1}$ (Snedaker and Lugo, 1973). Other figures quoted by the same authors for Panama, Puerto Rico and India ranged from 1.25 - 2.5 $g.m^{-2}.day^{-1}$.

Data on litter fall at a wide spectrum of sites on Hinchinbrook Island followed over several years reveal levels within the range 1.0 - 7.7 $g.m^{-2}.day^{-1}$, encompassing and exceeding the above rates. In general, the Queensland rates are up to twice as high as those recorded in the Americas and place mangroves among the most productive of natural plant communities. We have no information at present for the production of long-lived woody tissues or roots. However, Snedaker and Lugo (1973) found wood production in Florida to exceed litter production by a factor of two and this may well be the case locally.

The data for Hinchinbrook Island provide a good guide to the levels of production to be expected further north. However, with the variability in character of the mangrove forests throughout the region, it would be difficult to assign a reliable datum on which to assess likely regional production. An added difficulty is that precise figures on the areal extent of the far northern or of any other Australian tidal forests are not available, although reasonable statistics could be derived from existing aerial photo reconnaisance.

It was probably Odum and Heald (1972) who most effectively began to bring about an understanding of the significance of detritus in mangrove food webs. Essentially, the principal resource flow was viewed as a process involving conversion of dead macroscopic plant parts initially by amphipods and subsequently by microbial action into a nitrogen-enriched finely particulate food substrate then utilizable through a succession of higher trophic level consumers. In essence, this set of mechanisms operates in the mangroves of Queensland. However, the magnitude of the tides and the regular efficiency of tidal flushing appears to present conditions in which the sequence and locale of events in litter conversion may be different to those in Florida. Equally, the question arises to what extent the aquatic mangrove fauna depends on above ground sources of plant food materials and to what extent on the products of root growth and overturn. Much of the protein-depleted above ground litter is exported from the tidal forests and its subsequent fate remains to be established. Whether and to what extent the resource is utilized by any of the adjacent reef biota is not known. In effect, the mechanisms of partitioning of the products of photosynthesis in the northern Australian tidal forests is very much an open question and it would be unwise to assume too readily any close analogy with events documented in the Americas.

Coastal stability

Extensive claims have been made for mangroves as land-makers, a conclusion based on their capacity to colonize bare mud within appropriate intertidal limits. However, their capacity to hold soft mud against fluvial action is limited as evidenced by an examination of any meandering sea water channel where vegetational regression and advance is at once apparent. Rather, it would appear more valid, as Walsh (1974) has done, to accept the mangrove forest as at once opportunistic and susceptible, utilizing and binding the substratum in fine balance with a temporally and topographically dynamic environment. Within these limits, it seems reasonable to consider the mangroves as buffering stabilizers. In their absence, the disposition of vast quantities of coastal sediment would become a matter for serious concern. It is questionable whether the mangroves could greatly minimize new sediment losses from the land attributable to ill-managed development in that sphere, although one might envisage their use through controlled culture to modify and control such losses.

One's best judgement leads to the view that natural environmental conditions in the far north place the mangrove ecosystems in a state of delicate balance and that the entire system of coast and offshore reefs might be disastrously and perhaps irreversibly damaged by a change in the state of any single component. Whether or not such a fear is justified is not at present susceptible to analysis for want of an adequate data base.

Research Needs

From this short account, it is patent that the mangroves north of Cooktown are a significant element in the system comprising the Great Barrier Reef, the coast and intervening waters as well as the land mass of Cape York Peninsula. The tidal forests, it is safe to predict, represent an important primary marine food resource whose partitioning and fate are poorly understood notwithstanding clearly recognized fisheries activity. Further, it is reasonable to conjecture that the trees of the mangrove exert an influence on coastal stability, the extent of which has not been measured. Biological interactions between reef and inshore animal communities are likely and these interactions may be expected to extend to the biota of open coastal waters, largely but not necessarily totally in trophic terms.

In my view, future research effort should be structured with a regional perspective and with the long term objective of providing the depth of understanding for enlightened total system management and protection. Many elements are involved and these span a range of disciplines. In this sense, basic scientific enquiry is at once appropriate, critical and directly applicable to human needs.

Any comprehensive program of enquiry should encompass the following:

1. Physical and geological e.g. physical oceanography of the near shore combined with river hydrology and sediment hydrodynamics.

   Geomorphological analysis of the coastline environment in dynamic terms.

   Sedimentological and palaeoecological analysis of existing substrata.

   Mesoclimatic characterization of representative mangrove environments.

2. Biological: especially a full determination of little known elements of the fauna with emphasis on establishing relative abundances, distributions, interdependencies and environmental tolerances.

3. Ecosystem studies with an emphasis on production ecology and questions of stability characteristics and the basis of mangrove vegetational expression. These sorts of enquiry should be aimed at predictive analysis of system and subsystem behaviour relevant to management.

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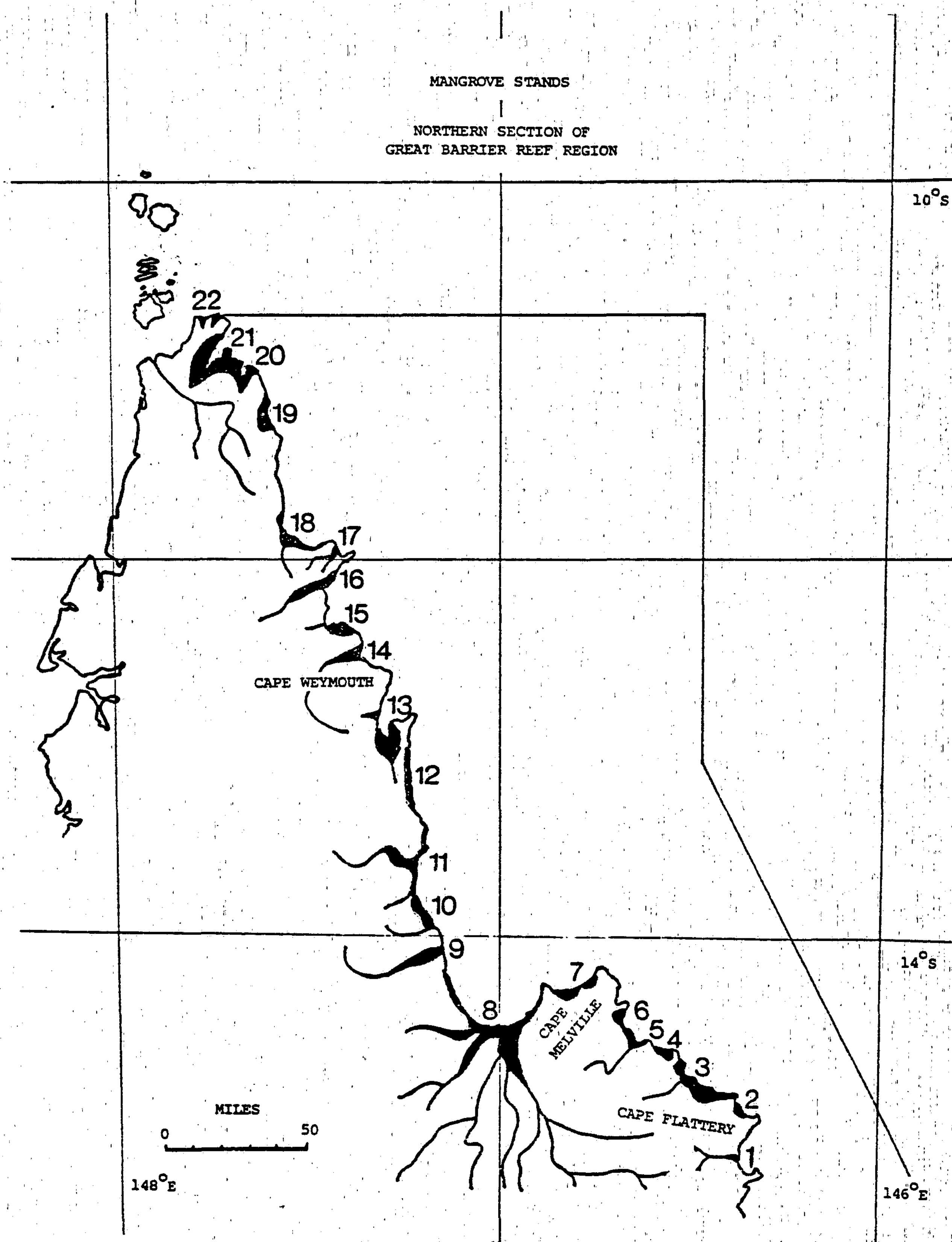
Mangrove centres, Cape York Peninsula north of Cape Flattery.

1. Morgan, McIvor River.
2. Cape Flattery to Lookout Point.
3. Mt Gargalee tidal flats.
4. Dead Dog Creek.
5. Howick Creek.
6. Saltwater Creek to Barrow Pt.
7. Bathurst Bay.
8. Princess Charltte Bay. N. Kennedy, Normanby and other rivers.
9. Port Stewart.
10. Breakfast and Massy Creeks and Rocky River.
11. Nesbit River.
12. Friendly pt to Round Pt.
13. Lloyd Bay. Lockart and Claudie Rivers.
14. Pascoe River.
15. Hunter Inlet.
16. Olive River.
17. Macmillan River.
18. Shelburne Bay.
19. Orford Bay.
20. Escape River.
21. Jacky Jacky Creek.
22. Barnia Creek and Mew River.


MANGROVE STANDS
NORTHERN SECTION OF
GREAT BARRIER REEF REGION
10°S
14°S
148°E
146°E
CAPE WEYMOUTH
CAPE MELVILLE
CAPE FLATTERY
MILES
0
50
1
2
3
4
5
6
7
8
9
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SEDIMENTS ON PLATFORM REEFS OF THE INNER SHELF, NORTHERN GREAT BARRIER REEF REGION

by P.G. Flood

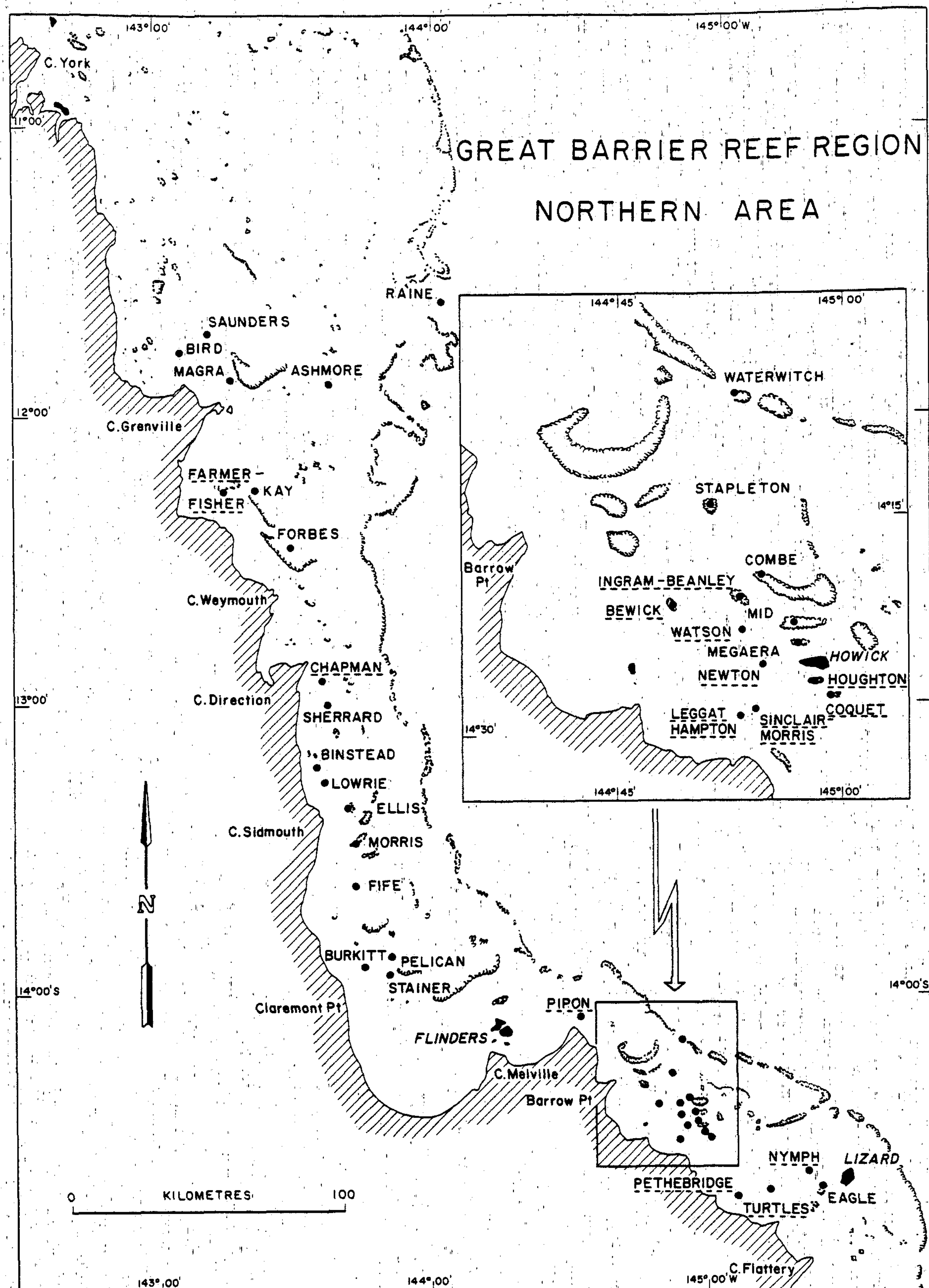
Geology Department, University of Queensland

Abstract

Reefal sediments of the northern Great Barrier Reef Region are predominantly bioclastic in origin having been produced by mechanical breakdown of skeletons of a variety of organisms. Variations in the grain-type composition result from differences in the percentage contribution made by the dominant organic groups, namely; coral, coralline algae, molluscs, Halimeda, and Foraminifera. These organisms display predictable patterns of associations depending upon the stage of reef evolution. The grain-size composition displays a consistent association with individual depositional environments (lagoon, reef flat, cay, rampart, mangrove) and is directly related to the competency of the transportation agent to remove skeletal detritus from growth areas to depositional areas. The size preferences shown by the skeletal elements of sediment-producing organisms only slightly modify this grain size/depositional environment relationship. This knowledge should prove useful when predicting the pattern of sediment composition in time as well as in space.

INTRODUCTION

In 1973 the Royal Society of London and Universities of Queensland conducted an expedition of six months duration within the area indicated by the Great Barrier Reef Marine Park Authority as a potential marine park for the northern Great Barrier Reef Region. Results of this expedition are to be published shortly in the Philosophical Transactions (series A and B) of the Royal Society of London. The islands (excluding the continent islands) which are indicated on Text-fig. 1, have been mapped at scales of 1:500 to 1:2500 by D.R. Stoddart (University of Cambridge). Sediments have been collected from islands to the south and north of Cape Melville by R.F. McLean (formerly Australian National University) and D. Hopley (James Cook University) respectively. Reef-top sediments have been collected in the same areas by the author collaborating with T.P. Scoffin (University of Edinburgh) and by D. Hopley respectively. Sedimentological studies (see Flood and Scoffin 1978, McLean and Stoddart 1978, and Hopley unpubl.) have concentrated on sediment attributes such as texture, composition, and distribution patterns of sediment types. Simultaneous observations of physical processes and sediment response have not been undertaken.



Text-fig. 1. Showing those reefs and islands examined during the 1973 Expedition. Low wooded islands are underlined. Sediments have been collected from the reefs and/or islands indicated. Continential islands are italicized.

This paper provides a summary account of the unconsolidated sedimentary deposits which occur on the platform reefs of the inner shelf. Wall or ribbon reefs of the outer shelf are not discussed because little is known about their sediments. Flood and Orme's (1977) sedimentation model which incorporates both process-response and source-pathway-sink concepts, relating sediments, dynamic processes, dispersal agents, and depositional environments is applicable to the platform reefs of the region. Reefs at various stages of morphological evolution display predictable associations of skeletal components in their sediments, whereas, grain-size composition of the sediments is mainly related to the energy of the prevailing hydraulic regime. Biota of the reef top are controlled by the existing sediment, but in turn they directly influence future products of sedimentation. Therefore sediments and sedimentation may be viewed both temporally and spatially. This has implications for planning proposals relating to marine parks.

ACKNOWLEDGEMENTS

Research within the northern Great Barrier Reef Region was conducted during the Royal Society and Universities of Queensland Expedition. The Australian Research Grants Committee also provided financial support towards this research. The author gratefully acknowledges the use of results provided by the members of the 1973 Expedition.

REEF MORPHOLOGY AND VARIETIES OF PLATFORM REEFS

REEF MORPHOLOGY

Generalized descriptions of the morphological zonation of platform reefs within the northern Great Barrier Reef Region have been provided by Steers (1929, 1930), Stephenson *et al.* (1931), Fairbridge (1950, 1967), Maxwell (1968), and Scoffin *et al.* (1978). Reefs consistently display three major topographic zones; reef slope, reef rim, and reef flat. In addition, other features such as cays, lagoons, ramparts, mangrove vegetation, surficial sediment deposits, etc. are developed to varying degrees. Traversing the reef from windward to leeward the following zones are encountered:

a) The windward reef slope is the inclined outer surface of the reef mass extending from the outer edge of the coralline algae encrustation downwards to the relatively flat continential shelf. It may be as little as 10 m in the case of the nearshore reefs, and averages 20-25 m for the mid-shelf reefs. Slopes of 15^{o} are common and are interrupted by terraces at 10-15 and 2-5 m (see Scoffin *et al.* 1978). Spur-and-grooves are only partially developed. Several species of the staghorn coral *Acropora* predominate on the upper surface of the reef slope.

b) The reef rim which may surround each reef mass, is exposed intertidally, and is encrusted by coralline algae forming a pavement. The topographic expression is less marked than on reefs of the southern region because surficial sediment deposits are usually higher than the rim. Coral shingle and coral boulders cover the reef rim as ramparts, spits, or boulder tracts. Soft brown algae with epiphytic Foraminifera, soft coral (*Polythoa*), and low profile corals such as *Favites* and *Montipora* are common.

c) The reef flat extends inward from the reef rim. It displays a concentric pattern of sediment type which produces an edaphic control on the marine phanerogams (notably *Thalassia*) and algae such as *Halimeda*, *Sargassum*, *Caulerpa*, *Laurencia*, *Padina*, *Turbinaria*, and *Chlorodesmis* (see Cribb *in* Flood and Scoffin 1978). Certain species display a preference for either hard or soft substrates and these occur in approximately concentric bands near to the reef rim. Epiphytic Foraminifera such as *Marginopora*, *Baculogypsina*, and *Calcarina* occur in abundance and live attached to the soft algae. Mangroves (especially *Rhizophora* and *Avicennia*) occur on the reef flats of the low wooded island variety.

d) Lagoons may occupy the central upper surface on the reef. Their depth below low water datum is usually less than 1 m (e.g. Stapleton Reef and Pipon Reef). A subtidal sediment wedge, representing the spill-over of swash-zone material produced by waves breaking on the reef rim, progrades into the lagoon.

e) The cays (or islands) are supratidal accumulations of either sand or gravel (shingle) or a combination of both. Several types of islands have been recognized by Steers (1929), Spender (1930), Fairbridge (1950), and Stoddart and Steers (1977). All cays except the shingle type are located towards the leeward margin of the reef.

f) The leeward reef slope extends for about half a kilometre from the outer edge of the reef rim. Massive coral (Porites), forming large heads up to several metres in diameter, is common in water depths to about 10 m. Bioclastic carbonate sand which has been washed from the reef flat produces a sandy sediment cone to the lee of the reef. During cyclonic conditions coral heads are cast up onto the reef surface to form a boulder tract.

VARIETIES OF PLATFORM REEFS

Fairbridge (1950) and Maxwell (1968) have provided diagramatic schemes illustrating the morphological development of the varieties of platform reefs present within the Great Barrier Reef Province. Within the inner shelf of the northern Great Barrier Reef region the following varieties occur; lagoonal platform, platform, and low wooded island (with or without lagoons). Steers' (1929) low wooded island variety displays several stages of development commencing with the initial mangrove colonization on the outer shingle deposits, through to complete mangrove cover of the reef flat including the enveloping of the cay.

The author presents a scheme which incorporates tectonic, isostatic, eustatic, and biological growth as variables explaining the serial changes within the varieties of platform reefs (see Text-fig. 2). The scheme is hypothetical and needs to be tested by subsurface drilling. It does, however, explain reef morphology in a temporal and spatial context as follows.

a) Holocene reef morphology is initially controlled by the shape of the pre-existing reef which was exposed to subaerial weathering by the lowering of the sea during the Pleistocene glaciations (see Orme and Flood 1977). The disolving action of meteoric water may differentially lower any area on the carbonate platform and subsequent reef growth

Text-fig. 2. The hypothetical scheme which incorporates tectonic, isostatic, eustatic, and biological growth as variables in explaining the varieties of platform reefs. The following details are inherent in the scheme.

a) The topographic expression of the surface of the pre-Holocene carbonate platform will determine the initial reef variety which developed during the Holocene transgression. As sea level rises slightly above the platform, a planar surface will give rise to a platform variety; a surface with a shallow centrally located depression will produce a lagoonal platform variety. Organic growth may not keep pace with the rising sea level. Therefore, coral growth on the higher platforms reaches the sea level first.

b) If the rate of vertical coral growth and associated reef development equals the rate of subsidence or eustatic sea level rise, the reef variety will persist.

c) If the rate of vertical coral growth and associated reef development is less than the rate of subsidence or eustatic sea level rise, then reef varieties which are at mean low water neap tide level will follow the reverse succession.

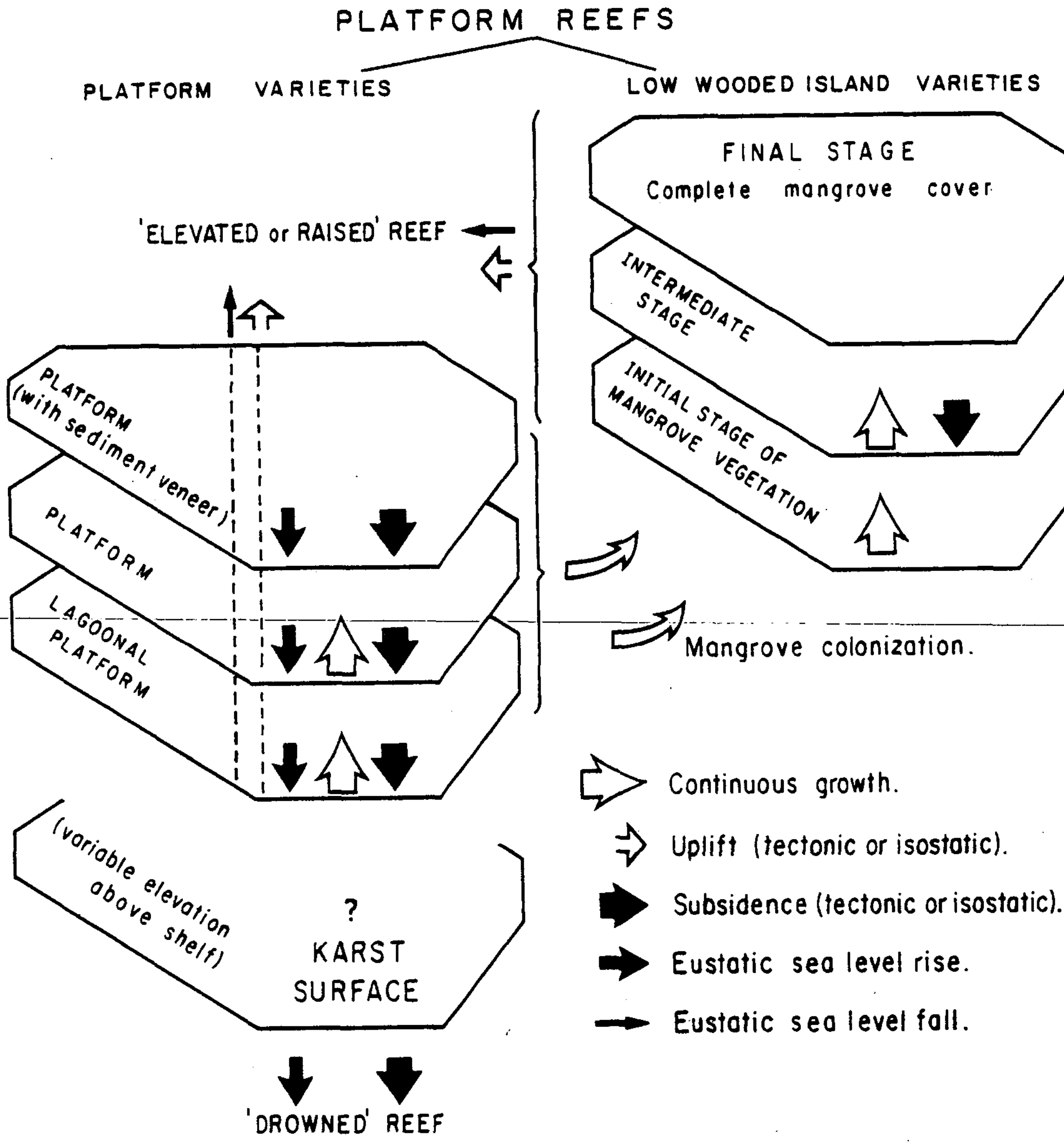
d) If the rate of vertical coral growth and associated reef development is greater than the rate of eustatic sea level rise or tectonic subsidence, then any reef which is at mean low water neap tide level will follow the indicated succession commencing at the stage of development existing at that time.

e) Once the coral growth has reached the level of mean low water neap tides, and providing stable sea level is maintained, then the reef type will develop through the indicated succession of varieties commencing at the stage of development which existed once it had reached this level of mean low water neap tide.

f) Rapid subsidence or eustatic sea level rise will cause the reef to be drowned.

g) If the reef is already at the level of mean low water neaps, either eustatic sea level fall or tectonic/isostatic uplift sill produce an "elevated or raised" reef.

h) With stable or slightly lowered sea level further development on the platform will result in the reef top being veneered by skeletal carbonate sand and gravel. Shingle spits or ramparts may provide a suitable environment for colonization by mangrove vegetation. Given sufficient time this vegetation will extend across the reef top encircling the leeward sand cay producing varieties of low wooded islands.


PLATFORM REEFS
PLATFORM VARIETIES
LOW WOODED ISLAND VARIETIES
FINAL STAGE
Complete mangrove cover
'ELEVATED or RAISED' REEF
INTERMEDIATE STAGE
INITIAL STAGE OF MANGROVE VEGETATION
PLATFORM (with sediment veneer)
PLATFORM
LAGOONAL PLATFORM
Mangrove colonization.
Continuous growth.
Uplift (tectonic or isostatic).
Subsidence (tectonic or isostatic).
Eustatic sea level rise.
Eustatic sea level fall.
(variable elevation above shelf)
?
KARST SURFACE
'DROWNED' REEF

during the Holocene transgression colonizes the topographic highs on the platforms (antecedent karst theory of Purdy 1974).

b) The stage of development of an individual reef is also related to the height of the carbonate platform (i.e. the pre-existing reef) with respect to sea level at the commencement of the Holocene transgression. Reef growth on the higher platforms will reach modern sea level before that on the lower platforms (see Davies 1975, Orme and Flood 1977).

c) When reef growth reaches the level of mean low water springs, only then does it interact with the prevailing hydraulic regime as envisaged by Fairbridge (1950) and Maxwell (1968). Subsequent modification is related to; lateral growth which is primarily to leeward (see Scoffin *et al*. 1978, Davies 1977), sediment infilling of the lagoons, replacement of the framebuilding organic groups including coral and coralline algae by the epithytic and benthic organic types such as soft algae, Foraminifera, *Halimeda*, and molluscs.

d) Shingle spits or ramparts are formed on the windward rim of the near-shore reefs (see Scoffin *et al*. 1978). Subsequently their less exposed parts are colonized by mangrove vegetation. Pioneer growth occurs on the loose ramparts but later extends onto the sheltered parts of the reef flat and eventually surrounds the leeward sand cay. The "low wooded island" variety represents surficial modifications of either the platform or lagoonal platform varieties (see Spender 1930).

SEDIMENTARY DEPOSITS

Traversing the reef from the windward side to the leeward side the following sedimentary deposits may be encountered.

a) Windward reef-slope deposits which consist predominantly of detritus of branching corals and minor proportions of dish-shaped corals and foraminiferans.*1 The former are deposited *in situ* whereas the latter are washed from the reef top on the ebbing tide. The composition of this talus slope accumulation is similar to that occurring in the shingle ramparts. These deposits rarely extend greater than 0.5 km from the reef.

b) Shingle islands, ramparts and spits on the windward reef rim consist of *Acropora* branches which are fragmented and deposited during cyclone activity. Subsequently the moulding action of waves produces large asymmetrical ridges (or called ramparts if they are continuous)

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*1 Refers to skeletal particles of Foraminifera.

50 to 100 m in wavelength and 0.5 to 3 m in amplitude. The outer slope of the shingle deposit is usually less than 5^{o} and the inner slope is as great as 60^{o}. The inner margin of the ridge is often cuspate shaped with tongues of steeply banked shingle projecting onto the reef flat surface. Commonly several sets of ramparts occur on an individual reef and seawater may be ponded between adjacent sets forming moats at low tide. The shingle deposit may be emergent at high water spring tides and then it is referred to as a shingle island. These are all located on the windward side of the "low wooded island" reef. Mangroves initially colonize the sheltered leeside of the shingle. Sediment consists predominantly of branching coral sticks (mainly Acropora). These rod-shaped clasts are moderately to well sorted. The obvious source is the coral thickets which grow in the windward reef slope. Reworked fragments of the cemented rampart-rock are a minor constituent. Other branching coral forms including Porites, Seriatopora and Pocillopora, and rounded corals especially Faviidae also occur. The stabilized shingle deposits are a dull grey whereas corals of the active beach shingle are brillant white. This is related to post-depositional modification by algae.

c) Reef-flat sediments are normally only a few centimetres thick. Typically there is a concentric variation in the sediment thickness across the reef flats and it is this variability which produces the marked concentric zones of algal vegetaion. Thalassis grass and some algal species only live where the sediment thickness is greater than 5 cm. Compositionally the sediments consist of grains of coral, benthic Foraminifera, Halimeda, molluscs, and green and red calcareous algae. The coral sand is supplied by the mechanical and biological breakdown of corals growing mainly on the windward reef slope. Benthic Foraminifera grow attached to the soft plants which frequent the reef flat. Marginopora is particularly abundant on Thalassia, whereas, Baculogypsina and Calcarina occur in vast quantities attached to the short fronds of Laurencia alga. These reef flat sediments are sand-sized, moderately to poorly sorted. The grains can be whole or broken, angular to subrounded, and occasionally are polished.

d) Mangrove sediments occur where reef top surface is vegetated by mangroves. The sand and silt sized sediments moving across the reef flat may be trapped and immobilized within the mangrove area. Organic mud, produced by the decay of the mangrove vegetation, extends only a short distance away from the leeward fringe of the living trees. Parts of this muddy environment appear to be a favourable locality for Thalassia, molluscs, and Halimeda. Considerable in situ additions of biogenic skeletal carbonate may be found within the mud. On several reefs it can be observed that mangrove sediments and vegetation are prograding across the reef surface towards the leeward sand cay. In some instances the mangroves have completely surrounded a pre-existing cay.

e) Blanket sands of the reef flat occur to leeward where the sediment has accumulated on areas of the reef flat. The deposits are sufficiently thick (>5 cm) as to be mobile. Asymmetrical sand ripples form under the action of bed-load transportation associated with the wave action. These sediments differ from the normal reef flat sediments by being well sorted, and the grains are often well rounded. Experiments using dyed sand on Ingram-Beanley Reef showed that the net movement over several days under the prevailing oceanographic influence was to leeward.

f) Sand cays develop towards the leeward reef flat where opposing sets of refracted waves converge. The intertidal sand body may become a morphologically coherent accumulation emergent at high water spring tides. Several distinct cay type may be recognized; sand cays, sand/shingle cays, and composite cays. The sand cays may be either unvegetated, with or without beachrock, or vegetated with beachrock. The former types are located on the large reefs possessing shallow lagoons. The latter are located on lagoonless reefs. In spite of the range of variability of size, shape, vegetation developments, etc., these sand cays display a homogeneity of sediment composition consisting of skeletal detritus derived from the reef flat. The percentage contribution of the various skeletal types differs on different islands suggesting that each reef possesses a unique biota (as is the case with the reef flat sediments). Also the component composition of the island sediments has changed throughout the history of their development. This presumably reflects the changing nature of the reef biota related to change in the physiographic/depositional environment.

g) Boulder tracts of the leeward reef rim occur as isolated boulders or may be so numerous that they form a continuous deposit. Each boulder is normally one coral colony (usually Porites) which formerly grew on the leeward reef slope in relatively shallow water

(<10 m). The boulder-sized coral heads are cast up onto the reef rim during storms or cyclones. There is no evidence to suggest that the boulders move; successive boulder tracts being separated by shallow moats.

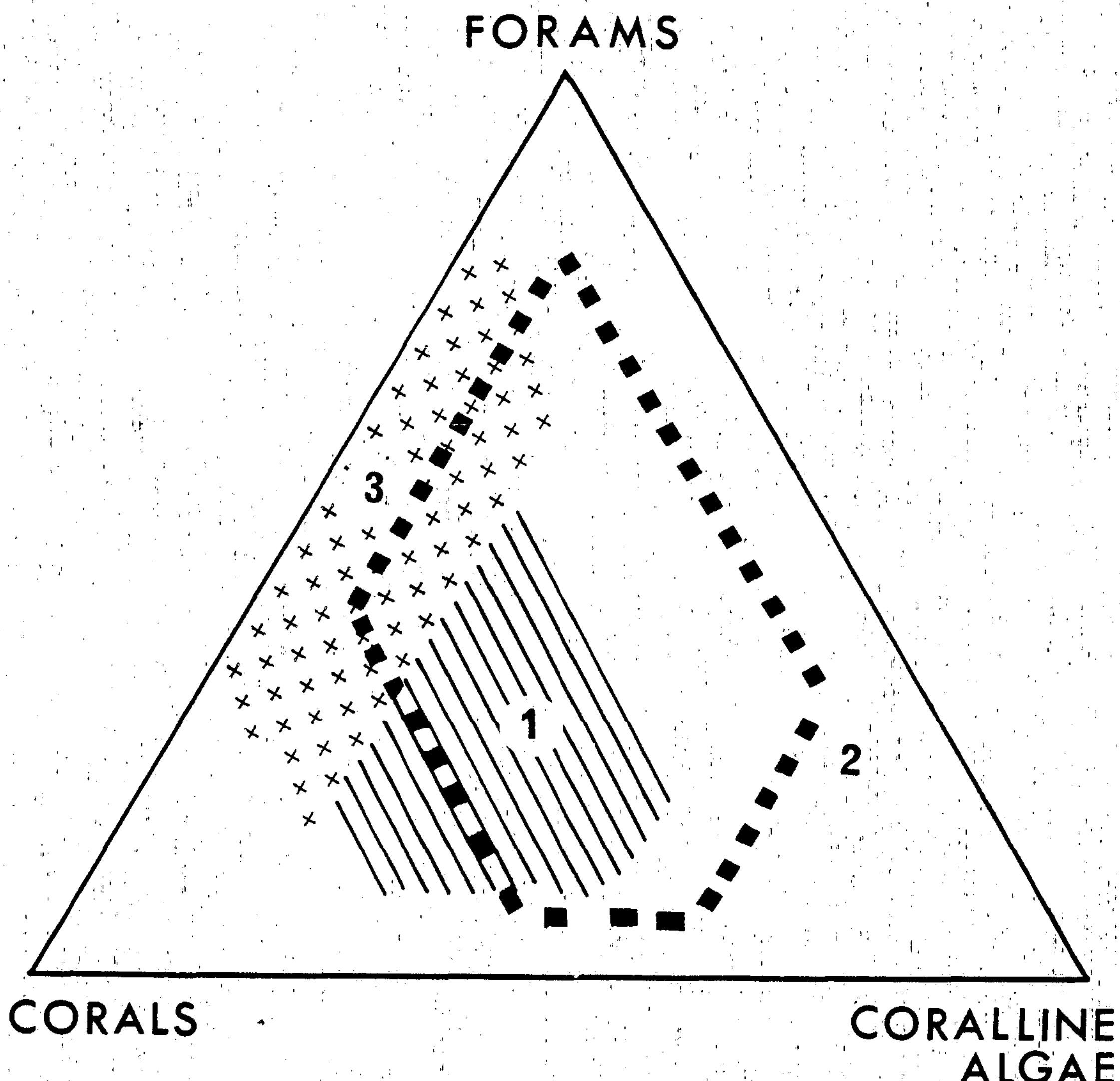
h) Leeward reef-slope deposits consist predominantly of reef-derived medium to very fine sand-size bioclastic sediments and benthic foraminiferans. These particles are transported from the reef flat by both translatory wave action and tidal run-off. The sediments produce a sediment cone in the energy shadow of the reef. The sediment is usually poorly sorted and rounding of the coarser particles attests to their bed-load transport history. However the very fine sand is frequently angular, having been transported in suspension. This sediment body usually does not exceed 2 km in length measured away from the reef.

GRAIN-TYPE COMPOSITION OF SEDIMENTS

Detailed analyses of the grain-type (i.e. skeletal component) composition of the reef sediments from the northern Great Barrier Reef Region (unpubl. data of Flood and of Hopley) show that variations in composition result mainly from differences in the percentage contribution made by five dominant skeletal types; coral, coralline algae, Halimeda, benthic foraminiferans, and molluscs. Several distinct sediment types may be recognized but their distribution patterns throughout the reef top do not constitute mappable units (i.e. sedimentary facies). This is because the distribution of skeletal detritus is controlled by either one or a combination of the following;

a) the distribution and abundance of living organisms,
b) the susceptibility of the skeletons to mechanical breakdown,
c) the production of specific size ranges upon breakdown, and
d) the movement of the skeletal detritus from growth areas to depositional areas under the action of breaking waves, translatory waves, and tidal currents.

Sediments possessing similar grain types, but markedly different grain sizes, may occur in different depositional environments. The following size preferences have been observed: coral, shingle sticks (-4 phi, 16 mm), coarse sand and granule (-2 to -.5 phi, 4.0 to 1.4 mm), very fine sand (3 to 4 phi, .125 to .063 mm); coralline algae, granule and pebble sizes (-1 to -6 phi, 2 to 64 mm); benthic foraminiferans, coarse sand (0 to 1 phi, 1 to 0.5 mm); Halimeda, pebble size (-2 to -6 phi, 4 to 64 mm), coarse to fine sand (0 to 3 phi, 1 to .125 mm), mud sizes (finer 4 phi, .062 mm);



Text-fig. 3. Showing the skeletal component compositional fields related to the varieties of platform reefs: 1, lagoonal platform, 2 platform, 3 low wooded island varieties. Compositions plotted on a coral, coralline algae, benthic foraminiferan, Halimeda tetrahedron (normalized to 100%) and then projected onto the base (the influence of Halimeda is not obvious on such a plot).

molluscs, gravel size (coarser - 1 phi, 2 mm), very coarse sand (-1 to 0 phi, 2 to 1 mm), fine sand (2 to 3 phi, .25 to .125 mm). The range of sizes mentioned for each component group does not preclude its occurrence as other sizes.

The changing nature of the grain-type composition of sediments associated with reefs at varying stages of development may be visualized on triangular or tetrahedral plots of the component composition (normalized percentage contribution) made by the three or four dominant organic groups. Areas representing observed compositions within the variety of reef types examined to the south of Cape Melville are shown in Text-fig. 3. Thus as the reef morphology changes according to the hypothetical scheme of reef development (see Text-fig. 2), the component composition of the bulk of the sediments also changes as the contribution made by framebuilders becomes subordinate to that made by the epiphytic organisms (especially benthic Foraminifera and Halimeda). This trend reflects the changing nature of the biota of the reef top throughout time.

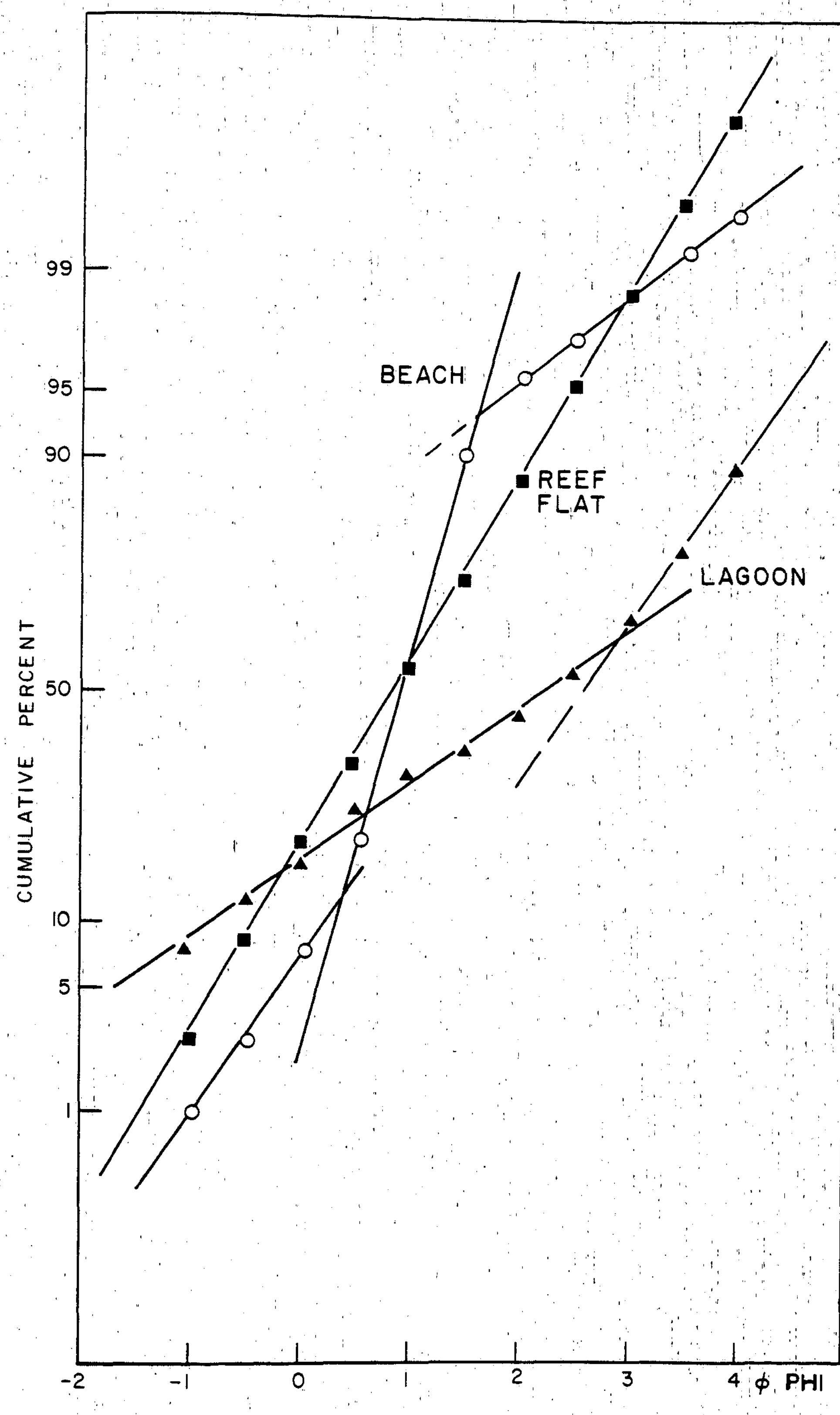
This relationsip has also been recognized by McLean and Stoddart (1978) within the sand/shingle islands of this region. Individual islands display marked changes in the component composition of sediments from the core to the outer margin. This undoubtedly reflects changes in the biota and in the variety of the reef throughout time.

GRAIN-SIZE COMPOSITION OF SEDIMENTS

Flood and Orme (1977) have shown that four grain-size (textural) sediment types may be recognized within reef sediments. Each depositional environment possesses a distinctive type. Lagoonal sediments may be differentiated from reef flat sediments, reef flat sediment from reef rim. etc. The distinguishing criteria are related to the complex interplay of oceanographic factors producing distinct grain-size populations, and are in no way related to the varying stages of the morphological evolution of the platform reef type.

Type I sediments are coarse sands and gravels, moderately to poorly sorted, strongly fine skewed or fine skewed. They consist predominantly of coral (Acropora) and coralline algae together with minor amounts of foraminiferans and Halimeda particles. These sediments occur towards the outer windward margin of the reef flat and on the reef rim. They appear to represent lag deposits remaining after wave and tidal action has removed the finer particles.

Type II are very coarse or coarse sands, moderately to moderately well sorted, strongly fine skewed to near symmetrical. They consist



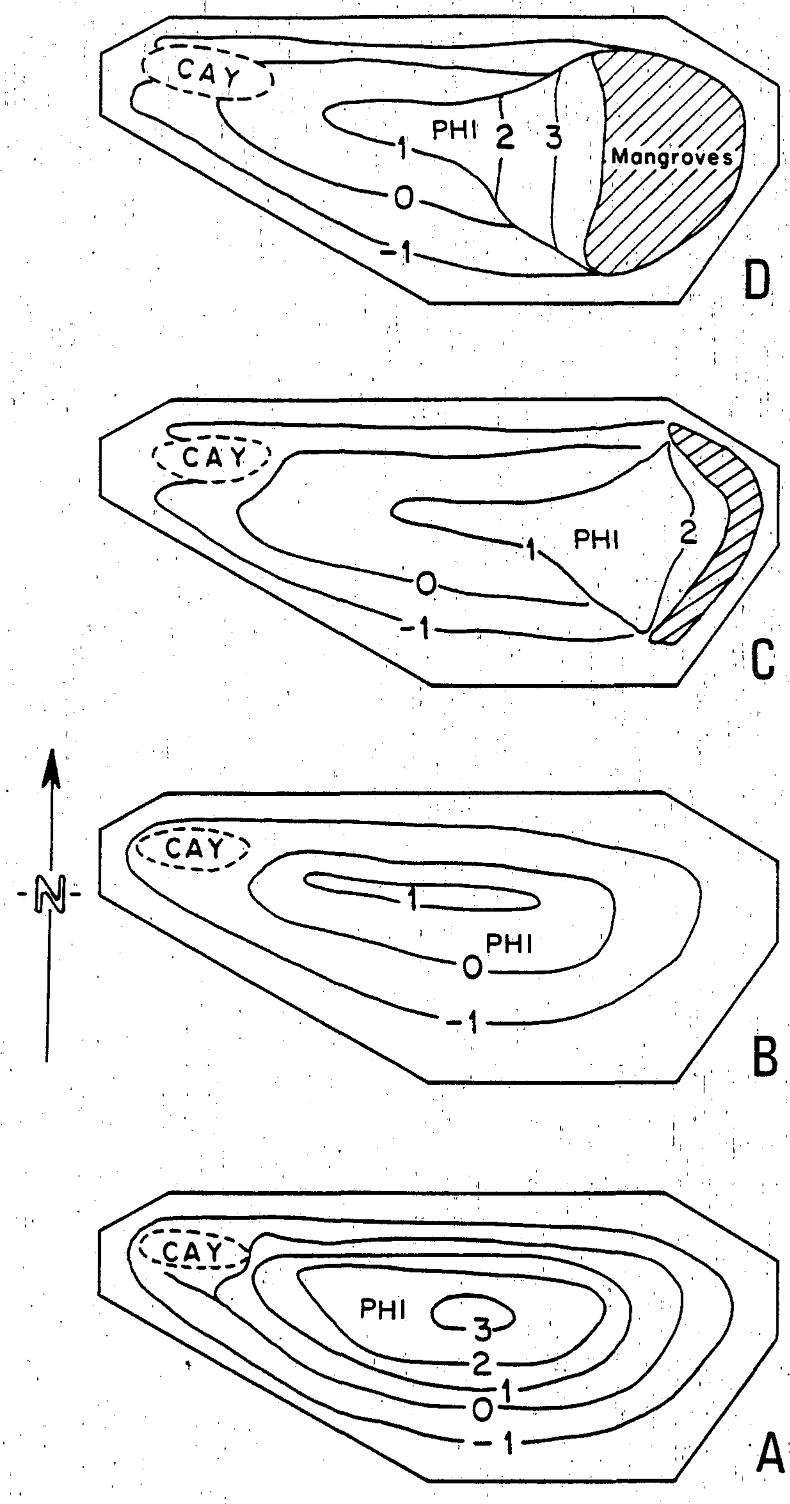
Text-fig. 4. Cumulative curves of grain-size data of sediments from different depositional environments. Several distinct log-normal grain-size populations are evident.

predominantly of benthic Foraminifera such as Calcarina calcar, C. hispida and Baculogypsina sphaerulata together with minor amounts of coral, coralline algae and Halimeda particles. These sediments occur on the reef rim on the windward side of the shingle spits and ramparts, or towards the central and leeward parts of the reef flat. Sediments of this type characterize the sandy areas that form as veneers on the reef flat.

Type III sediments are medium to fine sands, moderately to poorly sorted, fine to moderately coarse skewed. They do not display a predominance of any skeletal group; foraminiferans, coral, Halimeda, and molluscan particles may be present in varying proportion. Sediments of this type occur towards the leeward parts of the reefs in areas where material is subjected to reworking by tidal run-off during low tide, or as the subtidal sand body prograding into the lagoons. Particles finer than 3 phi (0.125 mm) constitute only a small percentage of the sizes in this type and in general such particles are characteristically absent on the exposed parts of the reef flats (i.e. they are removed in suspension by wave or tidal currents).

Type IV sediments are very fine sands, moderately to poorly sorted, moderately to strongly coarse skewed. They consist of a predominance of coral fragments (finer than 3 phi) and minor amounts (10 percent) of mud-sized particles which include Halimeda dust, sponge spicules, planktic foraminiferans etc. These sediments are restricted to the central or more protected parts of the lagoons on the lagoonal platform reefs. Material that constitutes this sediment type appears to have settled from suspension especially during periods of ebbing tide.

Detailed examinations of the frequency and cumulative distributions of phi (phi = $-\log_2$mm) grain size classes within these sediments revealed the presence of distinct log-normal size populations similar to those recognized by Visher (1969) within siliciclastic sediments (see Text-fig. 4). Multivariate R-mode cluster analysis of the data obtained from the sediments collected both from the reefs and the islands to the north and south of Cape Melville (data in Appendices 1 and 2 supplied by D. Hopley and data used by Flood and Scoffin 1978 respectively) also indicates the presence of distinct grain-size populations. Inflection point occurs at approximately 1 phi (0.5 mm) and between 2.50 to 3.00 phi (0.18 to 0.125 mm). The latter break may correspond to the intersection of the settling velocity, roughness velocity and threshold velocity curves relating the competency of current-velocity and grain-size (see Inman 1949). Thus interpreted the 3 phi break represents the size at which sediment is most easily transported in suspension. This explains the absence of particles finer than 3 phi



Text-fig. 5. Distribution of modal size of sediments: A lagoonal platform, B platform, C low wooded island (initial mangrove colonization), D low wooded island varieties of platform reefs. (Somewhat idealized).

on the exposed intertidal portion of the reef, as well as the predominance of such particle sizes within the subtidal lagoons. The 1 phi break is interpreted as representing the demarcation between saltation and traction modes of transportation.

The sediment types are therefore interpreted as being;

Type I - primarily traction load deposits (lag deposit),

Type II - primarily traction load together with saltation load (sediment in the process of moving by bed-load transport mechanisms),

Type III - primarily saltation load with varying amounts of traction and/or suspension load, and

Type IV - primarily suspension load deposits with lesser amounts of saltation load (or what could represent the suspension load sizes capable of being carried from the reef flat during periods of higher energy (e.g. cyclones) to be subsequently deposited in the lagoonal areas).

The distribution pattern of grain size of reef sediments (mean size and particularly modal size) reflects the systematic patterns of the sediment types throughout the various depositional environments (see Text-fig. 5). This pattern remains constant for the varieties of platform reefs of similar surface area. Smaller reefs tend to have coarser grained sediments than the larger ones. This merely reflects a decrease in the amount of energy available to transport sediment from windward to leeward across the larger reefs. Correspondingly the grain size of the island sediment on the smaller reefs are much coarser than those on the larger reefs. It is interesting to note that the mean grain size of sediments of reef flats and sand cays do display obvious correlation. They may, however, be readily distinguished on the basis of their sorting values (see Text-fig. 6).

CONCLUSION AND RECOMMENDATIONS

Basic inter-relationships between the biota, sediments, dynamics, and environments have been illustrated. However, subtle departures from the norm do exist. They may be related to;

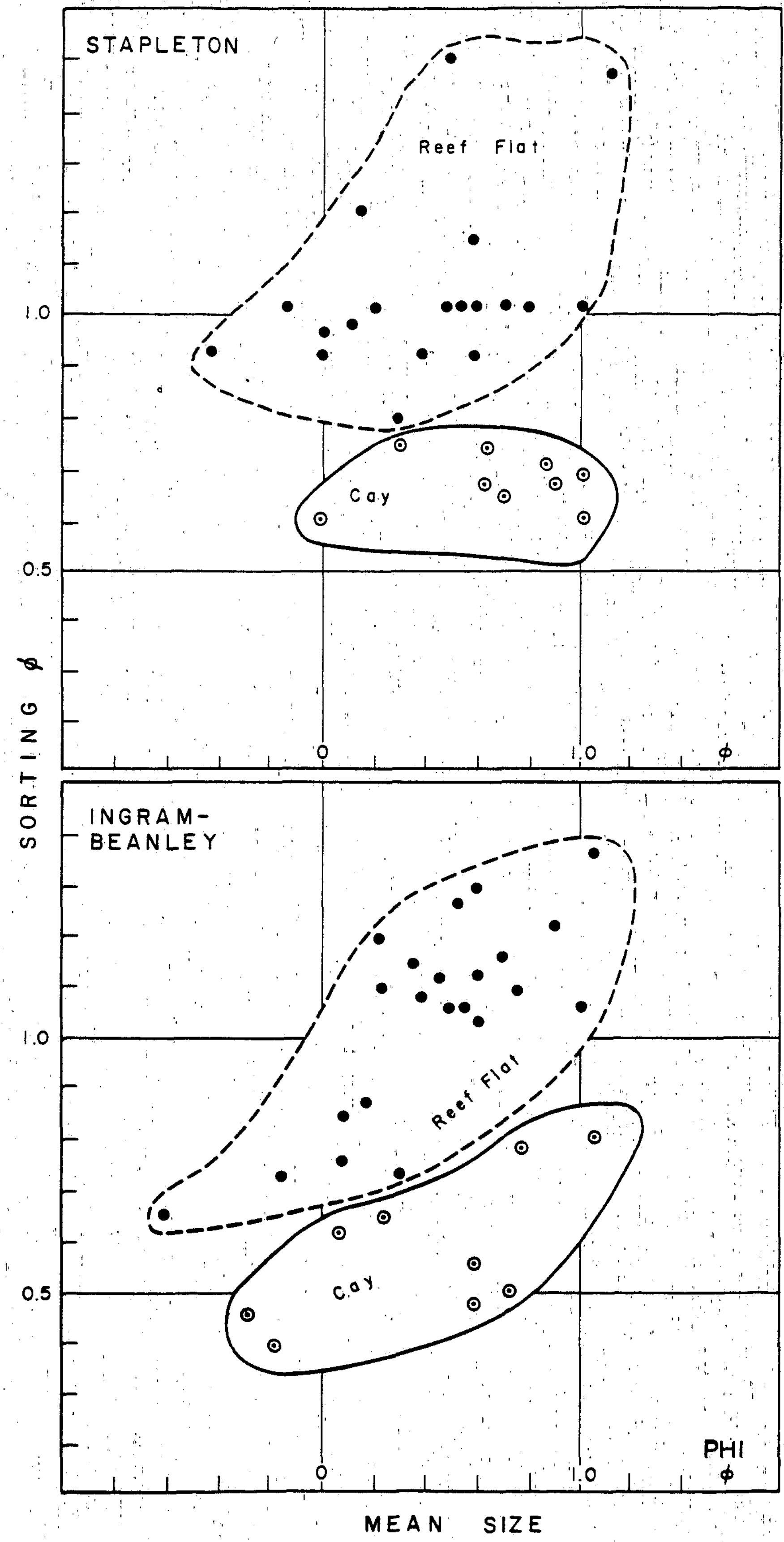
a) intensity of cyclonic activity experienced by different reefs from time to time,

b) different sizes of individual reefs,

c) influence of terrigenous mud which progressively diminishes across the shelf,

d) degree of exposure of the reef to the prevailing energy conditions (primarily wave action),

e) different hydrodynamic behaviour of skeletal carbonate particles of similar size, and



Text-fig. 6. Bivariate plot of mean size vs sorting of sand cay and reef flat sediments. (After McLean and Stoddart 1978)

f) hitherto unrecognized changes in environmental conditions existing during the period of Holocene reef growth..

This study indicates the perfunctory nature of the data upon which generalizations have to be made concerning reef sediments and sedimentation. Therefore it is recommended that a multi-disciplinary process-orientated study of reef sedimentation be undertaken to ascertain in a quantitative manner sediment source, transport, and accumulation on these reefs of the northern Great Barrier Reef Region. The programme should embrace the following;

a) systematic sediment sampling,

b) monitoring of the dynamics of water movement,

c) examination of sediment transport mechanisms,

e) analysis of the interaction of biological/sedimentological/and oceanographic factors.

Such a long-range, co-ôrdinated study would have not only scientific importance but would also be immediately relevant to the needs of the Great Barrier Reef Marine Park Authority as a basic reference for future meaningful planning of resource utilization and/or exploitation.

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A P P E N D I X 1

GRAIN-SIZE AND SKELETAL COMPONENT DATA, REEF-FLAT SEDIMENTS OF PELICAN REEF AND FARMER/FISHER REEF FROM THE NORTHERN GREAT BARRIER REEF REGION [1,2]

1) Data supplied by D. Hopley of James Cook University, Townsville

2) Sediments were collected in 1973.

C coral and coralline algae, M molluscs, PF platey foraminiferans
SF spherical foraminiferans, H Halimeda, U unknown

SAMPLE	GRAIN SIZE — PERCENT WT RETAINED AT HALF PHI INTERVALS														GRAIN TYPE					
	-2.0	-1.5	-1.50	-0.5	0.0	-.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	MUD	C	M	PF	SF	H	U
PELICAN																				
112	.5	1.8	.5	9.8	12.1	15.2	15.5	15.4	14.8	8.0	3.8	1.4	-	.8	39	21	1	1	11	27
113	1.7	1.2	4.4	9.2	12.6	12.4	13.6	15.2	14.2	7.8	5.8	1.2	-	.6	51	25	-	-	10	14
114	-	.5	1.8	4.5	6.8	8.6	9.8	10.8	12.6	12.4	16.0	11.0	-	4.5	21	11	2	2	2	62
118	2.6	3.0	5.8	7.4	8.8	9.4	10.1	12.2	16.5	14.0	7.3	1.6	-	.4	21	30	1	1	5	42
119	.4	.6	1.4	3.8	7.6	6.6	13.4	15.5	19.0	16.2	8.2	2.2	-	1.6	22	28	-	1	-	49
FARMER/ FISHER																				
222	2.4	1.2	4.8	9.4	11.6	12.7	12.6	13.2	12.6	11.6	6.6	1.8	-	.8	30	28	-	1	5	36
225	1.0	2.0	7.0	9.4	11.8	16.2	17.6	15.6	12.2	5.7	1.3	.2	-	.1	18	18	12	18	20	14
~~226~~	~~13.4~~	~~11.2~~	~~19.4~~	~~24.3~~	~~17.0~~	~~11.6~~	~~2.5~~	~~.4~~	~~.1~~	-	-	-	-	-	~~65~~	~~15~~	-	~~6~~	~~4~~	~~10~~
227	7.2	8.2	19.2	28.0	20.6	13.0	2.2	.1	-	-	-	-	-	-	70	15	-	10	-	5
229	.3	.9	2.0	3.8	5.3	6.8	6.5	6.2	14.2	26.2	22.6	3.9	-	1.0	27	11	2	8	8	38
230	-	-	-	-	25.9	9.2	8.2	8.6	12.2	14.9	14.4	4.5	-	1.2	21	20	2	2	8	47
231	1.6	1.8	3.2	3.6	3.8	3.8	4.9	7.4	14.3	18.7	23.3	9.2	-	3.0	5	2	2	1	5	85
232	2.0	3.4	5.4	8.8	14.6	30.6	21.8	8.4	3.6	1.0	.2	.1	-	-	28	15	10	23	9	15
233	6.2	3.4	3.4	5.3	8.2	20.3	31.8	12.4	4.7	2.0	1.2	.4	-	-	15	31	10	25	3	16
234	-	.4	2.6	7.3	11.6	14.4	15.4	14.8	13.2	10.8	6.2	1.4	-	-	20	5	2	1	1	71
235	1.8	3.7	6.2	12.8	17.0	16.3	14.2	11.1	9.0	5.0	2.2	.4	-	.2	51	25	1	1	2	20.
236	4.2	2.0	5.4	8.6	11.3	13.7	14.6	16.3	12.7	8.6	1.9	.8	-	-	40	25	1	11	2	21
238	0.2	0.1	1.9	6.2	9.8	10.4	11.8	12.6	16.0	15.2	10.8	3.8	-	1.8	22	10	6	2	6	54
239	2.0	2.9	11.6	22.2	20.0	14.4	9.0	5.8	4.8	4.0	2.6	.6	-	.2	57	17	-	-	2	24
240	.2	2.8	8.0	11.6	13.6	12.6	12.4	11.0	6.8	8.7	5.6	1.8	-	1.2	40	12	-	8	5	35
241	.4	1.0	4.4	13.0	14.4	13.2	10.9	9.1	10.4	6.8	7.6	2.4	-	1.0	39	10	2	1	10	38
242	1.0	2.0	7.2	13.6	17.5	19.4	11.2	7.8	7.8	7.0	4.4	1.0	-	.4	35	30	8	3	8	16
243	.4	1.6	5.2	11.6	26.2	44.2	9.8	.4	.1	-	-	-	-	-	20	6	-	50	4	20
244	.9	1.4	8.0	15.6	17.6	17.1	12.7	8.6	7.2	5.4	3.2	1.2	-	.8	40	18	-	-	3	39
245	.2	2.0	3.8	11.2	34.3	37.0	9.0	1.2	.1	-	-	-	-	-	45	9	1	10	5	30
246	.1	2.4	8.0	11.6	14.0	17.0	12.2	8.8	8.6	8.2	6.4	1.6		.8	35	18	9	7	10	21
247	.1	.6	.7	1.6	2.6	-	23.6	25.8	4.0	22.0	14.8	2.8		1.2	10	15	-	-	5	70
248	.2	1.8	6.0	11.0	12.6	11.6	11.4	11.6	13.1	12.0	7.3	1.7	-	.6	41	20	-	1	1	37

PGF MARCH '78

A P P E N D I X 2

GRAIN-SIZE AND SKELETAL COMPONENT DATA, SAND-CAY SEDIMENTS FROM THE NORTHERN GREAT BARRIER REEF REGION 1,2

1) Data supplied by D. Hopley of James Cook University, Townsville

2) Sediments were collected in 1973.

C coral and coralline algae, M molluscs, PF platey foraminiferans
SF spherical foraminiferans, H *Halimeda*, U unknown

SAMPLE	GRAIN SIZE PERCENT WT RETAINED AT HALF PHI INTERVALS														GRAIN TYPE					
	-2.0	-1.5	-1.0	-0.5	0.0	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	MUD	C	M	PF	SF	H	U
STAINER																				
107	3.8	9.4	16.0	21.0	17.6	11.7	8.4	7.4	3.6	1.2	0.4	-	-	-	43	35	-	4	11	7
108	0.1	0.1	0.1	0.2	0.2	1.0	10.2	40.0	38.2	9.0	0.6	-	-	-	11	20	-	1	1	67
PELICAN																				
115	1.0	1.8	6.0	10.2	13.6	11.8	9.4	11.8	19.2	11.4	2.4	0.2	-	-	59	28	1	1	7	4
116	-	-	-	0.5	22.0	8.7	15.8	18.6	28.4	21.0	3.6	-	-	-	10	19	-	3	9	59
120	6.0	4.0	8.6	13.2	15.2	14.8	12.7	9.4	9.4	5.4	0.8	-	-	-	20	42	2	3	8	25
121	1.4	3.4	11.6	19.7	19.8	18.6	11.2	6.0	4.8	2.4	0.6	-	-	-	45	35	-	1	5	14
122	-	-	0.2	0.5	1.4	4.6	13.4	24.9	34.0	15.0	1.9	-	-	-	10	11	-	2	3	73
123	1.8	0.4	1.6	4.6	8.0	11.4	11.8	14.2	20.2	15.4	6.4	2.2	-	1.4	22	20	1	2	8	47
124	-	0.6	4.6	22.0	30.0	21.6	10.8	5.8	3.4	0.8	-	-	-	-	40	28	2	3	6	21
125	4.1	8.0	11.8	15.1	11.2	11.8	15.4	11.0	8.3	2.0	0.3	-	-	-	40	49	1	-	3	7
FIFE																				
126	1.5	2.6	6.1	14.1	21.0	21.0	17.1	12.4	3.7	-	-	-	-	-	48	40	1	-	-	4
127	0.6	1.4	3.0	11.5	26.8	25.9	12.0	7.6	4.6	3.8	2.4	-	-	-	21	31	1	2	20	25
129	2.0	2.6	14.6	32.8	27.4	15.4	3.8	0.2	-	-	-	-	-	-	39	28	1	3	8	21
130	2.2	0.8	2.3	6.8	11.0	12.0	10.0	15.6	24.8	11.2	3.2	0.4	-	-	20	30	-	2	11	37
132	-	-	-	-	0.2	2.7	8.4	36.0	27.0	16.2	8.3	0.2	-	-	1	5	-	-	-	94
MORRIS																				
134	-	-	-	0.2	1.0	11.8	17.6	21.4	16.0	17.4	13.6	2.3	-	-	5	18	-	1	5	71
135																				
136	-	-	-	1.0	2.4	3.2	6.2	18.6	42.0	21.8	3.4	0.3	-	-	15	22	-	1	7	55
ELLIS																				
138	-	-	-	0.8	3.6	13.2	16.9	33.0	19.5	2.8	-	-	-	-	29	10	-	1	1	59
LOWRIE																				
139	18.8	4.1	4.0	6.1	10.2	7.1	17.4	17.6	12.7	6.7	1.4	-	-	-	45	29	-	2	1	23
SHERRARD																				
141	-	0.2	0.9	4.0	11.6	34.0	28.8	12.7	5.8	0.7	-	-	-	-	11	30	-	25	5	29
142	3.7	0.6	1.2	8.2	14.8	41.4	27.6	1.1	-	-	-	-	-	-	15	30	-	22	5	28
143	-	-	-	0.7	20.2	64.8	5.5	4.2	4.4	-	-	-	-	-	30	25	31	2	3	9
CHAPMAN																				
153	9.6	8.0	7.1	9.0	13.0	17.7	12.6	9.8	8.4	4.4	-	-	-	-	15	40	-	13	-	32
154	-	-	0.8	3.8	5.4	46.0	26.6	6.4	0.2	-	-	-	-	-	17	25	1	25	3	29
FORBES																				
155	-	-	-	0.4	5.4	36.2	44.4	7.6	2.4	1.6	-	-	-	-	25	10	1	9	1	45
156	-	0.8	1.2	4.6	7.4	11.8	17.4	15.4	13.8	12.2	10.6	3.9	-	0.6	30	11	-	4	1	45
RAINE																				
159	2.4	2.5	5.2	10.8	12.0	14.8	17.8	28.2	4.7	0.6	-	-	-	-	10	39	3	20	5	23
ASHMORE																				
185	-	-	-	1.2	10.0	36.8	35.5	14.9	0.6	-	-	-	-	-	26	25	-	10	-	39
186	13.3	17.2	9.2	6.6	7.0	24.3	20.3	2.1	-	-	-	-	-	-	57	27	-	9	-	7
187	2.2	7.2	9.0	19.8	28.1	21.6	9.6	2.1	-	-	-	-	-	-	40	50	-	3	3	4
188	36.7	16.2	11.4	9.2	8.9	3.2	-	-	-	-	-	-	-	-	63	25	-	2	1	9
MAGRA																				
193	-	0.4	0.2	0.6	2.4	7.0	14.6	34.7	31.4	7.0	1.0	-	-	-	10	18	-	3	1	68
194	0.8	3.2	4.8	9.8	50.7	26.8	3.4	0.2	-	-	-	-	-	-	19	35	3	7	10	26
195	-	-	4.4	2.0	4.4	9.3	37.6	42.1	0.4	0.2	-	-	-	-	10	30	-	3	3	54
SAUNDERS																				
198	-	-	-	0.9	4.7	8.2	7.4	6.5	9.6	9.8	2.7	-	-	-	20	29	-	3	5	43
200	2.8	3.9	11.2	21.8	23.9	22.4	10.0	2.6	0.2	-	-	-	-	-	11	15	-	3	1	70
201	-	-	-	2.4	16.1	48.0	23.0	7.5	2.7	0.4	-	-	-	-	21	30	-	9	4	36
206	-	0.4	9.6	39.4	23.8	12.3	6.2	4.2	0.6	-	-	-	-	-	80	15	-	3	-	2
208	-	0.4	1.9	7.2	15.0	17.8	14.6	12.0	12.8	14.0	4.4	0.2	-	-	11	18	1	5	4	61
BIRD																				
210	0.2	1.0	4.3	23.0	41.2	25.8	4.0	0.4	-	-	-	-	-	-	35	25	-	9	3	28
211	6.6	7.2	12.4	14.2	16.4	18.5	10.8	6.4	4.2	2.2	0.8	-	-	-	43	33	-	5	6	13
PIPER																				
212	0.2	1.4	4.8	13.4	22.0	22.8	20.8	10.8	2.4	0.7	0.4	-	-	-	20	38	-	3	2	37
213	-	0.7	2.3	8.6	20.0	29.6	22.5	12.2	3.1	0.2	-	-	-	-	42	8	-	3	2	45
214	-	0.1	0.6	4.6	43.2	42.5	8.6	0.4	-	-	-	-	-	-	30	35	-	3	4	28
218	6.9	11.0	15.9	17.1	15.8	12.2	3.0	-	-	-	-	-	-	-	35	50	1	1	5	8
FARMER																				
221	4.0	7.4	11.6	14.6	14.2	12.8	10.4	8.0	8.6	5.8	2.4	-	-	-	50	19	-	1	3	27
223	0.4	1.3	6.8	22.4	22.5	17.3	12.8	7.6	1.6	0.8	-	-	-	-	69	22	-	1	5	3
224	-	-	-	-	-	0.7	5.6	23.6	39.9	24.6	5.2	0.2	-	-	1	5	-	1	-	97

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CHARACTERISTICS OF MARINE FISH COMMUNITIES OF THE GREAT BARRIER REEF REGION, AND IMPLICATIONS FOR MANAGEMENT

F.H. Talbot and G.R.V. Anderson

Species richness:

The fishes of coral reefs of the northern Great Barrier Reef are a part of the richest assemblage of shallow water fishes in the world. The Great Barrier Reef Province borders on the tropical central area of the Indian and Pacific Oceans (Indo-West Pacific Faunal Region of Ekman, 1953) and which is considered by Briggs (1966) and ~~Randall (1955) to have been the centre of world marine~~ shallow water speciation. The species richness of the Great Barrier Reef is known, but to put it into context we can say that in the Lizard Island region we would expect to find some four times the freshwater and marine fish fauna of the whole of Tasmania. At One Tree Island, at the southern end of the Reef (Lat. 23°31'S.) some 800 species have been collected. Extrapolating from some of the groups which are known we might expect one-and-a-half to twice this number in the Lizard Island region of the Reef. (See Table 1, Figure 1). In a 20m radius of coral reef one might find 150 species of fish co-existing, two to three times what would be found in a sub-tropical or temperate area.

Structure of a typical reef fish community:

A typical reef community that we have studied would have the following characteristics:

(a) One or two small species in very large numbers.

(b) Many species present at very low densities.

(c) Most species of small size, and only a few of large size.

(d) In terms of biomass only 2% of the individuals are over 250 gm. weight, i.e. easily usable as food or for sport. But this 2% of individuals form 50% of the biomass. In other words, a few large fishes comprise half the weight of the fish community. (See Figure 2, Figure 3). The same pattern emerges for explosive samples from One Tree Island and from Yonge Reef on the outer Barrier near Lizard Island. It is likely that these large individuals have fewer natural predators than smaller species.

Importance of fish as grazers and predators:

Although they contribute only 0.01 to 0.1% of the total respiration of a reef ecosystem (Smithsonian CITRE Workshop, Glovers Reef, 1972), herbivorous fish graze almost all algal-covered reef surface every day, and much evolutionary development of reef organisms, especially invertebrates, is related to fish feeding (Bakus, 1972; Ehrlich, 1975). Structure, cryptic coloration, and the very common development of biologically active compounds - poisons, irritants, etc. - can in many cases be related to fish predation.

Territoriality and Home Range:

Fish communities are in general closely related to an area of reef. Many of the smaller species are territorial (reviewed in Ehrlich, 1975), and in species of *Chaetodon* we have seen the same individuals using the same night roosting sites for a year or more (*C. auriga*, *C. trifasciatus*, pers. obs. Long Reef, Lizard Island Lagoon).

For larger species such as serranids it has been common to find individuals with home ranges staying in one area for some months, but gradually being replaced by others (Bardach, 1958; Randall, 1961; Springer & McErlean, 1962; Reese, 1973; Goeden, 1974).

Variation in Communities in Different Reef Habitats:

We talk of a coral reef fish community as though it is homogeneous. It should be realised that there are major differences in fish faunas from area to area of the same reef and these also show different trophic structure. (See Figure 4 and Figure 5).

There are at least three scales of habitat differences: (1) broad coral zones reflecting the degree of wave action and depth; (2) geographical variation in the same zone from north to south along the reef and from inshore to offshore; and (3) patchiness within such a zone (different coral species, dead and living coral, sand patches, etc.). With groups of samples from each broad zone ((1) above) at One Tree Island Reef over many different zones only 27 of 208 species (13%) occur in all zones (Goldman & Talbot, 1976). 60 species were found only on outer reef zones (29%) and 17 species were found only in the lagoon (8%). Fishes, in spite of their mobility are closely allied to particular bottom topography and show marked zonal preferences. Repeated sampling suggests that many species do not range far, but these were day samples, and it is now well known that many species have widely different nocturnal and diurnal feeding and roosting places (Hobson, 1965; Schroeder, 1967; Collette & Talbot, 1972).

In addition to the differences on a single reef, there are differences between inshore, central and outer reefs across the Reef Province at any one latitude. The mainland coast and the reef areas have in fact been named different provinces (Pope, 1967). Be that as it may, in the little work that has been done, variations are found in relative abundances across the Reef Province as well as in presence and absence of species (Anderson et al, mss.).

Dispersal of eggs and larval fishes:

Although little is known of the population dynamics of reef fishes, recruitment tends to be primarily in the summer months, when huge numbers of juveniles settle on the reefs (Russel et al, 1977). There is sparse information of the length of time the eggs and larvae drift before the young fish settle, but periods up to three months of larvel life are known (Randall, 1961; Leis & Miller, 1976). For example, a three knot drift over fourteen days gives a thousand sea miles of range for a developing egg and larval fish before settling. Most larger (and food) fishes are pelagic spawners with surface eggs and larvae (Russell et al, 1977).

Between-year variability and stability of reef fish communities:

There is little constancy in recruitment on reefs from year to year in observations made so far. We have found that a species which has heavy recruitment one year, may have very many less juvenile settling the following year. Some of the common species, for example, may have up to ten-fold differences in consecutive years (Russell et al, 1977). For a long time high diversity systems such as coral reefs and rain forests were considered to be extremely stable, and thought not to show the marked population fluctuations of less complex ecosystems. High diversity equals high stability was considered a fundamental principle. This has now been strongly queried on theoretical grounds by May (1973), and by others on observational grounds (see review by Connell, 1978). Certainly at even the scale of whole reefs there may be extinctions of a species (Goldman, pers. obs.) and as has been stated above there are marked differences in year to year recruitment, and fluctuations in the number of adults. In terms of always seeing the same species in roughly the same numbers, coral reefs are not as stable as we imagined a decade ago. As will be shown, the scale of observations so far is too fin , but in spite of this we would surmise that fluctuations of major proportions are to be found. It is also likely that 'stability' under non-stressed conditions may have little to do with the ability to withstand man-induced stresses if these touch important processes. Predation may be one of these processes.

Predation on settled juveniles and adults:

From our observations high predation on settled juveniles and adults has turned out to be one of the most interesting and probably most important factors of the reef fish communities. The predation rate is so high that 62% of species settled in summer on artificial 'reefs' did not persist for 6 months. Some of this loss may be due to emigration from the observed reefs, but much of it is due to predation, and predation rates have been seen to increase in storm surge (Sweatman, pers. comm.). (See Figure 5). It has been suggested that juveniles may settle on reefs on a chance basis, i.e. that at the time at which juveniles are ready to settle, the first rocky substrate reached is settled on. Certainly at the small scale of our work individual replicate artificial 'reefs' (concrete block structures) have different sets of species and settlement seems to be random. Heavy predation cuts down numbers and the result may be that many species in a patchy environment may be separated from each other, with concomitant reduced competition for resources. Alternatively, low numbers resulting in easy access to resources, results in minimal competition (Sale, 1977, but see Anderson *et al*, mss.). However, the scale on which such observational work has been done to date is small. Nevertheless, we would consider the high predation rate to be an important characteristic of these reef communities.

Protagynous polyandry:

Many reef species start off life as females, and only larger specimens may be males. Fishing, which may remove more fishes at the larger end of the scale could very seriously affect social organisation of these species.

Summary of characteristics that may be of management importance:

Structure:

1. High species richness.
2. Very few species in very high numbers.
3. Many species very low in numbers.
4. A few individuals comprise most of the biomass.
5. A Majority of species are of small size.

Distribution:

6. As adults most species are substrate linked and do not range far.
7. Different reef zones have markedly different species composition.
8. Inshore, middle and outer reefs across the Great Barrier Reef system have fish populations, which show differences (Anderson, *et al*, mss.).
9. Most species are pelagic breeders, and their eggs and larvae drift in the surface waters. They may have long dispersal distances. It is therefore possible that their structure is on a larger scale than for most terrestrial vertebrates.
10. Juveniles of some reef species may need the protection of sheltered waters such as lagoons and estuaries.

Dynamics:

11. Recruitment of most species is seasonal.
12. Recruitment success for species may vary markedly from year to year.

Identification of Research Needs:

(1) Much of our understanding of reefs is based on work there on small units - small patch reefs and 'bommies', and artificial reefs of concrete blocks. It is becoming very necessary to study fish communities on a larger scale. A study of larger areas with carefully planned sampling to optimise effort is a possible approach.

(2) Although there is information on movements, home ranges and territories of some smaller fish species (see Ehrlich, 1975; Reese, 1964; Sale, 1971), we rely for information on larger fishes on very little work (Bardach, 1958; Randall, 1961; Springer & McErlean, 1962; Reese, 1973). Many more studies of individual species need to be done (see Goeden, 1974), in particular the tagging of medium and larger sized fishes to understand home ranges and migrations. Many such movements are known by island peoples, and they are often complex (Johannes, 1976), but virtually nothing is known in the Northern Great Barrier Reef area.

(3) No real understanding of populations and communities can be obtained until there is more information on transport of eggs and larvae. Studies on planktonic eggs and larvae are much needed.

Implications for Zoning and for Management:

Our general understanding of coral reef fishes and specific knowledge in this region (however hazy this knowledge might be at present) has nevertheless major implications for the setting up of marine park areas, and for their management.

The region is extraordinarily rich in species and there is no other Australian area where there is more justification for the setting up of marine parks from a marine ichthyological viewpoint.

If, as seems likely, the dispersal of eggs and larvae occurs over long distances, we may be talking of genetically homogeneous interbreeding populations covering long distances. This is supported by allozyme studies of Soulé and co-workers (Soulé, 1973, Ehrlich, 1975). This could suggest that juvenile recruitment events on a reef off Lizard Island, for example could be unrelated to the adults on that reef, but instead be affected by breeding success 500 kilometres farther north. It is not sensible to protect small areas in the hope of retaining their communities, as communities on small areas of reef are not self-perpetuating. In addition rare or sparse species may be present on a reef area one year, and absent in the next, and only large areas will be viable for such species. For these reasons park areas must be larger than terrestrial national parks to be effective. One is reminded of the great migratory herds of antelope in the South African veld. With the advent of farmers and fences, huge areas of Southern Africa became untenable for many species.

In the setting up of parks it should be borne in mind that there are differences in fish communities from inshore to offshore reefs, and there is need for sheltered waters for the juveniles of some species. This suggests areas should include complete sections of reef, from estuarine and inshore systems to the outer barrier.

It is a common finding on coral reefs that heavy fishing on one reef results in drastic changes to the catches of bottom fish in a relatively short time. This is understandable when only 5% of the fish assemblage is fishable (see earlier), and when many benthic species are site attached. Lutjanidae, Lethrinidae and Serranidae comprise the bulk of the angler's species and these groups can be markedly reduced in numbers by fishing (personal observations on Tutia Reef). The most commonly fished pelagic species, carangids and scombrids, are also predators on reef fish. These large species have few natural predators so fishing represents a very unnatural mortality that can be expected to have profound effects on the reef fauna. If, as we surmise, competition for resources is reduced by intense predation, the level of predation will be extremely important in the maintenance of the complex dynamic structure of the prey community. If predation is reduced, shifts in species abundances and even local extinction of species is likely.

This suggests an incompatibility between a reef protected for its coral reef ecosystem, and fishing. In many park management systems, fishing is permitted (although it is rigorously excluded in the Virgin Islands National Park, a rich coral reef area). I conclude that any multi-use area must have non-fishing zones. If true protection of the dynamics of the reef systems is considered, these will have to be large. We are dealing with a large and open ecosystem, and to protect it may require quite different strategy from terrestrial areas. Large areas of coastline of hundreds of miles under protection, with localised concessions where impacts are permitted may be the only way to keep these systems viable (Rooney, et al, 1978).

In this paper we have considered only the fish fauna, but no proper understanding of even the fish fauna, far less the structure and trophic relationship of even a small reef, can be considered without much more work on the primary producers, invertebrates, decomposers and the plankton.

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ALGAE OF THE GREAT BARRIER REEF REGION
FROM LIZARD ISLAND TO CAPE YORK

Ian R. Price

Botany Department
James Cook University of North Queensland
Townsville, Queensland.

ABSTRACT

Apart from Lizard Island and nearby areas, there is virtually no published data on the algae of the region. More published information is available for areas to the south (e.g. Low Isles) and further north (Torres Strait). Most of these accounts concern systematic and descriptive ecological studies, although some functional investigations have recently been undertaken. Nevertheless, over much of the area under consideration algae are the only primary producers present and they therefore have fundamental importance in marine trophodynamics. They provide food, substrate and shelter for numerous organisms and may be the main food-source for various animals which may have economic importance, such as fish, turtles and, under certain conditions, dugongs. The importance of benthic algae in such processes as cementing, sediment-formation, nitrogen-fixation and bioerosion in coral reefs, in addition to primary production, is not generally appreciated. Although algae are not presently utilized by man in the region, some areas may be suitable for the farming of economically important seaweeds such as *Eucheuma*. The algae also represent a possible source of biologically active chemicals and may be implicated in Ciguatera toxicity. They may also be significant in pollution and fouling. Although few studies on algae have been carried out in the region, the results of investigations carried out in other tropical areas may be relevant.

INTRODUCTION

In much of the northern region of the Great Barrier Reef under consideration, mangroves and sea-grasses are absent and algae - planktonic, benthic, and symbiotic - are therefore the major photosynthetic group of organisms present. They are especially significant as primary producers, as well as in other roles, in living communities such as coral reefs. However, few scientific studies of algae have been carried out in the region. The initial aim of this paper is to survey the information available on these organisms in the northern region of the Great Barrier Reef and neighbouring areas. Emphasis is placed on the benthic algae because of their vital importance in reef ecosystems, with only brief mention of symbiotic and planktonic algae. The survey is followed by an assessment of the available information and the need for further studies.

PHYTOPLANKTON

A detailed study of fluctuations in the abundance and composition of the phytoplankton in Great Barrier Reef waters, particularly in the vicinity of Low Isles but also at some stations as far north as the Lizard Island area, was made by Marshall (1933) during the Great Barrier Reef Expedition of 1928-29. This was accompanied by a systematic account of the silicoflagellates (Marshall, 1934). Some reference to the Barrier Reef dinoflagellate flora was made by Wood (1954).

More recently, the pigment and systematic composition of the phytoplankton in reef waters in Princess Charlotte Bay was examined by Jeffrey (1968). In the Lizard Island area, the productivity of the phytoplankton has been investigated by Griffiths (1976) and by Scott and Jitts (1977). The latter workers compared the photosynthetic production of the phytoplankton with that of symbiotic zooxanthellae.

Among planktonic forms, special mention should be made of the blue-green alga *Trichodesmium*. This genus is often the most abundant form in the phytoplankton of Barrier Reef waters and sometimes produces blooms, which can have deleterious effects on other organisms (Marshall, 1933; Cribb, 1969b). *Trichodesmium* is reported to fix molecular nitrogen (Carpenter and Price, 1976).

SYMBIOTIC ALGAE

Most important among symbiotic algae in coral reefs are the zooxanthellae, which are associated with a variety of animal partners, notably reef-building corals (Taylor, 1973). Some of the earliest experimental studies of the relationship between zooxanthellae and reef-building corals and tridacnid clams were carried out at Low Isles during the Great Barrier Reef Expedition of 1928-29 (Yonge and Nicholls, 1931a, 1931b; Yonge, Yonge and Nicholls, 1932; Yonge, 1936). More recent studies on zooxanthellae in the Great Barrier Reef have been carried out by Jeffrey and Haxo (1968), by members of the Great Barrier Reef Photorespiration Expedition of 1973 (e.g. Bishop, Bain and Downton, 1976), and by Crossland and Barnes (1977). The significance of these symbiotic algae in reef-building corals has been reviewed by Muscatine (1973).

Apart from zooxanthellae, considerable attention has recently been given to the association between green prokaryotic cells and colonial ascidians in Barrier Reef waters (Newcomb and Pugh, 1975; Thorne, Newcomb and Osmond, 1977; Thinh and Griffiths, 1977).

BENTHIC ALGAE

In his compilation of "The marine benthic algae hitherto recorded from north-east Australia" Lucas (1931) listed two species from Cape Flattery and 76 species from Cape York, but gave no records for the intervening coastline or for reefs of the Great Barrier in that region. Apart from the mainland coast, Stephenson *et al.* (1931) listed four taxa from Yonge Reef, while five genera were recorded by Goreau and Yonge (1968) from deeper water at Lizard Island. More recently a preliminary list of more than 80 marine benthic plant species from the Lizard Island area has been published (Price *et al.*, 1976).

Outside the region under consideration, systematic data have been published for Queensland waters further south (Lucas, 1931, 1934; Stephenson *et al.*, 1931; May, 1951; Cribb, 1954, 1956, 1958a, 1958b, 1960, 1965b) and to a lesser extent to the north (Lucas, 1931; Cribb, 1961). Earlier references dealing with the benthic algae of Queensland were listed by Cribb (1954).

In relation to benthic algal ecology in the region, a short description of Yonge Reef, with some mention of the algae, was given in the Scientific Reports of the Great Barrier Reef Expedition, 1928-29 (Stephenson *et al.*, 1931). The Expedition provided much more detailed information on the distribution and ecology of reef organisms, including algae, on the reef flat and seaward slopes of Low Isles (Stephenson *et al.*, 1931; Manton and Stephenson, 1935).

Descriptive ecological accounts, dealing particularly with the reef-flat algae of coral cays, have since been published for a number of reefs towards the southern end of the Great Barrier (Cribb, 1965a, 1969a, 1972, 1975), in particular Heron Island (Cribb, 1966). The results of such studies have recently been summarized by Cribb (1973) in a paper entitled "The algae of the Great Barrier Reefs", which also includes discussion of the factors influencing the distribution of algae in coral reefs, and their roles in reef communities.

Limited (unpublished) observations on algal distribution on the reef flat and seaward slopes (to 20m) of Tijou and Yonge Reefs were carried out by the author during the Royal Society and Universities of Queensland Expedition to the Great Barrier Reef in 1973.

A range of physiological and biochemical studies on various benthic algae and other plants was carried out at Lizard Island during the Great Barrier Reef Photorespiration Expedition (Tolbert and Osmond, 1976). Calcification in Barrier Reef algae has been investigated by Borowitzka and Larkum (1976). Crossland and Barnes (1976) demonstrated that "dead" coral skeletons actively fix nitrogen, possibly due largely to perforating blue-green algae.

In contrast to the types of studies listed above, emphasis has more recently been given to the dynamic interrelationships between reef organisms and to the metabolic functioning of reef communities as a whole. The importance of the many and complex interactions between algae and associated organisms in reef communities (Dahl, 1974) is indicated by recent studies at Heron Island (Potts, 1977). Studies of the carbon, nitrogen and calcium metabolism of reefs have recently been conducted at Lizard Island (LIMER 1975 Expedition Team, 1976), and are being extended (Dr D.J. Barnes, personal communication). Benthic, symbiotic and to a lesser extent planktonic algae play essential roles in reef metabolism due to their activities in processes such as photosynthesis, nitrogen-fixation and calcification. The benthic algae also play important structural functions in reefs in sediment formation (Maxwell, 1968), cementation (Ladd, 1961) and bioerosion (Cribb, 1973).

UTILIZATION

There appears to have been no direct utilization of algae by man in the region in the past, nor are they utilized at present. Although some coastal areas might be suitable for the farming of seaweeds such as *Eucheuma* (Doty, 1973a), a valuable source of carrageenan, this may be uneconomic due to high labour costs. Algae also represent a possible source of biologically active chemicals, and may produce ciguatoxin in reef ecosystems (Banner, 1976; Bagnis, Chanteau and Yasumoto, 1977).

Directly, or indirectly, algae form the basis of food chains in the oceans, and benthic algae are a significant food source for various animals which may have economic importance, such as fish, turtles and, under certain conditions, dugongs (Heinsohn and Spain, 1974).

DISCUSSION

From the above account it can be seen that our knowledge of the algae in the northern Great Barrier Reef, with perhaps the exception of Lizard Island, is meagre. In comparison with the conspicuous hermatypic corals of reefs in the Great Barrier, the algae have been neglected. Consequently, distribution, abundance, seasonal variation and relative importance of the various algae in different types of reefs and reef communities in the region is poorly understood, as are the factors influencing their distribution. This is also true of possible variation in the flora from north to south. We are particularly ignorant of algae in deeper waters. More extensive studies on certain of these aspects have been carried out in other tropical areas and the results of these may be applicable to this region.

Comparative floristic and ecological studies of the algal communities of different reef types, including aspects such as their relative importance in primary production and nitrogen-fixation, their significance in bioerosion, and their role in the "algal rim" on windward reef margins, are required. The possible use of algae as environmental indicators, at both small-scale and broad-scale levels, should also be investigated. More detailed correlations between studies of reef metabolism and community structure might enable estimates of metabolic activities to be made from the structure of the community.

In terms of reef management, the responses of algal populations to environmental and human influences should be monitored. A dramatic example of the effect of human activity is the widespread death of coral and prolific growth of the alga *Dictyosphaeria* in Kaneohe Bay in Hawaii (Banner, 1974). Predation of reef-building corals by *Acanthaster* in the Great Barrier Reef likewise resulted in greatly increased benthic algal biomass on affected reefs, although this algal growth should not necessarily be considered detrimental. Changes in the algal communities present may also influence the incidence of ciguatera toxicity in reef areas (Bagnis, Chanteau and Yasumoto, 1977).

Discussing the ecology and conservation of tropical marine algae, Doty (1973, p. 183) wrote that "The rational use of man's resources requires knowledge we do not yet have. This is conspicuously true for the marine organisms". These statements certainly apply to algae in the Great Barrier Reef and the development of appropriate guidelines for the management of the region will require continued scientific effort.

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Marine Mammals of the Northern Great Barrier Reef Region

GEORGE E. HEINSOHN

Department of Zoology

James Cook University

ABSTRACT

The Great Barrier Reef region and other coastal waters off northern Australia are major refuges for dugongs and small cetaceans. Recent aerial surveys have shown that the coastal waters of Queensland, particularly inside the northern Great Barrier Reef region, have large populations of dugongs, a species that is rare and in danger of extinction in most other areas of its range in the Indian and Western Pacific Oceans. Pertinent aspects of dugong biology are discussed. Very little is presently known about the species, distribution, and abundance of cetaceans found in the Great Barrier Reef waters. Most of the cetacean data comes from stranded and accidentally killed whales and dolphins (e.g. the Irrawaddy dolphin *(Orcaella brevirostris)*, previously only known from S.E. Asia, is the dolphin most commonly caught in shark nets near Townsville). The once common large whales seen along the Queensland coast are now rare due to heavy exploitation. There is an urgent need to determine the species and to assess the populations of cetaceans along the entire Queensland coast. An annotated check list of cetacean species that are known or may be expected to occur in the northern Great Barrier Reef region has been prepared.

INTRODUCTION

As large to gargantuan, air-breathing, warm-blooded animals that suckle their young, marine mammals are among the most spectacular and interesting creatures of the seas. They have become completely adapted to and dependent on the sea. Marine mammals from two orders occur in the waters of the Great Barrier Reef, these being the order Cetacea, which is represented in Great Barrier Reef waters by approximately twenty or more species of whales, porpoises and dolphins, and the order Sirenia which is represented by one species, the dugong (*Dugong dugon*) in Australian waters. These mammals spend their entire lives in the sea with all activities such as feeding, resting, mating, birth, and suckling and care of young occurring in the water.

The coastal waters of sub-tropical and tropical Australia, including the Great Barrier Reef region, are major refuges for dugongs, which are endangered or threatened with extinction in most other parts of the world where they occur (Heinsohn, 1977a). At least 22 species of cetaceans are known to occur in Queensland waters. Very little is known about most of these species (Bryden, in press). The full importance of the northern Great Barrier Reef region for these species is not known.

The purposes of this paper are to summarize what is known about the marine mammals which occur or may be expected to occur in the waters of the northern Great Barrier Reef; to emphasize the lack of scientific data, particularly for cetaceans; to discuss present and potential threats; to make recommendations for research necessary for future management; and to discuss future conservation and management. Information on the single species of sirenian, the dugong, which occurs in Barrier Reef waters will be summarized and discussed separately and differently from the cetaceans.

THE DUGONG (*DUGONG DUGON*)

Distribution and Status

The dugong, which is the only herbivorous mammal species that is strictly marine, is one of four living species in the order Sirenia. The other living sirenians are the three species of manatees, genus *Trichechus*, which occur in both coastal marine environments and in fresh waters of the sub-tropical and tropical Atlantic Ocean and Caribbean Sea region, that is West Africa, south-eastern North America, Central America, and northern and north-eastern South America.

The dugong, which grows to a length of about 3 meters and can weigh between 300 and 400 kg (Spain and Heinsohn, 1975), occurs in the shallow coastal waters of the tropical and sub-tropical Indian and western Pacific Oceans. The complete distribution and present status are given by Bertram and Bertram (1973) and Heinsohn (1976). Due to extensive hunting and netting for food, Bertram and Bertram (1973) consider the species to be rare over most of its range and to be approaching extinction in some regions. Large populations of dugongs still occur in the tropical and sub-tropical coastal waters of Australia (Bertram and Bertram, 1973; Heinsohn, Spain and Anderson, 1976; Heinsohn, Marsh, Gardner, Spain and Anderson, in press; and Heinsohn, 1977b). Much of the inshore waters of the northern Great Barrier Reef region is particularly important for dugongs. The largest concentration of dugongs yet seen during an aerial survey was observed along this coast in November 1976, north of Point Lookout (Heinsohn, Marsh, Gardner, Spain and Anderson, in press).

Ecology, Life History and Conservation

Dugongs inhabit warm inshore marine areas and require sheltered bays with seagrass beds (Heinsohn, Wake, Marsh and Spain, 1977). They normally feed on seagrasses (families Potamogetonaceae and Hydrocharitaceae). Marine algae are also occasionally eaten, especially if seagrasses are scarce or not available, and invertebrate animals are also sometimes taken (Heinsohn, Wake, Marsh and Spain, 1977). The most important predator of dugongs is man. It is also stated that the estuarine crocodile (*Crocodylus porosus*), the killer whale (*Orcinus orca*) and large sharks prey on dugongs, particularly young ones (Heinsohn, Wake, Marsh and Spain, 1977).

Little is known about seasonal movements, including possible migrations of dugongs. Recent aerial surveys indicate that dugongs may be migratory in some areas (Heinsohn, Marsh, Gardner, Spain and Anderson, in press) and resident in others (Heinsohn, Lear, Bryden, Marsh and Gardner, submitted). Dugongs feed on seagrasses both in the littoral and sub-littoral zones. Daily movements and activities are largely determined by tides and by weather (Heinsohn, Wake, Marsh and Spain, 1977). Very little information is available on natality, recruitment and mortality. A single calf is born and is thought to accompany the female for more than a year (Heinsohn, 1976). However the frequency of calving is not known. Marsh (submitted) states that dentinal growth layer data suggest the following: a life span of between 40 and 50 years for females, a maximum life span of at least 34 years for males, and a minimum age of 7 to 8 years for the occurence of sexual maturity in both males and females. Depending on whether one or two dentinal layers are produced per year, Mitchell (1976) suggests that dugongs can attain an age of just under 60 or just over 30 years and that they can reach sexual maturity at about either 10 or 15 years of age. The above data indicate that the dugong is a long-lived mammal with a low reproductive rate.

Dugongs occur singly and in groups of 2 to more than 100 (Heinsohn, 1976). Areas with extensive shallow sand banks may be used as calving and nursery areas (Heinsohn, Marsh, Gardner, Spain and Anderson, in press).

Heinsohn, Wake, Marsh and Spain (1977) and Heinsohn (1977a and 1978) review the effects of human activities on dugong populations. These include direct exploitation by hunting and netting for meat and other products, incidental and accidental netting in commercial fish nets and in shark nets, and environmental modification through habitat disturbances and pollution. The inshore seagrass beds on which dugongs depend are particularly vulnerable to environmental disturbances such as dredging, sedimentation, pollution, and excess fresh water run off. Severe disturbances to terrestrial ecosystems can have noticeable harmful effects on inshore seagrass beds. Direct mortality can also occur through toxic pollutants and collisions with boats and boat propellors. Marine national parks and other reserves for the protection of dugongs need to be established. The determination of sizes, numbers and distribution of such reserves in order to guarantee the protection of dugong populations is dependent on a sound knowledge of dugong population dynamics, movements and habitat needs.

Dugongs in the Northern Great Barrier Reef Region - Results of Aerial Surveys

Aerial surveys for dugongs were first begun in northern Australia in late 1974 (Heinsohn, Spain and Anderson, 1976), the main purposes being to (1) confirm the presence and obtain data on relative numbers of dugongs along various sections of coast; (2) locate major habitats or areas utilized by dugongs; (3) obtain information on movements, mainly by sequential surveys of given areas; (4) determine aspects of behaviour such as herd sizes and activities; (5) obtain data on recruitment and reproduction by means of calf counts; and (6) to monitor changes in dugong population sizes over a period of many years. With the exception of a survey made of the Torres Strait region in December 1975, the methods used are those given by Heinsohn, Spain and Anderson (1976) and Heinsohn, Marsh, Gardner, Spain and Anderson (in press). A high wing, single engine Cessna 182 was flown at speeds of between 130 and 204 km per hour at an altitude of about 275 m. For the Torres Strait and northern Cape York flight of December 1975, a low winged twin engine Aztec PH23 was used, flying at speeds of between 204 and 250 km per hour at an altitude of 152 m. Aerial surveys for dugongs in the northern Great Barrier Reef region were carried out as follows: Nov. 2, 1974, Cape Flattery to Bizant River (Princess Charlotte Bay); April 12, 1975, Cape Flattery to Cape Melville; Dec. 9, 13 and 14, 1975, Torres Strait Islands and northern Cape York; April 10 and 11, 1976, Cape York to Jeannie River (90 km north-east of Cooktown); Nov. 1 and 2, 1976, Annan River (south of Cooktown) to Cape York.

On November 2, 1974, 248 km of coast from Cape Flattery to the mouth of the Bizant River in Princess Charlotte Bay were surveyed (Heinsohn, Spain and Anderson, 1976). A minimal count of 168 dugongs was made along this 248 km length of coast, including two large herds of at least 27 and 67 individuals each. Except for the two herds, the remaining sightings were of solitary individuals or of groups of 5 or less. The weather conditions were ideal for aerial survey with calm water and sun.

On April 12, 1975, the coast between Cape Flattery and Cape Melville were surveyed. Weather conditions were very bad with heavy cloud cover, turbulent seas, and rain storms making dugong spotting difficult. Only 18 dugongs were seen.

In 1976 two areial surveys were made, one in April and a second in November, covering the Queensland coast from near Cooktown on the Cape York Peninsula, north along the east coast of Cape York to and including the Western Torres Strait Islands (including Mabuiag, Badu, Moa, Hammond, Goode, Wednesday, Thursday, Friday and Prince of Wales Islands), and south along the Gulf of Carpentaria coast to and including the Wellesley Islands near the Northern Territory border. The purpose of these flights was to locate major dugong habitat areas, get estimates of relative dugong numbers, and obtain information on possible large scale movements of dugongs during the year, such as possible seasonal migrations from one side of Cape York to the other. The timing of the surveys was chosen to coincide with major weather changes, with the April flights being at the end of the summer rainy season, and the November flights, near the end of the dry season. Unfortunately the April survey was not quite completed as the flight had to be terminated about 90 km northeast of Cooktown due to a tropical storm front. The general results of these two flights are summarized in Table I. Most of the 23 dugongs seen along the east coast of Cape York on the April 1976 survey were seen in the Flinders Group of Islands off Bathurst Head under good conditions of visibility.

In November 1976, 867 of the 1288 dugongs seen were sighted along the east coast of Cape York, with the largest concentrations occurring between Lookout Point, north of Cooktown, and Cape Sidmouth, north of Princess Charlotte Bay. Approximately 500 to 600 dugongs (the largest concentration yet seen from the air) were seen along one 13 km length of coast in this region on November 2. In this huge concentration subgroups ranged in size from individual animals to discrete herds of over 100 dugongs. Eleven per cent of one subgroup consisted of calves. The coast in this region is bordered by mangrove forests.

Of three survey flights made of the Torres Strait Islands in December 1975, only one was made within the area of the northern Great Barrier Reef. This flight included the coast of Cape York and adjacent islands from the mouth of the Escape River to the tip of Cape York plus reefs between Turtle Head Island off the Escape River and Dugong Island. Only two dugongs were seen on this flight, both on Whyborn Reef north of Turtle Head Island. It is interesting to note that no dugongs were seen in the eastern Torres Strait Islands including isolated cays such as Don, Anchor, and Bramble Cays at the northernmost end of the Great Barrier Reef.

Importance of the Northern Great Barrier Reef Region and Research Requirements

The most important dugong areas are the inshore areas, particularly those protected by headlands and islands. The largest numbers of dugongs have been seen between Cooktown and Princess Charlotte Bay. Other areas north of Princess Charlotte Bay (e.g. Temple, Margaret, Shelburne, and Newcastle Bays) may also be very important and need further investigation. Because of the large variability in visibility and weather conditions on survey flights, it is difficult to make definite conclusions about possible seasonal migrations around Cape York, although large changes in numbers were observed. The difference, in numbers of dugongs seen along the east coast of Cape York in April and November, can be accounted for by long-distance migrations, e.g. around the northern tip of Cape York into the Gulf of Carpentaria, north into Papua New Guinea waters, or south along the Queensland coast. It is also possible that, during periods with strong easterly and southeasterly winds, dugongs utilize protected offshore areas inside the Great Barrier Reef. These northern reef waters contain an extensive network of coral reefs, sand cays, and islands. It is planned to do further aerial surveys in this region during periods of favourable tides and weather to further assess the areas already surveyed and to fully determine the importance of islands, cays, and reef flats as dugong habitats. The movements of dugongs need to be studied through tagging to establish whether or not dugongs migrate, and, if so, how far and where. If dugongs are migratory or nomadic, a series of reserves would have to be set up for their full protection. Experiments with tagging have begun at James Cook University.

CETACEA

Queensland Cetaceans

Relatively little is known about the cetaceans found in Queensland waters and virtually nothing is known about those species occurring in the waters of the northern Great Barrier Reef. Most Queensland data comes from stranded and accidentally killed whales and dolphins. Data also come from sightings and from animals kept for commercial display in Oceanaria. The humpback whale (*Megaptera novaeangliae*) is known from data collected during commercial whaling operations in southern Queensland.

The order Cetacea (whales, dolphins and porpoises) is divided into two suborders: the Mysticiti (baleen or whalebone whales) and the Odontoceti (toothed whales).

In the southern hemisphere, mysticetes feed almost exclusively on euphausids ('krill') and other planktonic crustaceans which they filter from seawater by their baleen plates (large keratinous downgrowths from their hard palates). Most of the baleen whales regularly migrate between summer feeding grounds in the Antarctic and breeding grounds in warm temperate to tropical waters. However Bryde's whale (*Balaenoptera edeni*) appears to form relatively localized subpopulations in tropical to subtropical areas, and carries out less extensive migrations (Gaskin, 1976). Five species of baleen whales have been recorded from Queensland. The humpback whale (*Megaptera novaeangliae*) supported a land based whaling operation in southern Queensland from 1952 to 1962. By the early 1960's, the catch statistics showed clear signs of over-exploitation as larger numbers of young animals were taken to fill the catch quotas (Chittleborough, 1962 and 1963, in Bryden, in press). Recent surveys suggest that the population of humpback whales migrating along the Queensland coast continues to remain small (Bryden, M.M., pers. comm.). The other mysticetes (blue, finback, sei and minke whales) are mainly known from occasional strandings and from sightings. A sixth species, Bryde's whale may also occur along the coast of Queensland (Bryden, in press).

Toothed whales range in size from the giant sperm whale, up to 19 m in length, to small dolphins of less than two metres in length. They appear to be opportunistic feeders, taking a variety of fishes, squids and some other invertebrates. Bryden (in press) suggests that 20 species of odontocete whales occur off Queensland, of which at least 16 species are oceanic and three species occur primarily inshore. The inshore species are best known. The Irrawaddy dolphin (*Orcaella brevirostris*) is the species most commonly caught in shark nets set off Townsville (Heinsohn, 1975; Mitchell, 1975). Until recently it was known only from southeast Asia. The other two species of inshore dolphins are the bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific humpback dolphin (*Sousa cf. chinensis*), both of which have also been caught in shark nets (Heinsohn, 1975; Bryden, in press). All three inshore species have been kept in captivity in Queensland (Bryden, in press), and all three have been observed feeding within a few meters of shore. The oceanic species of toothed whales recorded off Queensland are mainly known from strandings and/or from sightings at sea.

Other than limited observations on the distribution and biology of bottlenose dolphins in southern Queensland, very little is known about the abundance, distribution, biology and ecology of any other toothed whales in Queensland waters, particularly the northern Great Barrier Reef region.

Annotated Check List of Cetaceans Thought to Occur in Waters of the Northern Great Barrier Reef

Table II is an annotated check list of cetacean species that can be expected to occur in the region of the northern Great Barrier Reef. The classification followed is that of the Marine Mammal Commission (1976), and species names are as given by Mitchell (1975). Most of the species are oceanic and may not normally come inside the Great Barrier Reef. All the species listed have extensive ranges, at least throughout the Indian and western Pacific oceans and, in some, worldwide. Certain species are included which have not yet been recorded from the Queensland coast, but which are to be expected. The species list is largely based on records from Indonesia , Papua New Guinea and the Solomon Islands to the north (Dawbin, 1972 and 1978) and from southern Queensland and northern New South Wales to the south (Longman, 1926; Dawbin, 1978; and Bryden, in press). Further information on the distribution and biology of cetaceans may be found in Nishiwaki (1972) and Mitchell (1975).

Research Requirements and Conservation

Ideally, life history parameters (age of attainment of sexual maturity for males and females, mortality factors, calving intervals, sex ratios, and age structures of populations), feeding biology, distribution, abundance, habitat requirements and preferences, and movement patterns need to be determined for important species. However, this requires specialized and very expensive research programmes. At a minimum, every effort should be made to collect biological data from stranded animals. (See Mitchell, 1975, on how to collect data from dead cetaceans). Surveys need to be carried out in the waters of the northern Great Barrier Reef to determine the species, distribution and abundance of cetaceans which occur there. It is now possible to reliably identify many species of cetaceans at sea using appropriate field guides, the best of which is Leatherwood, Caldwell and Winn (1976), and efforts should be made to record species of cetaceans sighted during research cruises in the northern Great Barrier Reef region. Mitchell (1975) summarizes methods and techniques that can be used for the biological investigation of small cetaceans.

The main potential threats to cetaceans in Queensland are through accidental or incidental netting mainly by commercial fishermen and by habitat modification including pollution. Monofilament fishing nets are particularly dangerous as they appear to be acoustically invisible to cetaceans (Mitchell, 1975). Some cetaceans are caught in shark nets (Heinsohn, 1975; Bryden, in press). To conserve cetaceans, the full range of marine habitats needs to be preserved. Since many, if not most, cetaceans probably range over very large areas of the sea their conservation and management and some research have to be carried out at an international level. One area of research necessary for the conservation and management of cetaceans is to determine unit populations or stocks and the distribution and movements of these stocks for each species. Many, if not most, cetaceans seen in Great Barrier Reef waters may well belong to unit populations or stocks that are international in their distributions and movements.

CONCLUDING REMARKS

The northern Great Barrier Reef region is a very important refuge for marine mammals. It is a vast and almost unspoiled wilderness of uninhabited coast, islands, reefs and open water. From the standpoint of marine mammal conservation the entire region from the coast to beyond the outer edges of the Great Barrier Reef should be declared Marine Park and managed under the single authority of the Great Barrier Reef Marine Park Authority.

The area is particularly valuable as Marine Park and as a wilderness area for a number of reasons: (1) Levels of exploitation of marine resources are still relatively low. (2) There are no polluting industries on the mainland. (3) Because of the lack of intensive agriculture there is virtually no pollution from pesticides. (4) Because of the generally low terrain of much of Cape York and the absence of land clearing there is little in the way of sedimentation occurring from human caused erosion.

A major threat to marine mammals would be through the establishment of large scale net fisheries which have been so destructive to dugongs in some parts of the world (Heinsohn, Wake, Marsh and Spain, 1977) and to small cetaceans (Mitchell, 1975). Oil pollution resulting from either drilling or from ship spills is another threat. Extensive disturbance by boating and other human activities can also have deleterious effects on marine mammals.

The northern Great Barrier Reef region should be managed to protect it from threats of extensive net fisheries and pollution, and other human disturbances. Long ranging migratory marine mammals are also threatened when they move from areas of protection to areas where exploitation occurs, e.g. marine mammal fisheries in other areas of the southwest Pacific could threaten animals protected in Australian waters.

Thus complete protection of some species requires international agreements. This is particularly true of the large whales and some small whales, dolphins, and porpoises, and possibly even dugongs.

Because of its scenic beauty, wilderness and scientific importance the northern Great Barrier Reef and Cape York region should be preserved as a vast scenic wilderness to be enjoyed and studied as a major reserve for tropical resources. Marine mammals are an important part of the biological resources of this region.

ACKNOWLEDGEMENTS

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TABLE I : NUMBER OF DUGONGS SIGHTED ON TWO AERIAL SURVEYS COVERING THE GULF OF CARPENTARIA, TORRES STRAIT ISLANDS, AND EAST COAST OF CAPE YORK PENINSULA (HEINSOHN, 1977C)

Coastal Areas Surveyed	APRIL		NOVEMBER	
	No. of Dugongs	Visibility	No. of Dugongs	Visibility
Wellesley Islands	154	Good	271	Good
Wellesley Islands to Torres Strait (Cape York)	174	Fair to Poor	66	Fair to Poor
Torres Strait Islands	96	Good	84	Good
Torres Strait (Cape York) to Cooktown	23*	Very Poor	867	Good
TOTAL	447		1288	

* Survey incomplete (terminated approximately 80 km northeast of Cooktown due to bad weather)

TABLE II : ANNOTATED CHECK LIST OF CETACEANS EXPECTED TO OCCUR IN WATERS OF THE NORTHERN GREAT BARRIER REEF

Suborder, Family Species	Notes
Suborder Mysticeti	
Family Balaenopteridae	
Blue whale *Balaenoptera musculus*	Oceanic, stranded remains from near Rockhampton, Qld. (Bryden, in press); recorded from Indonesian waters (Dawbin, 1972).
Fin whale *Balaenoptera physalus*	Oceanic, recorded from Indonesian waters (Dawbin, 1972); listed by Bryden (in press) as a Qld. species.
Bryde's whale *Balaenoptera edeni*	Oceanic, possible sighting from air off southern Qld. in 1976 (Bryden, in press); recorded from Indonesian waters (Dawbin, 1972).
Minke whale *Balaenoptera acutorostrata*	Oceanic to inshore, specimen found at Caloundra in 1971 (Bryden, in press); recorded from Indonesian waters (Dawbin, 1972).
Sei whale *Balaenoptera borealis*	Oceanic, records in Qld. museum including skeleton from Tin Can Bay (Bryden, in press); recorded from Indonesia (Dawbin, 1972).
Humpback whale *Megaptera novaeangliae*	Oceanic to inshore, seen in southern Qld.; stocks in Qld. waters have not yet recovered from whaling although now protected, breeds in equatorial waters (Bryden, in press); occasionally seen as far north as the Gulf of Papua, Solomon Islands, and New Britain (Dawbin, 1972).
Suborder Odontoceti	
Family Physeteridae	
Sperm whale *Physeter catodon*	Oceanic (Bryden, in press); stranded remains recorded in Qld. museum; not abundant (Bryden, in press); occasionally sighted in Solomon Islands, New Guinea region (Dawbin, 1978).
Pygmy sperm whale *Kogia breviceps*	Oceanic, several strandings in Qld. at Yeppoon, Caloundra, Sandgate, and Fraser Island (Bryden, in press); stranding on north coast of New Guinea (Dawbin, 1972).
Family Ziphiidae	
Longman's beaked whale *Mesoplodon pacificus*	Oceanic (Bryden, in press); species described from skull and jaw found on beach near Mackay, Qld. in 1882 (Longman, 1926).
Blainville's beaked whale *Mesoplodon densirostris*	Oceanic, strandings at Yeppoon and Sarina, central Qld. (Bryden, in press).
Strap-toothed whale *Mesoplodon layardii*	Oceanic, strandings at Southport, southern Qld., and near Emu Park, central Qld. (Bryden, in press).

TABLE II (Cont'd)

Cuvier's beaked whale *Ziphius cavirostris*	Oceanic; stranding at Maryborough, Qld. (Bryden, in press).
Family Delphinidae	
Irrawaddy dolphin *Orcaella brevirostris*	Common inshore dolphin, recorded at Townsville, Qld. (Heinsohn, 1975), Cape York Peninsula, Gulf of Papua, Cairns (Dawbin, 1978).
Melon-headed whale *Peponocephala electra*	Oceanic; mass stranding Moreton Island, 1976 (Bryden, Harrison and Lear, 1977); Mission Beach, north Qld. (Bryden, Dawbin, Heinsohn, and Brown, 1977); recorded in Indonesia (Dawbin, 1978).
Pygmy killer whale *Feresa attenuata*	Oceanic (Bryden, in press); not reported from Qld., one stranding at Kingscliffe, N.S.W., near Qld. border (Bryden, 1976; Bryden, in press); taken by natives in Solomon Islands (Dawbin, 1978).
False killer whale *Pseudorca crassidens*	Oceanic (Bryden, in press); east coast of Australia, Solomon Islands, Gulf of Carpentaria, north of New Guinea (Dawbin, 1972 and 1978; Bryden, in press).
Killer whale *Orcinus orca*	Oceanic to inshore; seen irregularly off Qld. coast (Bryden, in press); sightings from all along east coast of Australia to Papua New Guinea (Dawbin, 1972 and 1978).
Short-finned pilot whale *Globicephala cf. macrorhynchus*	Oceanic, several strandings in Qld. (Bryden, in press); 1976 stranding near Proserpine, Qld. (Heinsohn, G.E. unpubl.); *G. melaena* reported Fiji, Solomon Islands and Papua New Guinea (Dawbin, 1972 and 1978).
Rough-toothed dolphin *Steno bredanensis*	Oceanic (Bryden, in press); tropical and sub-tropical distribution; stranding at Barrow Island, northwestern W.A. (Butler, 1975, in Bryden, in press); known from Indonesia and southern Solomon Islands (Dawbin, 1978).
Indo-Pacific hump-backed dolphin *Sousa cf. chinensis*	Common inshore species (Bryden, in press; Heinsohn, 1975; around Qld. coast as far south as Sydney, N.S.W. (Dawbin, as personal communication, in Bryden, in press); recorded as *Sousa borneensis* in Indonesia and along Queensland coast between Brisbane and Gladstone (Dawbin, 1978); caught in shark nets, Townsville, Qld. (Heinsohn, 1975).
Fraser's dolphin *Lagenodelphis hosei*	Oceanic, described in 1956 from a skeleton collected on a sea beach in Sarawak before 1895 (Fraser, 1956); species may be continuously distributed in high seas tropical waters of the Pacific and Indian Oceans; one specimen washed ashore at Coffs Harbour, N.S.W., in 1971 (Perrin, Best, Dawbin, Balcomb, Gambell and Ross, 1973).

TABLE II (Cont'd.)

Common dolphin *Delphinus delphis*	Oceanic, probably remain outside Great Barrier Reef, occurs world-wide in warm temperate and tropical waters, recorded in southeast Qld., not recorded from north Qld. (Bryden, in press).
Bottlenose dolphin *Tursiops truncatus*	Common inshore species, very common in southeast Qld. (Bryden, in press); caught in shark nets, Townsville, Qld. (Heinsohn, 1975); commonly seen in north Qld. (Heinsohn, G.E., unpubl.); common, north coast of Papua New Guinea (Dawbin, 1972).
Risso's dolphin *Grampus griseus*	Oceanic, known from one skull in Qld., observed in Papua New Guinea region (Bryden, in press); seen along New Guinea coast, skulls collected from Solomon Islands (Dawbin, 1978).
Spotted dolphin *Stenella cf. attenuata*	Oceanic, not yet known from Qld., no Qld. Museum records (Bryden, in press); ranges from Solomon Islands to New Guinea (Dawbin, 1978).
Spinner dolphin *Stenella cf. longirostris*	Reef waters, recorded from Michaelmas Reef near Cairns (Heinsohn, G.E., unpubl.); Oceanic (Bryden, in press); Solomon Islands to New Guinea and along Qld. coast (Dawbin, 1978).
Striped dolphin *Stenella coeruleoalba*	Oceanic (Bryden, in press); known from Solomon Islands, one skull North Island of New Zealand, still unknown from coast of Australia (Dawbin, 1978).

SEA TURTLES OF THE NORTHERN GREAT BARRIER REEF

Colin J. Limpus

Abstract

Of the four species of sea turtles (Family Cheloniidae) inhabiting the northern Great Barrier Reef area of north-eastern Australia - the loggerhead turtle (Caretta caretta (L.)), the green turtle (Chelonia mydas (L.)), the hawksbill turtle (Eretmochelys imbricata (L.)) and the flatback turtle (Chelonia depressa Garman) - only the last does not breed there.

Lizard Island ($14^{o}40$'S latitude) is the northern limit of nesting by the loggerhead turtle; on the other hand, large populations of green turtles breed on cays of the northern outer barrier reef and low-density hawksbill turtle nesting is a feature of the adjacent inner shelf cays.

The green turtle rookery on the 30-ha Raine Island ($11^{o}36$'S, $144^{o}01$'E) is apparently the largest for this species throughout its pan-tropical distribution; longer distance recoveries of these turtles tagged at Raine Island have been made from south of Cooktown to throughout Torres Strait and southern Papua New Guinea west to Aru Island in Indonesia. In these regions large numbers of green turtles are harvested by the indigenous peoples.

Research being conducted on these northern sea turtle populations by officers of the National Parks and Wildlife Service of Queensland and of Applied Ecology Pty. Ltd. are now being centred on Raine Island. Because this also supports the largest populations of some other faunas, a long-term synecological investigation is being devised with the island as one of a series of Nature Reference Sites, or permanent "bench-marks", being established throughout the State for conservation purposes.

CROCODILES IN THE NORTHERN REGION OF THE GREAT BARRIER REEF PROVINCE

Grahame J.W. Webb

There are two species of crocodile in Australia, but only one, Crocodylus porosus (the estaurine or saltwater crocodile) is likely to occur within the proposed park. The second species, Crocodylus johnstoni, is almost invariably found in the freshwater upper reaches of rivers, away from tidal influence.

Overexploitation in order to supply skins for the hide trade has resulted in C. porosus becoming seriously threatened throughout most of it's range (from India and South East Asia in the north, down through the islands of Indonesia to Papua New Guinea and Australia in the south). In Australia, the species is now protected, and in the areas of Western Australia and the Northern Territory which have been surveyed, the populations are beginning to recover. Unfortunately, there appears to be no published data on the current status of C. porosus within the rivers which drain into the proposed park. The present discussion thus relies heavily on the results of research carried out in the Northern Territory (see chapters 13 to 18 in "Australian Animals and their Environments", editors Messel and Butler, Shakespeare Head Press, Sydney; a general discussion of results), and attempts to convey in general terms, what can be expected from C. porosus in the park now, and in the future.

Crocodiles as a group tend to be inhabitants of the water's edge, and C. porosus is "typically" found on the edge of the mangroves in the tidal rivers which run to the coast. Populations exist in freshwater rivers, creeks, swamps and billabongs, however such areas appear to be secondary habitat. On the east coast of Cape York, most of the remaining C. porosus would be in the rivers of the mainland, with occasional individuals moving around the coast and/or drifting out to the islands and cays. A permanent freshwater swamp or creek on an island, could support a nesting female, and perhaps a small population, but because the limits of the proposed park only extend to the river mouths, the majority of C. porosus on the east coast of Cape York would be outside the park.

The number of C. porosus within the park will ultimately reflect the distribution and abundance of the species on the mainland. Thus, the rate at which the mainland populations recover can be expected to govern the rate at which the population within the park increases.

Although no quantative data are available, the present distribution and abundance of C. porosus within the mainland rivers will have been determined mainly by:

1. the number of adults which avoided the hunters, usually by becoming wary of boats and/or lights;
2. the number of adults from inaccessible swamps and billabongs which have moved back into the tidal rivers since protection;
3. the success of nesting by the remaining adults;
4. the survivorship of hatchlings and juveniles;
5. the dispersal patterns of hatchlings and juveniles;
6. the level of poaching, particularly of juveniles.

The most important single parameter which will have determined the rate of recovery to date, is nesting success. Nests are mounds of vegetation constructed during the wet season (particularly at the beginning of the wet), and each one contains an average of 50 eggs; it appears that a female will only make one nest in any one year. Typically, nests are constructed adjacent to sections of the river in which salinities do not exceed 25 - 30^{o}/oo for long periods of the dry season. That is, they avoid the river mouths, unless there are conveniently located freshwater swamps.

Extensive flooding of the tidal rivers during the wet season results in most nests being inundated by flood waters for at least some part of the 90 day incubation period. In Arnhem Land, 90% of nests under study were at least partly lost to flooding, and at Edward River, on the west coast of Cape York, the Applied Ecology project is finding the same major source of egg mortality. The literature indicates flooding as a cause of egg mortality in areas outside Australia, so it appears that C. porosus's habit of nesting just above high water mark during the wet season, jeopardises the chances of the nests surviving floods. On the east coast of Cape York, flooding is expected to be a major source of egg mortality.

Surprisingly, once a nest survives the floods (and predators) and the eggs hatch, survival rate of the hatchlings is high. In Arnhem Land, 60% of 52 hatchlings marked at the nest were either caught or seen one year later. This high survival rate is possibly an artifact of the low numbers of larger C. porosus.

The size at which juveniles may leave the river mouths and thus enter the proposed park depends on how far upstream the successful nests were constructed. Usually (unless there were swamps near the river mouth), the nests would be well upstream of the mouth, and the hatchlings, which if undisturbed would probably form crèches, would mark the nest site. One year olds tend to be mainly in the same region as the hatchlings, with the males showing a significant downstream movement. Two-year-olds, three-year-olds and four-year-olds tend to be further downstream, with the males moving more than the females. Thus, in a longer river, the older age-size cohorts tend to be downstream of the younger ones, with males of any age group tending to be downstream of the females. If the nesting areas are 10km from the mouth, two-year olds would readily move out of the mouth, however if the nesting areas were 30km upstream, it would be the four-year olds which would reach the mouth. The greater mobility of males is reflected in the fact that almost all juveniles caught in the mouths of rivers are males.

Little is known of the movements of the juveniles once they leave the mouth of a river. On the Arnhem Land coast, juveniles are occasionally sighted on beaches, and the impression is gained that they drift mainly within sight of land. However, some juveniles make definite long sea journeys - recently(30 June 1977) John Parmenter sighted a 1m specimen on Mimi Island in the Torres Strait; 27 km from the nearest island an an unknown distance from the nearest C. porosus population.

The extent to which adult C. porosus leave the rivers and move either around the coast or out to sea, is also imprecisely known. Most sightings of C. porosus "at sea" are of individuals moving within a few kilometers of land and evidence from Arnhem Land indicates that at least some males may include a segment of the coast within a regular cruising or home range. As with the juveniles however, some records indicate long sea journeys. For example, a 3.8m male C. porosus recently arrived at Ponape, Eastern Caroline Islands, 1360 km from the nearest known population (Allen, G.R.: Copeia, 1974:553). With C. porosus having the ability to travel long distances at sea, it is possible that individuals from Papua New Guinea and the Bismarck Archipelago could drift into the outer islands of the proposed park.

In conclusion, it is clear that although the biology of C. porosus on the east coast of Cape York is not expected to differ from that in other parts of Australia, there is virtually no data with which to confirm or reject this expectation. The "status" of C. porosus on the mainland is essentially unknown, and surveys would be needed to rectify this situation. The determination of which rivers were supporting a breeding population of C. porosus is an urgent requirement, as the recovery of C. porosus could in fact be dependent on one or two river systems; in many rivers, widespread flooding and/or high salinities during the dry season appear to result in no successful C. porosus reproduction.

Within the area of the proposed park, freshwater swamps and creeks should be listed, and if possible surveyed, as they represent possible C. porosus nesting habitat. Sightings of C. porosus within the area of the proposed park should be registered in a central log book, and if possible estimated size, distance from shore, direction of travel and exact location should be noted. Numbers sighted during aerial surveys across the reefs could give some quantitative data on the abundance of the species.

At the present time, C. porosus numbers are so low everywhere, that they are unlikely to be a major vertebrate within the park. Recovery should take many years, because approximately 10 and 16 years are required for females and males respectively, to mature. However, once numbers do begin to build up C. porosus could become a regularly sighted vertebrate within the park. At this time, their habit of feeding on mammals of the water's edge could pose some real management problems, and certainly some public relation ones.

The declaration and zoning of a marine park which does not include tidal rivers should thus not have a major influence on C. porosus one way or the other. However, there would seem to be considerable merit in trying to incorporate at least some rivers into the park. Many species of fish migrate back and forth between the fresh and salt water, and if such rivers were included in the park, netting could be controlled, and these rivers would serve a valuable role as both a control on the rivers which are being netted, and a refuge for the species which move between fresh and salt water.

TWO BRIEF SURVEYS OF CORAL REEFS OF THE NORTHERN GREAT BARRIER REEF

R.G. Pearson
Queensland Fisheries Service

INTRODUCTION

Two surveys were undertaken in the region currently of interest to the Great Barrier Reef Marine Park Authority, i.e. between Princess Charlotte Bay and the latitude of Thursday Island, as part of the Queensland Fisheries Service monitoring programme on the crown-of-thorns starfish (Acanthaster planci) on the Great Barrier Reef. Previously no systematic searches had been made for Acanthaster in this region (which represents almost one third of the entire length of the Reef). The first survey was in June/July 1974 of the region between Princess Charlotte Bay and Curd Reef (12°36'S), while the second was in November 1975 of the region between 12°36'S and 10°30'S. The objectives were to determine the distribution and abundance of Acanthaster on as many reefs as possible and to assess the impact of their predation on coral assemblages. The surveys were too broad to obtain anything other than the barest information on the coral assemblages encountered.

METHODS

To determine the presence of Acanthaster aggregations a spot-check technique was used which was developed for the rapid surveying of large tracts of reefs like those existing at the southern end of the Great Barrier Reef (the so-called "hard-line" complex). This technique has been described elsewhere (Pearson & Garrett 1976; Pearson & Garrett ms). It consisted of making brief observations at regular intervals around the margin of each reef visited. No attempt was made to inspect the reef flat unless Acanthaster aggregations were suspected to occur there. Observations were made from two dinghies which started from the same point and travelled in opposite directions around the reef margin until they met again on the opposite side. Each dinghy carried an observer (R.G.P. and R.N.G.) and a helmsman. At each spot check or station, the observer simply leant out over the gunwhale and using a face mask, viewed the substrate for a known period, usually one minute. During this time the dinghy was slowly manoeuvred along the reef edge from shallow water near the reef crest to deeper water on the reef slope. At the completion of the observation period, the number of Acanthaster observed was recorded and exceedingly brief notes were made of the following -

(i) hard coral growths - either a subjective assessment (poor, average, good or excellent) or alternatively a visual estimate of the percent cover.

(ii) proportion dead standing hard coral.

(iii) dominant substrate type - sand, rubble, bare rock, etc.

(iv) degree of reef slope - steep, average, gentle, etc.

(v) visually dominant organisms - Acanthaster, Porites heads, staghorn Acropora thickets etc.

The dinghy was then moved rapidly a distance of several hundred metres to the next observation site (station) on the reef perimeter. The maximum depth to which observations could be made was about 15 m, less if the water was turbid. The location of each station was recorded on an outline drawing traced from an aerial photograph of the reef.

With respect to mapping the distribution and abundance of Acanthaster over a large section of the Great Barrier Reef, the results obtained using this spot check technique compare favourably with those obtained using the more expensive and time-consuming tow technique used by Kenchington and others (Pearson & Garrett 1976; Kenchington 1976; Kenchington & Morton 1976). The main weakness of the method lies in the coral assessments which were invariably subjective. Until such time as an objective set of criteria are available for such broad scale surveys, and attempts are now being made to develop these, readers must bear with the coral assessments in this report. For the moment they are to my knowledge the only ones available for such a large area.

A more recent comparison of the two methods used to assess coral communities on a broad scale has been completed (Done et.al. in prep.) and the results are now being analysed using a computer programme developed by Dr. Done. Indications are that whereas visual estimates of percent coral cover and proportion of dead standing coral are similar, results differ as to the visually dominant corals recorded. The reasons for these differences are to be investigated. It should be emphasised that at the time the two surveys were conducted, the spot check technique was being used primarily to determine starfish numbers and to assess coral damage.

One problem encountered during the surveys was that few of the reefs are named; in fact many do not appear on maps or charts. Reefs visited were thus assigned a letter or number chronologically.

RESULTS

(a) First Survey, Princess Charlotte Bay to Curd Reef, June/July 1974

A total of 42 reefs were visited during the 11 day survey (Fig. 1) which commenced at Tydeman Reef (14°00'S), an outer barrier reef and continued northwards along the almost continuous chain of outer barrier reefs to Log Reef (12°40'S). From there the survey was switched to the inner patch reefs commencing at Curd Reef (12°36'S) and continuing southwards to Clack Reef (14°04'S). The following reefs were visited - Davie, Wilson, Rodda, Tijou, Bligh, First Small, Burke, Zenith, Wye, Chapman, Sherrard, Osbourne, Celebration, Ellis, Morris, Fife, Noddy, Magpie, Lytton, Pelican, Hedge, Grub and unnamed reefs "K" to "Z". During the return voyage to Cairns, Ingram Island (14°26'S) was surveyed. Observations were made at 875 stations at an average of 20.3 stations per reef (range 4 to 72) (R.G.P. and R.N.G. data combined). I surveyed mostly the lee sides of reefs, particularly the outer barrier reefs, whereas R.N.G. surveyed mostly the weather sides.

Acanthaster

It was only on the last day of the survey that any Acanthaster were observed, 7 on Clack Reef and 10 on Ingram Reef. Starfish were observed at 4 of the 24 stations on Clack Reef and 4 of the 16 stations on Ingram Reef. On both reefs starfish were restricted to the southern perimeter. Extensive areas of dead standing hard coral, particularly stands of staghorn and tabulate Acropora, were present around the perimeter of both reefs. On Clack Reef 10 of the 24 stations were recorded as having at least 50% dead standing coral while on Ingram Reef 11 of the 16 stations were in the same category. At several of these stations mortality of the once good coral growths was estimated to exceed 90%.

Of some interest was the finding of small numbers of dead tabulate Acropora in deeper water on the more protected seaward slopes and tips of the outer barrier reefs. As in my experience these usually signify the presence of Acanthaster, it may be that small populations of starfish exist on these reefs.

Coral Assemblages

As this report has been written nearly four years after the survey, very few memories of individual stations still exist. Consequently almost total reliance is placed on field notes, which, as mentioned before, were exceedingly brief. Typical examples of the data recorded at each station were as follows -

(i) 1974 Tijou Rf, station 1, lee side, very good corals in 30' to 40' on gentle slope, some big Porites heads, a few tabular Acropora, and some small thickets of staghorn Acropora to 3' high

(ii) 1974 Pelican Rf, station 4, lee side, average corals, branching Porites, massive Porites to 6', small heads, occasional tabular Acropora, heavy Pavona, Pectinia, a few explanate Echinopora, some soft coral.

(iii) 1974 Noddy Rf, station 5, weather side, poor to average corals, on small bommie, Diploastrea, soft corals, massive colonies to 18", occasional Acropora.

Considering just my own data on 38 reefs at 354 stations (40.5%), I recorded coral growths as being in the categories shown in Table 1. A greater proportion of sites assessed as either excellent or good occurred on the outer barrier reefs and a higher proportion of poor and average sites were located on the inner patch reefs (Table 2). The best areas were located on the lee sides and ends of the smaller outer barrier reefs. The only sites on the exposed seaward slopes of the outer barrier reefs where there were rich coral growths were on the small reefs orientated north-west to south-east rather than north to south e.g. Tydeman, Fife, and unnamed "W". The remainder are much more exposed to the prevailing south-easterlies which must inhibit the full development of corals as seen in more protected locations. The poorest areas were located on the western margins of the inner patch reefs. Generally the water on these reefs was very dirty, underwater visibility being about 5 m compared with 20-30 m on the outer barrier. This may have been partly responsible for assigning more stations to the poor and average categories since the assessments were made of a much smaller and shallower section of reef slope viewable in one minute. However, the vast quantities of fine sediments observed on these inner reefs, particularly those bordering Princess Charlotte Bay, must adversely affect the development of luxuriant coral communities. The most dominant corals on these reefs appeared to be branching and massive Porites and soft corals.

Other Observations

The only other observation of note, apart from the diversity of vegetated and unvegetated coral cays in the area, was the existence of numerous dead giant clams, Tridacna gigas, on Curd and Burke Reefs. I presume that Taiwanese clam boats were responsible.

(b) Second Survey, 12°36'S to 10°30'S, November 1975

A total of 68 reefs were examined during the 11 day survey. All except seven of them were located along the chain of outer barrier reefs (Fig. 2). The main reason for selecting these reefs was because either aerial photography or Landsat imagery was available which could be used to pinpoint the location of each station. The vast area between the outer barrier and the mainland appeared to contain a maze of shoals and ill-defined reefs making accurate navigation extremely difficult. The survey commenced at unnamed reef no. 1 on the outer barrier (12°34'S) and extended northwards along the outer barrier to unnamed reef no. 61. (10°32'S). From there the survey moved westwards towards Thursday Island through a small group of inner patch reefs, finishing at Dugong Island (10°31'S). Observations were made at 1195 stations, at an average of 17.6 stations per reef (range 2 to 64) (R.G.P. and R.N.G. data combined). In contrast to the First Survey I surveyed mostly the weather sides and channels between the outer barrier reefs, whereas R.N.G. surveyed mostly the leeward reef slopes.

Acanthaster

Only 5 Acanthaster were observed during the entire survey at three reefs, including three individuals on one reef. All were inner patch reefs located between the tip of Cape York and the outer barrier.

Extensive areas with a high proportion (>50%) of dead standing hard coral were observed on eight outer barrier reefs between 10°33'S and 10°46'S. Some dead standing hard coral was observed on a further 16 outer barrier reefs, mainly between 10°38'S and 10°59'S. Most dead coral occurred on the leeward reef slopes or on the almost vertical walls of the deep (40 m plus), narrow (100 m or less), channels which separate reefs in this region. This damage is attributed to Acanthaster although none were seen during the survey

(Pearson and Garrett ms.) However, Birtles and Zell (pers comm) reported sighting 64 Acanthaster on a channel wall of one of the outer barrier reefs ($10^{o}42'$S) near Yule Entrance in November 1974.

Coral Assemblages

As for the First Survey almost total reliance was placed on field notes in assessing coral assemblages. Typical records for each station were as follows -

(i) 1975 unnamed reef no. 9, station 56, weather side, average slope to sand at 50', greater than 30% live hard coral cover including large Acropora palifera, staghorn and some tabular Acropora.

(ii) 1975 unnamed reef no. 46, station 25, weather side, very gently slope with scattered small corals, less than 5% cover in 20' to 40'.

(iii) 1975 unnamed reef no. 57, station 7, shoad 20' to 40', mostly dead except for some yellow Porites lichen and encrusting Millepora.

Considering just my own data on 66 reefs at 550 stations (46.0%), I recorded coral growths as being in the categories shown in Table 3. Comparison of Table 3 (Second Survey) with Table 1 (First Survey) shows almost twice the number of stations in the poor and average categories for the Second Survey (69.1% as opposed to 35.3%). There appear to be two reasons for this difference. Firstly there was a larger number of stations on the Second Survey with a high proportion (>50%) of dead standing hard coral - 151 out of 1195 (12.6%) compared with only 28 out of 875 (3.2%) for the First Survey. As a result more stations were categorized as poor or average on the Second Survey. Secondly, the proportion of stations in each category refer to my data only, which as mentioned previously, covered mostly the lee sides of the outer barrier reefs on the First Survey (Table 2) and mostly the weather sides and channels of the outer barrier reefs on the Second Survey (Table 4). Fewer stations were recorded in the good or excellent categories in the Second Survey simply because there is less chance of encountering luxuriant coral growths on the highly-exposed, weather sides of the outer barrier reefs.

Other Observations

Very large numbers of small species of dark-blue trigger fish were noted on the seaward slopes of several outer barrier reefs e.g. Reef nos. 47, 52 and 55. Several hundred of these fish could been seen at each spot check which covered about 50 m of the reef edge. They were dispersed just above the gently sloping substrate which appeared almost smooth with little coral cover. The total population of this species must be very large indeed as similar numbers were observed at adjacent spot checks which were spaced at intervals of about 600 m.

A spectacular fish assemblage was observed on the exposed, northern tip of Reef no. 12. It comprised three very large gropers, a number of sharks and a school of perhaps 500 chaetodons, Hemitaurichthys zoster (Bennett), normally an uncommon species, at least in my experience.

Another interesting observation concerned the curious circular features visible on aerial photographs of the lagoon between Curd Reef and the outer barrier at approximately 12°33'S, e.g. Division of National Mapping, August 1972, C A B 7082, Run 17, no. 213. Despite making one traverse across the lagoon using an echo-sounder it could not be established whether these features were surface phenomena i.e. patches of discoloured water, or whether they indicated unusually-shaped, deep water shoals. Data were forwarded to Dr. V. Elliot Smith (U.S.A.), who had been studying Landsat imagery of the Great Barrier Reef, in the hope that these features could be detected on recent satellite imagery. Unfortunately no reply has yet been received.

DISCUSSION AND CONCLUSIONS

The two surveys, which were undertaken primarily to determine the distribution and abundance of Acanthaster, have also provided an overall indication of the condition of coral growths to be found on reefs in the region between 14°00'S and 10°30'S. A far more detailed picture of several reefs in this region is provided by the survey work of Dr. J. Veron and his colleagues (see this publication).

From my point of view the most interesting aspect of the surveys related to the Acanthaster findings. The presence of some starfish (a declining infestation?) and much dead coral on Clack Reef and Ingram Reef suggests that there may be other reefs between Lizard Island and Clack Reef which have supported large starfish populations during the last 5 to 10 years. A survey of this particular area is warranted. Another region that requires further investigation is along the outer barrier reefs between 10°59'S and 10°33'S, where much dead standing coral was observed. Although there is circumstantial evidence to suggest that Acanthaster is responsible, confirmation by direct observation of aggregations is needed. I am unable to offer an alternative explanation for the observed dead coral especially on the channel walls.

Apart from the "hard-line" reefs of the Pompey Complex near the southern end of the Great Barrier Reef, there are few other regions where such unusual reef habitats occur as these steep-sided channels between the outer barrier reefs. Strong tidal currents occur in them and the walls are sometimes just smooth bare rock with only scattered encrusting corals. One wonders whether coral growth balances erosional forces, or whether the channels are becoming wider or narrower. If Acanthaster is active in this habitat it may play a significant role in determining the outcome.

The surveys were too crude to enable different coral communities to be recognised. Use of a more refined spot check method, which is now being developed, would provide a more detailed overall picture of the shallower portions of many reefs in the region. It would also pin-point areas of particular interest. It would involve making two or three separate surveys, each of about 15 to 20 days duration and each costing $6,000 to $8,000. However before this could be achieved adequate charts and aerial photographic coverage of the region are required. Air photography alone is estimated to cost much more than the proposed surveys.

To avoid confusion, navigational problems etc., a systematic naming of reefs in the region is required.

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Table 1. Assessment of coral growths, First Survey (38 reefs, R.G.P. data only).

category	approx. % cover	no. of stations	% of records
poor	< 15	83	23.4
average	15 - 30	126	35.6
good	30 - 50	83	23.4
excellent	50 - 100	42	11.9
no record		20	5.6
		354	100.0

Table 2. Comparison of inner patch and outer barrier reefs with respect to coral assessments, First Survey. Figures are percent of records (R.G.P. data only)

reef type	zone	total stations	coral assessment				
			poor	average	good	excellent	no record
inner patch	lee	69	39.1	43.5	13.0	2.9	1.4
	weather	46	30.4	34.8	26.1	0.0	8.7
outer barrier	lee	201	20.9	37.8	20.9	15.9	4.5
	weather	38	0.0	10.5	52.6	21.1	15.8

Table 3. Assessments of coral growths, Second Survey (66 reefs, R.G.P. data only.)

category	approx % cover	no. of stations	% of records
poor	< 15	215	39.1
average	15 - 30	165	30.0
good	30 - 50	98	17.8
excellent	50 - 100	9	1.6
no record		63	11.5
		550	100.0

Table 4. Comparison of inner patch and outer barrier reefs with respect to coral assessments, Second Survey. Figures are percent of records (R.G.P. data only).

			coral assessment				
reef type	zone	total stations	poor	average	good	excellent	no record
inner patch	lee	43	30.2	16.3	20.9	2.3	30.2
	weather	25	24.0	20.0	32.0	20.0	4.0
outer barrier	lee	30	13.3	30.0	10.0	3.3	43.4
	weather	246	31.3	39.4	26.8	0.8	1.6
	channel	206	54.9	54.9	5.8	0.0	16.5

Chart showing location of reefs visited on First Survey June/July 1974.

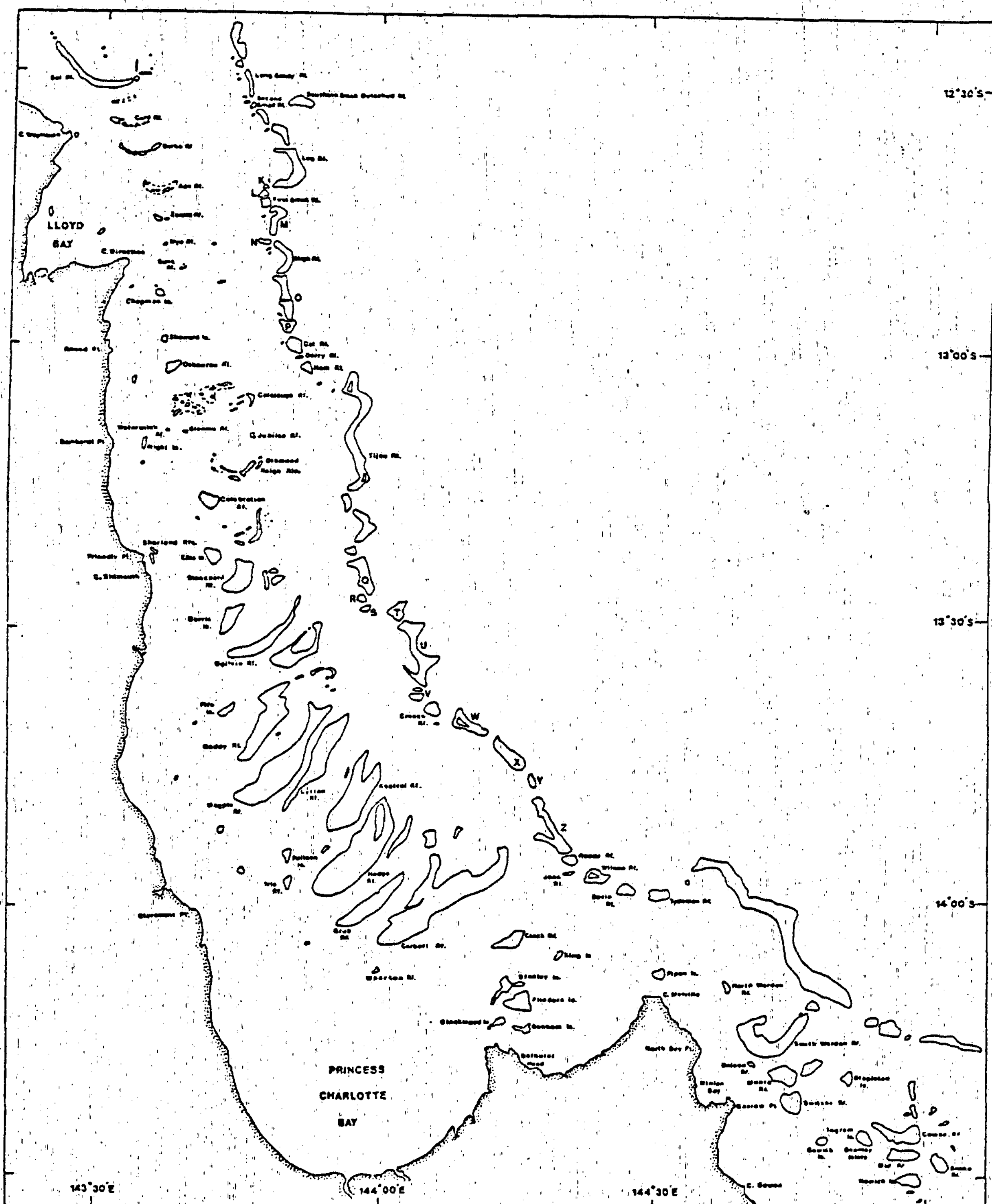

Figure 1

Chart showing location of reefs visited on Second Survey November 1975.

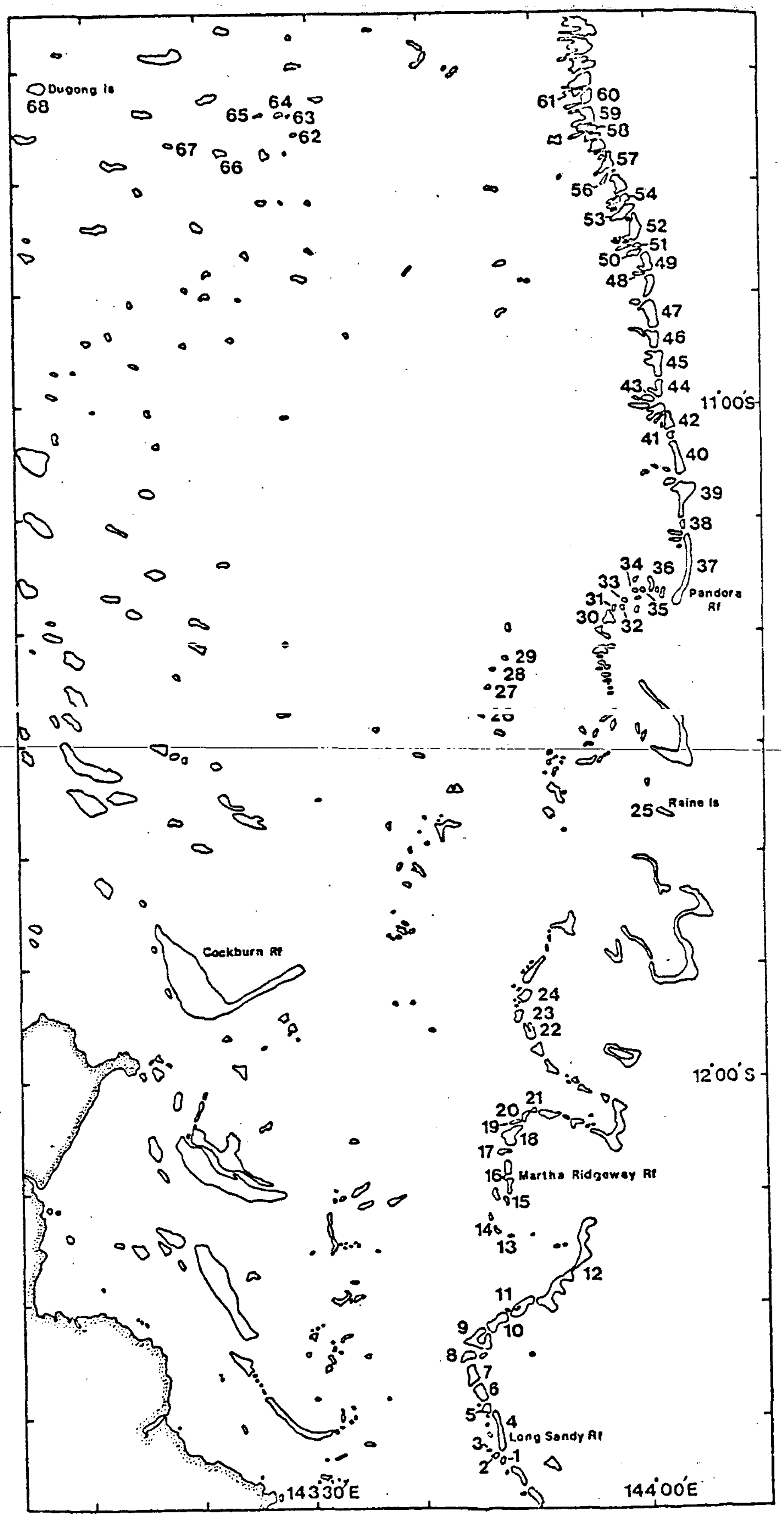

Figure 2

CRUSTACEANS - A NATURAL FEATURE OF THE AREA

R.R. Pyne

Department of Primary Industry, Canberra

Whilst most of us have some personal knowledge of crustaceans, be it because of their value as food, or because they have destroyed the hull of a vessel or a wharf or harbour installation constructed of wood, or it may be because of their parasitic behaviour, most of us are still ignorant of the vital zoological importance of crustaceans. Schmitt (1965) states that, "vast hordes of certain kinds are at the base of the pyramid of aquatic life. Remove them, and most of the other aquatic creatures will perish, for crustaceans are the main food animals of the waters. Certain species subsist to a larger extent than any other animals on the microscopic vegetable life of the sea - chiefly diatoms. Transmitting this relatively inaccessible food supply into their own minute forms of life, these species in turn become the food of many fishes and other animals. The world's largest living animals, the blue whales - which may measure a hundred feet in length and weigh a hundred tons - as well as the tiny, transparent fish fry - so small that one could hold a hundred in one hand - depend chiefly upon small crustaceans for their food supply. To play so large a part in zoological economy, crustaceans must exist in unbelievable numbers".

Zoogeographic Relationships of the crustacean fauna in the Lizard Island to Cape York area.

Discussing the crustacean fauna of Papua New Guinea, Holthuis (1972) described the marine crustacean fauna of that area as forming, "part of the Indo-West Pacific fauna, which ranges from the east coast of Africa, including the Red Sea, to southern Japan, northern Australia and Polynesia. The animal life in this area is richer in species than that of any other marine zoogeographic area, while within it the Indo-Australian province is again the richest."

Based on the conclusions reached by Pope (1967) which are illustrated in Figure 1, it is suggested that within the area under consideration, further research will reveal that the crustacean fauna is composed of elements from the Malayan and Indonesian, Japanese and Philippine and Pacific crustacean faunas.

Within Australia, most marine researchers today acknowledge the concept of shallow-water flora and fauna marine provinces as proposed by Hedley (1904). However, as evidenced by recent reviews by Knott (1952), Bennett and Pope (1953), Endean (1957), Womersley (1960), Knox (1963) and Pope (1967), a great deal more research is required before precise boundaries can be defined.

In tropical Australia, Hedley (1904) recognised two distinct provinces, viz. DAMPIERIAN for the marine fauna extending from Torres Strait to the Houtman's Abrolhos; and the SOLANDERIAN for the marine fauna of the Queensland coast. Whitley (1932) however, introduced the name BANKSIAN as the province embracing the fauna of the mainland coast of Queensland and restricted the SOLANDERIAN province to the

Great Barrier Reef (Figure 2). Pope (1967) suggested that recent research by Endean, Kenny and Stephenson (1956 a and b) and Endean (1957) demonstrated that, "the biota of coastal mainland Queensland is so closely allied with that to the west of Torres Strait that it should more properly be regarded as belonging to the Dampierian Province which may now be regarded as embracing the whole northern coast of Australia from approximately 25°S in the east, northwards up the Queensland coast, through Torres Strait and thence westward round to about Geraldton in Western Australia." Whilst recognising this apparent strong biogeographic resemblance, Pope (1967) also acknowledged that differences also existed, and suggested that the arrangement which best fitted the known distribution of shallow-water marine biota is that which is illustrated in Figure 1.

Discussing the shallow-water marine provinces and climatic regions in Australia, George (1967) suggests that, "the correlation of climatic events and faunal assemblages seems more than mere coincidence and it is suggested that it is the regularity and reliability of the climate of a particular geographic area which determines the distribution of the marine fauna of its coasts." Expanding this premis, George (1967) suggests that it is the nature of the regional coastal climates which modify the basic marine environment in such a way that additional discrete regional faunal units can be recognised. Furthermore, it is within these discrete regional units that the faunas must be responding in all their biological characteristics (i.e. spawning times, larval behaviour, juvenile settling time and place, etc) to the environmental situation which is largely dictated by the climate.

It is suggested, based on the foregoing discussion, that a good deal more research is required, not only in the Lizard Island to Cape York area but in tropical Australia as a whole, before precise zoogeographical relationships or shallow-water marine provinces can be defined.

Discussion

While acknowledging the valuable contributions made in respect of crustacean taxonomy in Australia, it is abundently clear from reviewing the available literature, that very little of this work refers to the Lizard Island to Cape York area, which has remained virtually untouched. Further, published accounts on the biology, distribution, and ecology of crustaceans in Australia as a whole are conspicuous by their absence, save for the majority of those species which are of commercial significance (i.e. rock lobster, prawn and mud crab, etc). Clearly, therefore, we understand very little and in the majority of cases nothing at all, about the role crustaceans have in the Australian marine ecosystem as a whole, let alone in the particular area under consideration.

Although many of us would like to consider it true that crustacea are a natural feature of the Lizard Island to Cape York area, and there is no evidence to suggest the contrary, the best that can be suggested at this juncture is simply:-

(i) it would be anticipated that in the area one would find free-living and sessile forms, planktonic species and bottom dwellers, commensals and parasites;

(ii) that the habitats occupied would be as diverse as the animals themselves;

(iii) that their size, colour and form would be truly remarkable.

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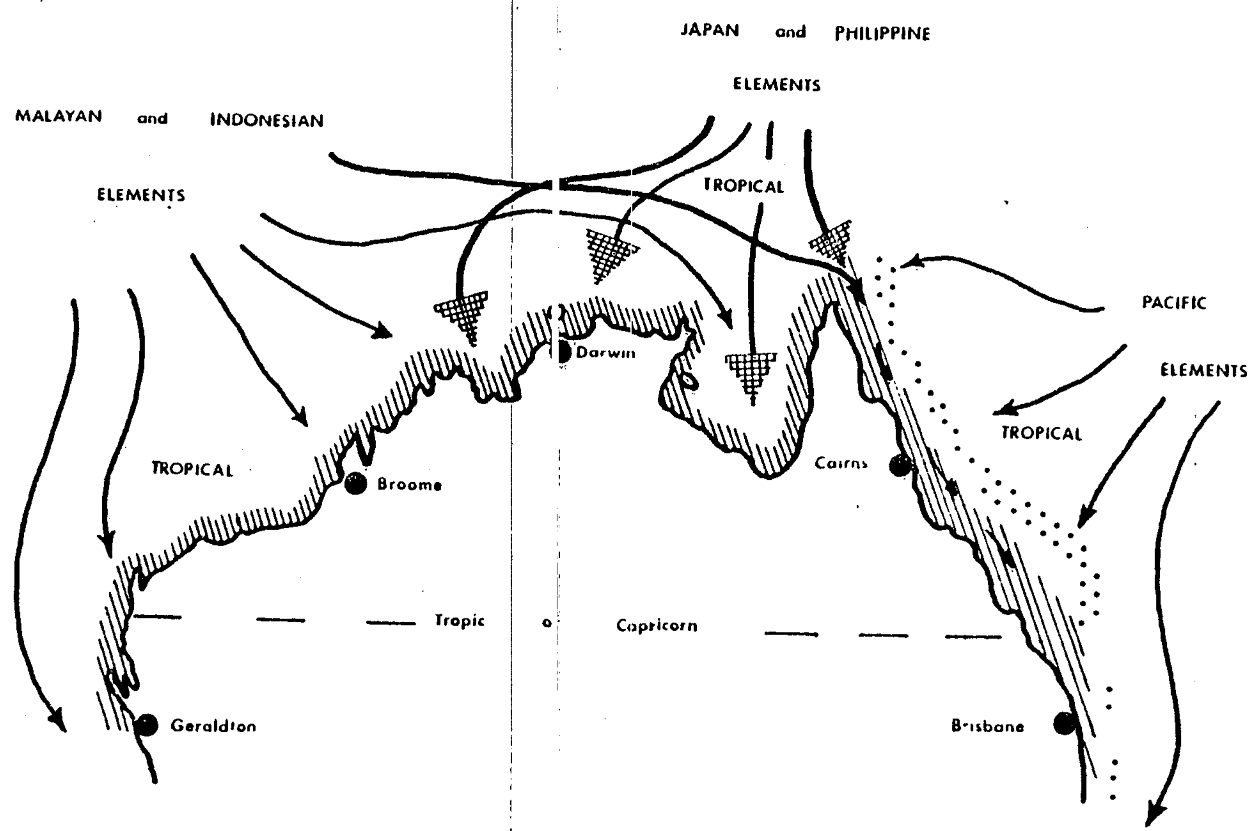
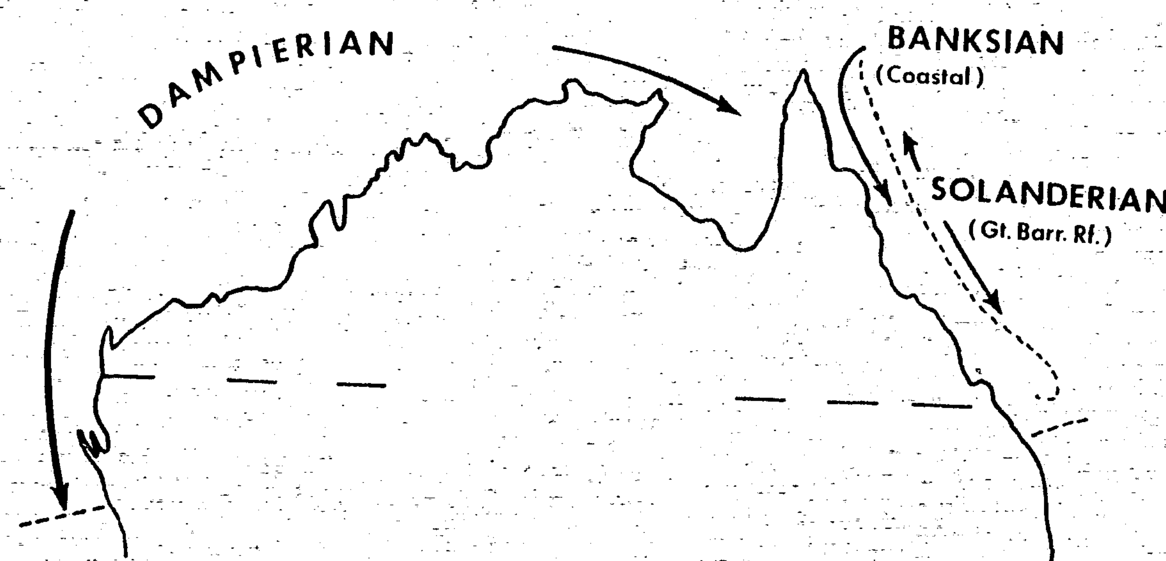


Figure 1: A Biogeographical scheme for tropical Australia proposed by Pope (1967)

Figure 2: Tropical Australian Zoogeographical Provinces according to Whitley (1932).



DISCUSSION SESSION III - NATURAL FEATURES

CHAIRMAN: DR. M. GILMARTIN

A. Birtles: I have a comment in relation to Mr. Limpus' paper on the turtles of Raine Island. He probably did not have time to get on to it, but from Mr. Limpus' work and other people's work it is quite clear that looking at the massing on beaches over a season you get a reasonably normal distribution and you can pick the peak of the season. Raine Island was visited in 1973 (The Royal Society), 1974 (James Cook University and ANZAAS), 1975 (John Kowarsky, Applied Ecology), 1976 (Mr. Limpus and myself on the A.B.C. National Parks trip) and 1977 (Mr. Limpus).

Although Mr. Limpus speaks of the vast tonnage one amazing night in 1974, the numbers are variable between years so that in 1973 they were about 400 a night, 1974 about 11,800, 1975 in the region of 50, 1976 a maximum of 1,000 and most recently in 1977 something like 50 to 100. So that perhaps an immediate reaction to the idea of 10,000 tons of turtle is - what a good resource! But it is not. It is a very variable resource.

C. Limpus: All I can say is that at the present moment this extreme variation in turtle numbers is not just peculiar to Raine Island - it is something that is happening on all the green turtle rookeries within the Great Barrier Reef. They are all fluctuating in parallel as far as we can see at the present moment, but we have not been able to find evidence of similar extreme fluctuations over the previous 30 to 40 years. We really do not know what is happening. All I can say with a little confidence, is that we appear not to have lost our female turtles from the feeding grounds. The Torres Strait Islanders give us no indication that the female turtles have disappeared from the feeding grounds. They are just not nesting or have not nested in big numbers over the last couple of years. We will just have to keep monitoring what is happening.

B. Goldman: Geological history I feel must play a part in this problem. Migrations of many animals have changed or been superimposed due to factors like rises and falls in sea level or varying continental spatial separation which might remove or induce a new area or system for breeding. The other feeling is that turtles have the requirement to come back to breed on the island on which they were born. Is this the case? Is there any evidence to the effect that turtles have some imprinting stage in their development and tend to return to the island on which they were born?

C. Limpus: It is assumed they do, although no one has established this, and the reason for the assumption results from the Caribbean situation where most of these ideas have been generated. Last century and early this century, elimination of most of the rookeries occurred, so there is only a couple of major rookeries left in the Caribbean. These rookeries are being used year after year and so the interpretation is that the turtles are coming back to where they are born, otherwise they would be spreading to the eliminated rookeries.

I feel that these are ancestral regions rather than ancestral beaches. The entire Capricorn-Bunker Group may be an ancestral region and I tend to think of it as a rookery region. Certainly the only place in eastern Australia where loggerhead turtles are breeding in any consequence is the Capricorn-Bunker Group and the adjacent mainland coast, and so presumably the loggerheads are coming back to that area. For the Raine Island area it is Raine Island, Pandora Cay and the unnamed sand cay about 15 to 20 miles further north that have rookeries but I cannot give you a better answer than that at the present moment.

C. Watkins: I was anchored at Bramble Cay for two months the summer before last fishing, and I only saw about 18 a night on the average; I counted by the tracks left the following morning.

C. Limpus: Yes, the season before last was not extremely low, but it was certainly below average for the rookeries we know well and I would assume that all of the green turtle rookeries in the Barrier Reef that season were below average. At Bramble Cay, from the very little first hand data available, I feel that there are probably about 500 to 700 turtles a season nesting there on the average, which comes down to about 50 to 80 a night in the peak of the season.

C. Watkins: Vessels from New Guinea used to come over occasionally too during the night and take them.

B. Goldman: The earlier implications was that it was quite possible that there is something tremendously strange in the productivity of the region to support this number of turtles. Previously I was trving to point out that it may be just a coincidence of geological history and of the habitat requirements of these animals, causing them to return to that place for breeding, which has resulted in such aggregations.

C. Limpus: I am well aware that this could be the case. There is the possibility that this island is very old by comparison with other islands. There is a possible interpretation similar to the view Carr has proposed: that Ascension Island has developed as a chain of islands further and further away from the feeding grounds of Brazil, so a migration of turtles between Brazil and the Ascension Islands occurs. I think we ought to look at least at this type of thing. It may not be just the environment that is important as it is now, it may be some past history of the place. I would be very interested to hear any comment as to whether there is evidence that the raised platform at Raine Island, and I realise that it is not beach rock, gives any indication that it is a very ancient island by comparison with other coral cays.

D. Hopley: We have only one C^{14} date from Raine Island which came from a Tridacna shell which is actually incorporated in what we assume to be part of the older phosphatic sandstone on the cay, and that was only from memory, about 2,000 years.

In other words it is very, very young. Getting back to the problem of sea levels and so on, and problems of changing environment, I think the important thing here is that although the maximum lowering of sea level was about 135 metres during the latter part of the Pleistocene, for most of the last 125,000 years the average lowering would have been about 50 metres. Now even with that amount of lowering, it means that the shoreline on the northern reef, with this very narrow and very shallow shelf, was transferred right to the edge of the continental shelf.

The amount of coral available, and it would be in the form of fringing reefs, fringing what were high limestone islands which are the present ribbon reefs, would be restricted to a very narrow zone. As we came down to central Queensland, where the shelf is much wider and certainly deeper on its outer edge, a minus 50 metres level would leave the outer third of the shelf under water. It would be this that would have been covered by reefs, again high reef limestone islands with fringing reefs, but obviously there would have been a great reef habitat.

The limiting factor as we come further south, of course, is that lowering of sea-water temperatures at this time was associated with world wide glaciation and it is possible that the southern limit of the Reef was actually moved northwards as well, which may indicate that this area off Townsville was the major reserve during most of the latter part of the Pleistocene.

R.P. Kenny: There have been various comments from time to time today about the possibility of sedimentation from the mainland being significant in the operation of reef systems. I wonder whether Dr. Flood could offer any information as to whether or not his examinations of sediment could give any information as to what amount of sediment is derived from the mainland as distinct from the oceanic environment.

P.G. Flood: Work that was conducted throughout the 1973 expedition by Dr. Orme, myself and other researchers indicate that the terrigenous mud from the mainland extends out across the shelf to a distance equivalent to the vicinity of Lizard Island, maybe 20 kilometres. That line extends down the shore itself, and is fairly clearly demarcated. Terrigenous mud perceptibly diminishes in percentage and once you move beyond that line it line it is zero. Whether that is just the result of the fresh water discharge coming out across the shore, or whether it is also made more compex by tidal fluctuations moving parallel to the mainland, or whether, once the terrigenous mud passes that line it is flushed out of the system with the enormous currents that develop through those gaps in the middle reefs, we do not know.

But the only work that we have on the reef tops themselves is the work of Marshall and Orr during the 1930 expedition, where they obtained in excess of 30% terrigenous mud in some of the areas of the Low Isles reef. That percentage I think, is equal or even greater now in the present sediment we have, but it is difficult to know just what you have really measured in this terrigenous mud that is related to just fresh water run-off, or whether it is actually moved up and down the coast from some other stream areas as well. There is no doubt that terrigenous mud does have a detrimental effect on coral growth.

B. Goldman: I would like to ask Dr. Heinsohn a question which has obvious connotations for the tourist industry. The suggestion has been made to me recently that the depletion of the whale population through fishing on the Queensland coast has had an effect on the *Chironex* and other jellyfish populations because these could form a part of the food of the whales. Obviously the jellyfish population is a problem with tourism because people do no go swimming for much of the year because they are frightened of being stung. Does this sound like a reasonable proposition to you or not?

G.E. Heinsohn: I do not know if they feed on jellyfish. They do feed on krill, crustaceans, and some species of fin whale feed on small fish I believe.

P. Mather: Dr. Bunt, you mentioned that you had carbon datings on the age of mangrove communities, presumably, not a mangrove tree?

J. Bunt: Yes, I am sorry! We have sent part of a big mangrove that we felled to Sydney for dating and I have not received that yet. I have been told that dating may be accurate within 200 years while others say they do not think this is feasible. We have just given them the material, and we will see what comes up. Earlier I was talking about the mangrove peat, which is almost lignite, at Missionary Bay. This has been essentially covered by coastal dune and subsequently exposed, and I would assume from the appearance of the place that it is very close to a coral foundation. That was dated at about 5,000 years.

General remarks: There was a discussion concerning the changing diversity of corals from the northern to the southern end of the Great Barrier Reef, and it was indicated by Dr. Veron that there was a reduction in the number of genera from north to south and in all probability in the number of species too.

P. Mather: Mr. Pearson, I would be interested to know at what stage the giant clam reaches sexual maturity, and from what distance the young may be recruited.

R. Pearson: This I cannot tell you until I have completed another year or two of my studies on this animal. As to recruitment, I think that one of the main problems is whether recruitment is inter-reef or intra-reef. Nobody has yet looked at the plankton to see if the larvae move around the reef or are carried downstream.

P. Mather: The only information we have on this is there is not a great deal of endemism associated with separate reefs. We have species with enormous geographic ranges in tropical regions, but until we have looked at the enzymes, we have to assume that they are the same interbreeding species and that gene flow is occurring between them. Another relevant aspect is that although there appears to be enormous selection pressure to reduce the free-swimming period of certain larvae, the larval stages have in fact been retained as free-swimming forms. In other words very few organisms in coral reef situations have become completely viviparous with complete loss of their free-swimming phase. This suggests that free larvae do have an adapting advantage, and it may be to maintain gene flow between reefs i.e. inter-reef recruitment.

F. Talbot: You cannot consider the health of a national park in a small sense because of drifting larvae and long dispersal phases. You really are talking about zonal management and I think this is one of the wonderful things about the Great Barrier Reef Marine Park Authority, that it is set up not just to create small national parks but to overview a whole area.

N. Haysom: Mr. Chairman, I have a comment about your paper. You say that in terms of biomass only 2% of the individuals are over 256 grams weight i.e. easily useable as food or for sport. Now I do not think there would be very many people in northern Queensland who would agree with that type of expression, and similarly I do not think that your assumption that it is unlikely that these individuals have any natural predators is correct.

F. Talbot: That is an error, it should be that they have few predators.

M. Gilmartin: Are you trying to indicate that perhaps the predation rate reduces as the individuals get larger?

N. Haysom: A 256 gram fish is a pretty small fish, and if you look at a more realistic size, say the size at first recruitment into a fishery (whether it is commercial or amateur), the percentage of bio-mass might be reduced from 50% to 20%.

F. Talbot: I accept that there are problems. The problem with our work is that the scale is small and one is looking at fairly shallow reefs. If we were looking at a deep reef I think the picture might be quite different for example. However, I think that it remains true that a large amount of your biomass is trapped in rather few large fishes so that it is possible to make a big impact. If, for instance, you wish to keep all the smaller species, then predation is an important factor. The point I suppose that we were trying to make is that we have in the past accepted fairly easily that one could fish within a national park area and make no major impact on the area, and I think I would have agreed with that a decade ago. I do not believe now that is quite so, in fact it looks as though by removal you could make a major impact. I would like to see somebody measure this. Perhaps one should consider some tourist reefs for restriction, to see what differences there are in the populations of the total fish.

B. Goldman: We heard a talk earlier on commercial fisheries in this region, but no estimates have been given on the impact of the sports diver regarding spear-fishing, say, and the sports fishermen, the people who get on a charter boat out of Cairns, Innisfail and Mossman and actually go out and line fish. I would like to ask Mr. Haysom what potential is there to develop a control and assessment or management policy on the recreational fishing and exploitation of the reef products.

N. Haysom: I think you will find in my paper, although I did not mention it when I was talking, that I commented on the level of impact that the sport fishing activities in the region might have. These are probably much lighter than they are anywhere else on the Queensland coast because of the remoteness of the area.

F. Talbot: Can I ask have there been changes that can be recorded, even anecdotally, in areas like Green Island or even more at Heron Island where there has been an increased impact of fishing over the past few decades.

G. Goeden: We have been looking over the past few years at fish populations, not whole communities but selected species that we feel represent your top 2%. We feel these species are good indicators of the kinds of activity that occur on various reefs, and we are attempting to correlate numbers with the involvement of man in various reef groups where we can get information on fishing pressure. What we have found is that in fact there are very substantial differences in the structure and total numbers, or at least an index of the total numbers of these selected population densities. They vary from, in a very unfished area, we will give it an index of 1; to a very heavily fished area, particularly one that is used for recreation, where the index would be about .1; so the numbers do drop down in these predatory species to about 10% of their original.

C. Watkins: From what I have seen during my fishing charter work out of Townsville, you could now call the Reef the "Great Barren Reef" - that is about what it is. The Crown of Thorn's Starfish made quite a difference too mind you, but I do not say that was the reason. Naturally a lot of it is overfished by amateur fishermen.

F. Talbot: So in the area, from memory, you would say that the fishing catch 20 years ago would have been much richer on the same reef.

C. Watkins: Yes, there is no comparison.

B. Hill: Mr. Chairman, a question to Dr. Bunt. He suggested that the very high productivity in mangrove systems might be important in terms of export to reef or adjacent waters, but mangrove sediments tend to accumulate organic matter and phosphates, so I wonder if you should not regard them as sinks since they are not in fact a net exporter, but a net importer.

J. Bunt: All the evidence we have indicates that the majority of litter goes out of the system while the root material that is produced within the sediment certainly appears to accumulate. We have been looking at root biomasses (i.e. living, dead, and everthing in cores), and it is approximately equal to the above-ground biomass. But the interesting point is, and this is something which we found just the other day: the nitrogen content of that root material in the top 20cms or so is quite good, but below that it drops remarkably. I have no explanation of this. We have no experimental evidence to check it, but one wonders whether there is not some sort of active denitrification going on and either the nitrogen is accumulating in the top layer, or in a lower zone with constant leaching out of the system.

I am also puzzled by the fact that presumably some sort of steady state condition is reached, but how then is that steady state maintained. If you look in the water moving up and down tidal channels, you find very large amounts of the same sort of material that comes up in cores. I do not know how it gets into the water, but one suspects that there may be mechanisms for this to be moved, it is possible that crabs etc. may act as a mechanism for moving this material up out of the sediment in some fashion, and that it is then washed away on the tide.

G. Webb: Where you have any meandering system, it must balance out because one bank is being continuously built up and the other eroded. When it reaches a certain level it just comes back the other way, the whole lot goes back into the river and washes out.

J. Bunt: A great deal of re-sorting is occurring. People are talking about mangroves being stabilisers, but for every leading meander there is an equal amount of sediment that is being washed away. That is a very obvious way that this material is getting out into the system, so it is building up and being lost all at the same time.

D. Barnes: On the idea of export from mangroves to reefs, I would like to point out that the reef is in fact three times more productive than the figure Dr. Bunt quoted for mangroves and I am excluding the carbon going into calcium carbonate. Now I cannot see it exporting carbon.

J. Bunt: If you are being well fed, it does not hurt to be a little better fed. We accept the fact that coral reefs are remarkably productive, but if we suppose that consumable materials are coming into it, there is no reason why they should not be utilised. I am not saying that the mangroves make the reef possible, but that I suspect that there is an interaction in such a large system.

P. Hutchings: The papers dealing with the fauna this afternoon and this morning concentrated on the large and easily visible members. I would just like to draw attention to the fact that there is a very much larger fauna which has not been described or discussed at this meeting, namely that which lives in the sediment, under the coral, and in the coral itself. This is because we just do not know very much about it - it may not have a very high biomass but probably in terms of rates of turnover it does make a significant contribution. I do not see this situation improving in the next five to ten years in terms of obtaining more information on this fauna because of the lack of systematic studies in this part of the world. Hopefully if you manage this part of the reef for the large and more visible components of the reef, such as fish and turtles, you will automatically manage this other component, the fauna which we have not discussed.

F. Talbot: I think we should also remember that there is an enormous planktonic fauna which we have also missed. I do not think we have attempted to be comprehensive.

N. Milward: I wonder Mr Chairman, if I could just address another comment to you in relation to the egg and larval stage. I agree that we have to consider zones for management rather than just isolated reefs. I would like to draw attention to a piece of work done for an Honours Degree at this University on the ichthyoplankton of the inshore and reef waters off Townsville. It showed that there seemed to be little exchange from the inshore waters to the reef waters. The fish eggs that were present at the surface were restricted either to the inshore or to the reef waters with apparently little exchange. The eggs developed rapidly and probably the larvae had some strategies for getting out of the surface water and perhaps getting down on to the bottom.

A. Birtles: I would like to point out two other areas of export from the mangrove. One is the growth of juveniles which subsequently leave the area. The other is the predators which come in at high tide and feed primarily on crabs and molluscs and leave again.

What I actually wanted to ask you, was to explore your idea of fragility. Until recently the accepted ecological dogma was that the more complex the ecosystem then the more stable it was with a large number of feedback mechanisms. Recent work, notably by Professor Talbot, and by Elton on rainforest insect populations in South America has shown that with complexity, you find partitioning can lead to extinctions and hence to a degree of instability and fragility. I recognise you termed it a feeling, what do you base your feeling on in relation to the mangrove?

J. Bunt: I base the opinion on the comment that was made about meandering. Any river mangrove is constantly changing as the meanders move, it is very fragile in that sense but as far as the species themselves are concerned, it is very difficult to be superficial about them. If you look at the simplified view Macnae presented where there are five zones, and then you go from that and you look at the distributions of individual species over a very large number of transects very carefully, you find that this zonal picture tends to represent very special circumstances; also you find that these species are not restricted to very tight zones, but the differences that make for presence or absence of any particular species are so slight that it is difficult to detect the reason. It could be just a very slight change in exposure to tides, or in topographic elevation relative to tides, or in fresh water incidence relative to tide height, so I am talking about fragile in that sense also, i.e. that the existence or non-existence of a species or a suite of species depends on just a slight fine tuning. So if any external forces come into being to exert that fine tuning, you could expect a substantial change in the system. The system is very vulnerable to a fickle environment.

Chairman: I think that we might formally thank our speakers. It has been a stimulating session.

SESSION 1V: SURVEILLANCE AND MANAGEMENT

METHODS OF SURVEILLANCE OF VAST AREAS

N.L. WEBB, Department of Defence

I take the opportunity that the presentation of this paper affords to discuss, in general terms, surveillance techniques presently available in Australia which might be of use to the GBRMPA in establishing its authority over those areas of the Reef it wishes to declare. In addition, I think it will be worthwhile to canvas alternative technologies which might be considered as being ultimately available for possible use by the Authority.

2. In the discussion which follows you might care to bear in mind several caveats which might usefully guide any discussion of surveillance to meet the needs of the GBRMPA. These are:

- surveillance costs money and the total investment ought to be in proportion to the real benefits gained;
- total investment must necessarily take into account the costs of the infrastructure of men and facilities needed to support the preferred surveillance techniques; and,
- relatively lengthy lead times may be involved in the acquisition and effective implementation of certain surveillance techniques.

In strict terms, these caveats may not appear to have direct relevance to the "technical" nature of this paper. However, if anything is to be learnt from the public comment in recent months about coastal surveillance arrangements in Australia, it is that the techniques of surveillance cannot be discussed, to any worthwhile purpose, without due recognition being made of the practical considerations which will ultimately intrude upon the selection processes.

3. I shall return to this theme later in the paper.

Some Definitions: "Surveillance", "Reconnaissance" and "Enforcement"

4. In order that we should all be agreed on the terms being used, I shall explain the Armed Service - oriented definitions of "surveillance", "reconnaissance" and "enforcement".

5. "Surveillance" we understand as the process of gathering information for later analysis. Although you might beforehand have a clear idea of what information is significant to your purpose, there is no suggestion in "surveillance" of searching only for specified targets or of concentrating effort to obtain particular information. In Service terminology, "surveillance"

is the long term operation designed to answer the broad questions of who, what, where, when and why.

6. Where the targets are defined and the objectives specified, the Services prefer to use the word, "reconnaissance". "Reconnaissance" then is the second phase; more immediate and more direct, and designed to answer the questions of 'what vessel', 'what type', 'what activity', etc.

7. The final or third stage - that being the physical act of ensuring a particular law or regulation is obeyed - is usually described as "enforcement". This action can be passive, in terms of regular activities and patrols much like those of the presence of a policeman on the beat; or active, such as the squad car responding rapidly to a reported offence at a precise location. In practice, most "enforcement" activities are a mixture of both passive and active action, with the impact of strong legal penalties as a further deterrent to law breakers.

8. Accepting then that what is usually called surveillance is in fact an amalgam of the 3 separate activities of "surveillance" "reconnaissance" and "enforcement", it must also be accepted that certain equipment and techniques have maximum cost-effectiveness in only some of these 3 roles. It may seem rather obvious but, all to often, public comment on surveillance arrangements focusses upon a particular piece of equipment as the solution to one's total needs. It is overlooked that, in maritime situations, for example, while a plane and/or radar may be excellent for the surveillance and reconnaissance phases they are of limited value for the enforcement phase - this is where the patrol boat comes into its own. Equally while a patrol boat may be essential for enforcement, it has a much less cost-effectiveness in the surveillance and reconnaissance phases over large maritime areas.

9. Equipment choices need then to be tailored to the objective to be achieved. Where it is intended to cover all 3 phases - "surveillance", "reconnaissance" and "enforcement", the resulting equipment and technique mix should reflect the importance and financial priority given to achieving the objectives of these 3 separate phases.

10. The priorities and dominance accorded elements of these equipment and technique mixes will necessarily vary according to the development stage of the authority concerned. In the initial period of its life, for example, an Authority may wish to develop its more permanent programs of reconnaissance and enforcement. As a result, decisions may be made to lease, rather than purchase, major equipment items with specialised surveillance capabilities. In a similar way, decisions for substantial purchases of equipment to be used in the long term in reconnaissance and enforcement activities, may be deferred pending analysis of the data and experience gained from the initial surveillance operations.

11. This step-by-step approach is, of course, the ideal and the pressures of the real world may well intrude and oblige early decisions to be made for long term equipment purchases.

12. It might now be timely to turn to individual equipment items readily available and to look at their capability to achieve objectives within our 3 phase parameters.

AVAILABLE RELEVANT DEFENCE FORCE EQUIPMENT

The Orion P3 Aircraft

13. The Orion is a long range maritime patrol aircraft in service with the RAAF. Its primary role is anti-submarine warfare. It has the high performance and long endurance capabilities necessary for this task and these in turn give it a good, general surveillance capability. Fitted with highly sophisticated radar, it can sweep in search of ocean-going trawlers in an area of about 300,000 square miles in an average sortie of 12 or so hours. It can dash to a search area at speeds above 400 knots and where necessary throttle back to a search-loiter of around 200 knots. When flying on a direct course in search of ocean-going trawlers, it has the capability of sweeping an area of some 50 miles to each side.

14. While the Orion can sweep these areas, the capability of detecting fishing vessels varies according to their size and type (ie., wooden or metal hull); the operating height of the searching aircraft; and the weather/sea states. By way of illustration, an Orion, of the most capable variant (the P3C model), is able to detect in ideal conditions a steel-hulled trawler out to 60 nm from a search height of 6,000 feet. Sorties against such targets in these good conditions could have a probability of detection in the order of 90%.

15. In conditions of bad weather and high sea states, this detection rate is, of course, reduced. Of particular interest to the area of concern to the GBRMPA is the radar capability in reef and archipelagic areas. Radar returns from reefs and islets complicate the problem of discerning the presence of illegal vessels and can result in an aircraft having to divert to visually identify suspect radar contacts. Such diversions detract from the overall coverage that should be achieved in the mission. Ideally, the Orion with its highly sophisticated radar system should be employed in areas where its capability to cover large areas quickly is optimised.

The Grunmen S2E Tracker Aircraft

16. The Tracker is a twin-engined, all-weather aircraft with a primary role as an aircraft carrier - borne anti-submarine aircraft. With a crew of 4 and a high radar detection capacity, it normally remains on patrol for 6 hours (in contrast to the Orion's 12 hours).

17. The Tracker has been used effectively in the North-West in operations mounted to monitor Indonesian traditional fishermen operating in the Ashmore and Cartier Reef areas. It is presently being used in daily patrols of the sea-approaches to Darwin in search of refugee small boat arrivals. The Tracker has a general search and loiter speed of around 150 knots (in contrast to the Orion's 200 knots).

18. Its radar sweep capability to either side is similar to that of the P3B Orion. But as with the Orion, its radar capability can be reduced by reefs and visual identification in such areas can become of primary importance. This again draws attention to the mixed efficiency of using highly sophisticated radar systems in reef areas for either surveillance or reconnaissance.

Attack Class Patrol Boats

19. The RAN's Attack Class patrol boats are currently being used for civil coastal surveillance. Equipped with high definition navigation radar, they can in good conditions provide a surveillance cover over 3,000 square miles a day. They have a speed of over 20 knots and presently carry out 14-18 day patrols, with fuel stops every 3-4 days. With a crew of 18 and accommodation for a passenger, they are used primarily to patrol the 12 mile Declared Fishing Zone for breaches of fisheries laws and to respond to evidence of other illegal activity.

20. These boats were constructed principally to meet Defence requirements and they are not specialist civil surveillance vessels. Their high-speed performance does not allow them to be used with maximum efficiency in steady walking-the-beat patrols. There can also be problems when dealing with very slow vessels as they have a relatively high minimum speed of 13 knots.

21. A further difficulty with patrol boats, of particular relevance to the Reef area, is their draught. Designed for ocean-going Defence work, problems can be experienced in the unchartered shallow reef waters where the channels between the reefs and the exact depths are uncertain.

NEW TECHNOLOGY

22. In recent months, public comment on surveillance arrangements in Australia, recognizing the costs and limitations (as well as virtues) of aircraft/patrol boat mixes, has turned for possible solutions to advances in technology. Indeed there are many exciting developments in this regard but as with all the other equipment types mentioned to date one needs to keep the question of cost/benefit always in mind as well as the practical limits of their effective use.

Radar

23. Radar, whether land-based or airborne (in a plane or balloon), can provide, at a significant cost, 24 hour surveillance

over considerable areas. In the future Over-The-Horizon (OTH) Radar may be the answer to broad area surveillance at long range. This capability derives from the fact that OTH Radar makes use of the ionosphere to bend the radar waves around the curvature of the earth; this is not possible with conventional radar. As yet the technique is still under development but it has the potential to become the most cost-effective solution to large scale/area surveillance requirements.

24. However, surveillance is pretty well all that radar can provide and it has a very resticted capacity to assist with reconnaissance and enforcement. Radar can tell you that something is probably there and by inference, it may be fishing or engaging in other economic exploitation activities. It cannot tell you anything further. To know more and/or to pursue the offending aircraft or vessel you need to have aircraft and/or patrol boats available for quick reactive missions. These are additional costs to the actual provision of your radar capability.

Satellite Systems

25. Satellites are another form of surveillance device which has been recently discussed. The main sensors used in surveillance satellites are:

a. Optical. Either visible light or infra-red frequencies can be used. A common measure of performance is resolution (a resolution of 1 metre means the system can distinguish objects 1 metre apart). Optical systems can be designed to detect, localise and sometimes classify targets within their field of view, but because their field of view is small, they are most inefficient unless the target's position is previously known and is directly beneath the satelite's track.

b. Radar. Generally, the type known as "synthetic aperture radar" is used. These radars are fixed to look left or right of the satellite's track with the satellite's motion providing the radar scan. These radars rely upon highly sophisticated signal processing technology to achieve a useable level of performance. Radar can neither classify nor identify targets.

c. Passive Receivers. Receivers mounted on satellites can detect radiations from radios or radars. This can provide information on location and possibly identification. This technique relies, however, upon the target making transmissions while it is within the satellite's reception range. This technique could, in the future, be used to track and identify licenced fishing vessels, but is likely to be limited to this application alone.

26. Surveillance satellites orbits are either geo-stationary (also called synchronous) or non-synchronous. When in a

synchronous orbit a satellite is positioned some 36,000 kilometres above the equator and moves from west to east at a rate which from earth gives the appearance of being stationary. A geo-stationary satellite positioned over the equator north of Australia would "see" about one third of the earth's surface including Australia and its approaches out to at least a few thousand kilometres. Non-synchronous satellites orbit at the relatively low altitude of 200-1000 kilometres and have a rotation period of about 90 minutes. The point at which the satellite crosses the equator moves west by about 22 degrees of longitude each orbit. Non-sychronous satellites can "see" a strip of earth some 3000-5000 kilometres wide beneath its track, but sensor limitations substantially reduce the width usefully surveyed. Geo-stationary satellites remain in orbit indefinitely, but non-sychronous satellites at 200 kilometres altitude are affected by atmospheric drag and usually re-enter the atmosphere and burn up after a few weeks in orbit.

27. The large distance from the earth (36,000 km) prevents geo-stationary satellites from supplying much useful surveillance information except for certain specialised applications, eg., weather monitoring, detection of launchings of satellites or ballistic missiles, or detection of nuclear explosions. From this distance, radar is not effective. It is doubtful if an optical or infra-red system could be built which would be able to detect even large ships with a reasonable degree of assurance.

28. Radar satellites for maritime surveillance offer some prospect of overcoming some of the limitations of other systems. However, problems of sea clutter, resolution and power requirements will probably limit detection to larger ships and limit coverage across track to some 1-200 kilometres. Visible light optical systems provide good resolution but weather and lighting conditions limit their availability to about 25%. Infra-red optical systems have better availability but poorer resolution. For both systems, turn-on time is limited by film or recording capacity. These limitations together restrict the coverage that can be achieved. In both cases the information is recovered by either de-orbiting the satellite, ejecting a capsule, or transmitting a television picture when the satellite is within range of a ground station.

29. The frequency of cover over a given point, and hence search security, is governed by the orbit, the swept width of the satellite sensor and the number of satellites in orbit. A three satellite passive system could provide 12 hourly coverage, but a three satellite radar system would provide coverage only once every two to five days. A six satellite radar system in near ($\pm 30^{\circ}$) equatorial orbit would provide three-hourly coverage in low latitudes, but none at all in polar latitudes. 24 satellites would produce coverage every 45 minutes.

30. Of currently approved satellite programs, on which we have information, NASA's SEASAT is the only known program which has capabilities which might be applicable to surveillance of a 200 nautical mile

economic zone. The program has oceanographic and earth sciences objectives. The first satellite is to be launched in late 1978 carrying state-of-the-art sensors with the objective of demonstrating the concept. An interim operational system is postulated for about 1983. The synthetic aperture radar on the interim operational system is expected to provide global coverage once every two to five days with a resolution of 25 metres. Provided they are sufficiently radar reflective, vessels of this size and larger could be detected. Data access arrangements are not yet clear but indications are that a time lag of weeks or months might be involved. In any case, current plans are to limit radar operation to the North American continental margins only. The other sensors do not have suitable capabilities.

31. A full capability SEASAT program, if it eventuates, could be operational by the late 1980's and could satisfy the requirements of fishing boat surveillance. There is as yet no assurance that such a program will be approved by US authorities.

32. Ground sensors are another method of operating surveillance regimes but as with radar they can do little more than tell you that something was probably at the particular area you placed your sensor. Being fixed and presumably in remote locations there are attendant problems with intentional or natural damage or interference.

REGIME TECHNIQUES - AN IMPORTANT CONTRIBUTION

33. In a very important way, the most cost-effective surveillance equipment/technique is the implementation of sensible licensing and other regime practices. Being thoughtful at the outset about what you really want to do, and of the cost implications, can produce great savings in money and effort later. Some states, for example, have made it a condition of licensing that people fish or conduct activities in certain defined areas; that they provide you with advance copies of their schedules; and that they either report in daily or maintain an electronic identification signal. The purpose of this is to make it relatively necessary for aircraft surveillance to check off the vessels at a distance without having to directly identify each vessel or to call out a patrol boat for a reactive mission. Vessels which aren't pre-registered can be more readily spotted and any diversions by the aircraft have a greater probability of being productive.

34. In a similar way, some governments stipulate that transitting fishing vessels use only certain approach corridors or channels when navigating areas. Vessels outside the corridors can through this be more quickly identified. A possibility exists that where groups of fishermen are given exclusive or shared fishing rights they could become their own "policemen". Such are the procedures which are variously envisaged to cut down on the total need for patrols either by sea or air and to increase the cost/benefit of reactive missions.

35. An aspect of the policing process that can restrict the effective use of one's area and equipment is the possible

slowness of judicial procedures. Where an officer on a reactive vessel is required to remain available in port for legal proceedings restraints are placed upon the effective utilisation of his boat and may in the long term require the acquisition of an additional boat and crew. Such practical problems need to be given close attention when establishing regimes and in ensuring access to speedy judicial processes in the interest of all parties.

IS THERE A NEED FOR COMPLETE ENFORCEMENT?

36. Frequently, discussion of surveillance arrangements is predicated on the presumption that there is a need to catch all offenders. In consequence, some consideration has been given to the acquisition of 24 hour surveillance capabilities and to total coverage. The costs of such capabilities will be high especially when one may not be seeking total detection and apprehension.

37. Law enforcement does not work on the basis of 100% detection. The community has come to accept the premise that deterrence can be adequate if there is a possibility of risk of detection rather than a guarantee of being apprehended. It is interesting here to reflect upon the typical apprehension rate for NSW crimes over one year (in 1974). They were:

- Offences against the person - 52%
- Sexual offences - 68%
- Property breakings - 11%
- Theft (other than from property) - 20%
- Fraud - 78%

38. The savings in aircraft, boats and people needed for surveillance could be significant once it is accepted and recognized that complete detection is not needed to deter offences against the law. The possibility of being caught by a random air or sea patrol (when it is known that such random patrols are of sufficient frequency and effectiveness) can have a similar sort of healthy and corrective impact as does the random checks of the Commissioner of Taxation upon the ordinary "law-abiding" taxpayer. I must add, of course, that the possibility of apprehension by itself has limited value without the support of appropriate legal penalties.

THE WAY TOWARDS A SOLUTION

39. The issues and problems I have canvassed today are not of concern only in relation to the Barrier Reef. They are at present the subject of a nation-wide debate on coastal surveillance in peacetime, to support civil authorities enforcing laws dealing with such matters as fishing, customs, quarantine, immigration and ecological protection. The debate has been stimulated, of course,

by the coincidence in time of the first steps towards a 200 nm exclusive economic zone (with a 200 nm fishery zone as the first step) and the arrival on our shores of small boats loaded with Indochinese refugees seeking haven in this country.

40. How we should organise and conduct coastal surveillance nationally is currently the subject of urgent examination by a Committee of Permanent Heads of the various Commonwealth Departments concerned. Proposals are being aired for new types of surveillance organisation, new techniques and new hardware. It would be imprudent of me to anticipate that Committee's recommendations, or the Commonwealth Government's decisions on them. We will all follow the Government's examination of that Report with keen interest.

41. The efficiency and effectiveness of any surveillance system, however, depends ultimately on the realism of the total management or control regime which it is required to serve. There must be a clear definition of objectives and priorities if value is to be obtained from the expensive business of surveillance. This is as important for the Barrier Reef as for other areas and aspects of surveillance. I am sure you will share the hope that this Workshop will contribute to this important process of defining objectives and priorities in relation to the management of the Great Barrier Reef Marine Park.

APPLICATION OF LANDSAT TO MANAGEMENT OF THE GREAT BARRIER REEF

Denis Warne
Department of Engineering Physics
The Australian National University

SUMMARY

Data from earth-sensing satellites, especially Landsat and, in the future, Seasat, can provide considerable information of interest to oceanographers and coastal zone managers. These sources offer advantages of low cost, repeated global coverage, and ease of operation in remote areas. The benefits must, however, be weighed against the limitations of this use of satellites: inability to sense beyond the surface layer of the ocean; limited resolution; susceptibility to cloud cover; and data handling inadequacies. Potential applications include seabed mapping, the study of coastal processes, environmental and regulatory monitoring, and oceanographic research. The Australian National University's Department of Engineering Physics has developed a production-oriented approach to hydrographic mapping using Landsat data and the insights gained in this project are relevant to many marine applications. Processing of data gathered over the Great Barrier Reef would give rise to a number of unique problems, but if these are resolved Landsat could contribute significantly to the management of the Marine Park once the Australian receiving station becomes operational in 1979.

1 INTRODUCTION

Management of an area as extensive as the Great Barrier Reef Marine Park requires monitoring capabilities providing broad coverage at low cost. Satellites can provide a vast amount of data for those concerned with such a task. To date there has not been any operational satellite primarily for marine studies, however several have been capable of providing relevant data. In the field of remote sensing of the earth's surface, the series of satellites which has received the most attention, at least outside the USA, is Landsat (formerly known as ERTS - Earth Resources Technology Satellite) and these have been considered for several oceanographic applications including:

(i) provision of information on near-shore ocean dynamics;
(ii) detection of coastal damage;
(iii) detection of thermal and chemical pollution and the monitoring of its dispersal;
(iv) monitoring of siltation;
(v) hydrographic mapping of the seabed in shallow waters; and
(vi) monitoring of nutrients and temperatures.

This paper concentrates on the Landsat MSS imagery which at present attracts the most widespread interest and, to illustrate the issues involved in marine studies, its application to hydrographic mapping of shallow water is discussed. A brief description of planned further developments in remote sensing from space, including Seasat, is also given along with a discussion of areas requiring research if Landsat is to be applied successfully to the management of the Great Barrier Reef Marine Park.

2 THE LANDSAT PROGRAM *

Each Landsat satellite follows a circular, sun-synchronous, near-polar orbit at an altitude of approximately 950 kilometres. The satellite orbits the earth 14 times per day, giving complete global coverage every 18 days. The orbit is trimmed to keep the maximum deviation of the track over the ground to less than 37 kilometres. The payload consists of three systems: the Return Beam Vidicon (RBV) camera; the Multispectral Scanner (MSS); and a Data Collection System (DCS).

This discussion concentrates on the MSS data, but the techniques developed here could be applied to any suitable digital multispectral imagery of the earth's surface. The MSS subsystem forms its imagery by sampling the radiance reflected by the earth's surface at fixed intervals along its scan. An oscillating mirror is used to sweep cross-track swaths of 185 kilometres, simultaneously imaging six adjacent scan lines in each spectral band as shown in figure 1. The Landsat-1 and -2

* For further details of the satellite and program see the ERTS Data Users' Handbook [NASA, 1971].

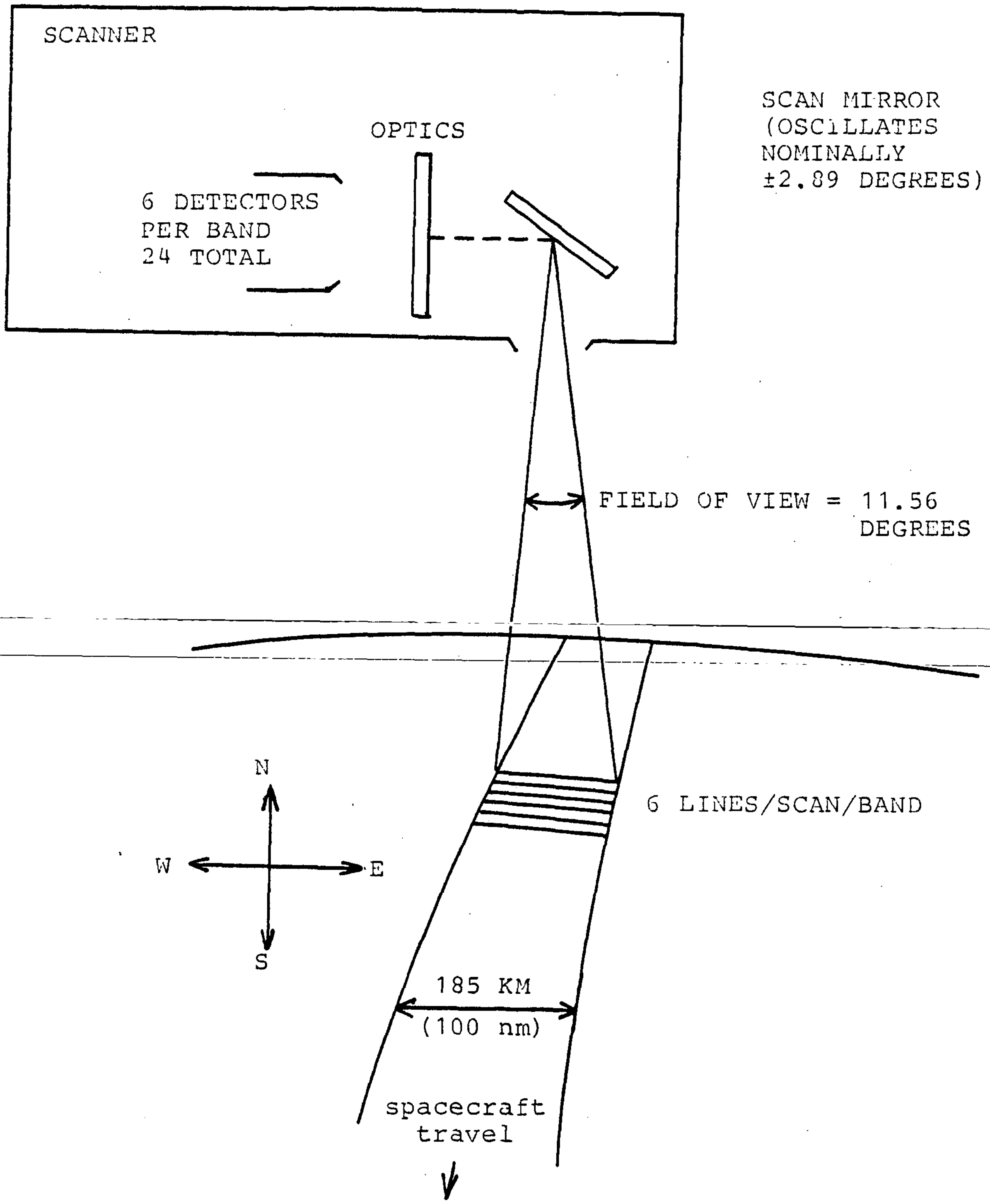


Figure 1: MSS system schematic (Thomas, 1975).

systems have four spectral bands ranging from the visible green into the infrared. Later satellites in the series will have further bands but the following descriptions apply only to the current four.

Each sample subtends an area of approximately 80 metres square on the earth's surface but overlap improves the effective cross-track resolution to 60 metres, giving about 3250 samples per scan line. Along track scan is provided by the orbital motion of the satellite advancing the system by the equivalent of six scan lines (approximately 470 metres on the earth's surface) per sweep of the mirror. Figure 2 shows the resulting scan pattern. The imagery is framed during processing on the ground so that each scene contains 2340 scan lines.

3 ADVANTAGES AND DISADVANTAGES OF SATELLITES

Because of the physical separation between the sensor and the object sensed, satellites share many of the benefits and shortcomings of aircraft as data collection platforms. Satellites are not, however, merely extra-high flying aircraft: by their very nature, their logistics and their economics, they must be considered in a different light.

Among the advantages that can be claimed for satellites as a data source are:

(i) low cost;
(ii) global coverage;
(iii) repetitive coverage;
(iv) spatially "continuous" coverage; and
(v) ease of investigation of remote areas.

Against these must be considered several disadvantages including:

(i) restriction to electromagnetic sensing;
(ii) limited resolution;
(iii) susceptibility to cloud cover;
(iv) critical weight and power considerations; and
(v) current inadequacies in appropriate data handling technology and expertise.

The low cost of satellite data results from the low post-launch operating cost and the fact that the same facility is shared between many users all over the world. But in order to satisfy this number of users several compromises must be made. A major trade-off exists between the area covered, the resolution and the overflight frequency. An increase in any

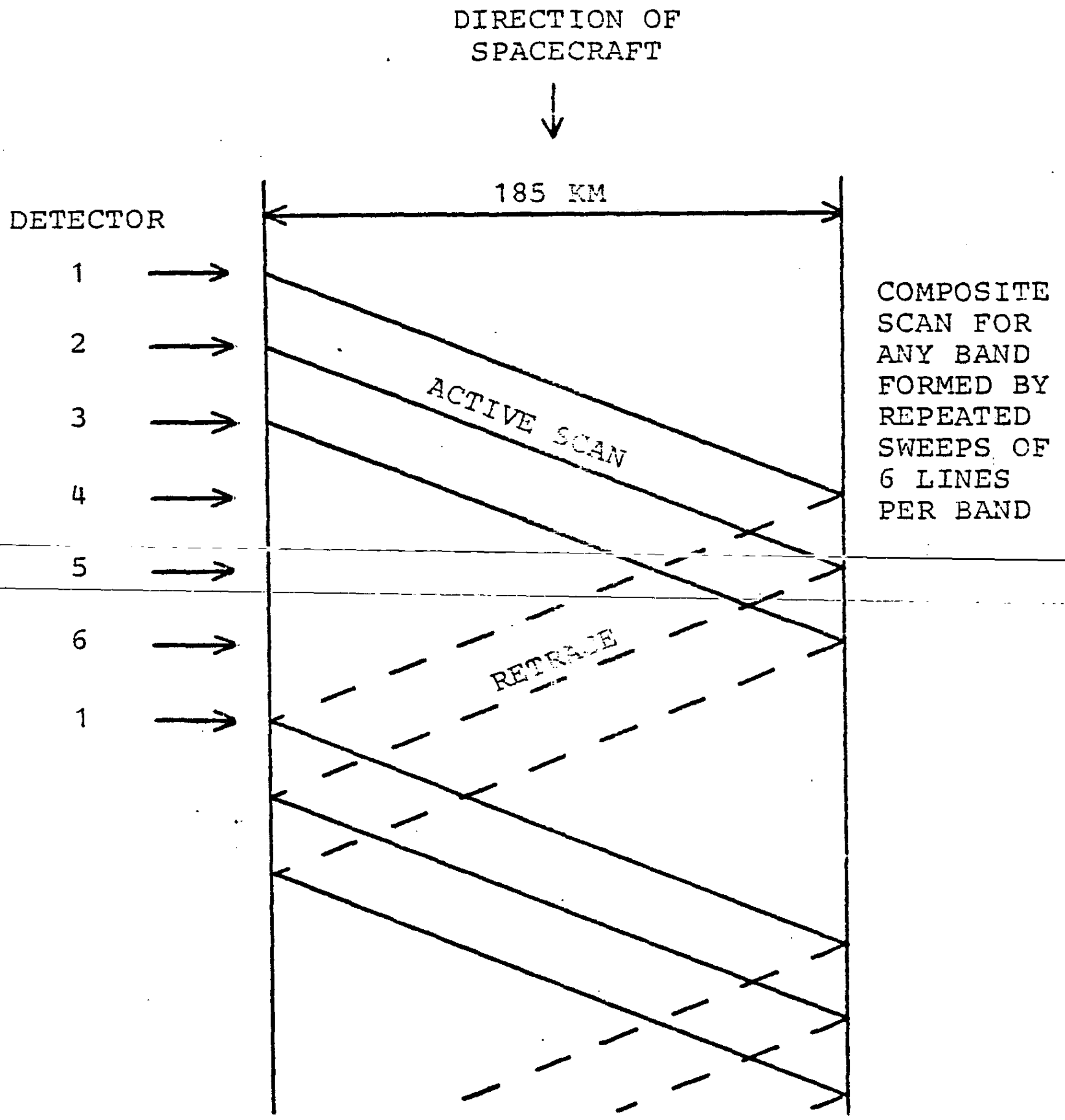


Figure 2: Ground scan pattern for MSS.

of these factors would result in the transmission to earth and subsequent processing of an increased amount of data. In many cases, however, both communication and data processing technologies are already reaching their economic limits in these satellites and hence any of these factors can be enhanced only at the expense of the others.

The broad scale coverage, albeit at a limited resolution, provides synoptic views not economically feasible by conventional techniques. The highest resolution imagery likely to be commonly available within the near future is that from the Seasat imaging radar which will have a resolution element of 25x25 metres, but there will be a high price paid for this resolution. Due to current limitations in data storage technology, it will not be possible to record this data on board the satellite and hence this sensor will be of use only within range of a ground receiving station. Although some portable receivers have been proposed, the inability to use on-board recording may limit utility of the imaging radar in studies of areas not within the range of a suitable receiving station. In other respects, because they experience no operational difference between remote and easily-accessible areas, satellites may be particularly relevant to studies of the ocean and coast. It is anticipated that all the Barrier Reef will be in range of a receiving station after 1979.

The restriction of satellite sensors to those which operate via electromagnetic radiation is reflected in the limitation of satellite sensing to a relatively thin surface layer of the ocean. The Landsat sensor with the greatest penetration can view only as deep as 20 to 30 metres in favourable circumstances and variations in sensor characteristics are unlikely to result in a substantial improvement.

Those detectors which sense visible and infrared radiation are susceptible to interference from atmospheric effects including the wispy clouds of the upper atmosphere. The danger here is not that a survey will be aborted due to bad weather, but that such fine atmospheric structures may go undetected while still distorting the results. Microwave sensor and imaging radar technology is now helping to make satellite sensing less susceptible to the quirks of the atmosphere and weather.

Users see satellite weight and power considerations reflected in the length of time for which sensors may be turned on in any one overflight; the amount of data that can be stored and transmitted; and the amount of on-board processing of the data that can be carried out. In the past data has been transmitted to earth while still in a very raw form and processing has been carried out on the ground at a central facility. However, it is anticipated that later versions of Seasat will have sufficient on-board processing capability to convert a limited portion of the data into appropriate physical units such as temperature, wave height, and wind speed and direction, and that this information would be continuously available to ground stations and ships without sophisticated processing equipment.

The current general lack of familiarity with the analysis of satellite data, especially when used in digital rather than photographic form, is one of the most significant factors preventing it from achieving its full utility. The sheer bulk of the data has, in itself, proved an impediment in that modern computers and programming techniques, for all their sophistication in conventional computational tasks, are inadequate in the face of so much information, especially when the data takes the form of imagery.

4 RADIOMETRIC ENHANCEMENT OF LANDSAT IMAGERY FOR MARINE STUDIES

In land-oriented studies radiometric defects in Landsat data usually lie within the tolerances of computational algorithms, but in oceanographic studies the limited useful signal range makes every defect critical. The defects of concern are:

(i) Random noise;
(ii) Six-line striping;
(iii) East-west bands;
(iv) North-south bands; and
(v) Data drop-outs.

These defects are more complex than generally acknowledged and sophisticated remedial action is necessary before quantitative marine studies are possible [Warne, 1978]. With suitable processing, considerable enhancement is possible but only at the cost of spatial resolution. In many marine applications spatial changes are gradual and loss of spatial resolution can be tolerated. However, the degree of enhancement possible in reef studies may be limited by resolution requirements.

5 HYDROGRAPHIC SURVEYING WITH LANDSAT

Neglecting multiple reflections within the body of the sea, the optical relationship between radiance measured at the detector, R, and water depth, z, can be expressed in the form:

$$R = a + b.\exp(-c.z) \quad \ldots \ldots \ldots \ldots \quad 1$$

where a, b and c depend on the prevailing optical characteristics of the sea and overlying atmosphere.

'a' represents the signal that would be returned from "infinitely" deep water and is the sum of atmospheric path radiance and radiance reflected from the sea surface and within the sea water itself. 'b' includes the effects of attenuation of the light at the sea surface. Both 'a' and 'b' include an atmospheric attenuation term. 'c' is the effective attenuation coefficient for light passing to and from the sea bed with appropriate allowance being made for the non-vertical, and possibly indirect, light path. More detailed discussions are given elsewhere [Austin, 1974; Lyzenga and Polcyn, 1976; Moore, 1946; Polcyn, 1976; Warne, 1978].

Coefficient values may be determined empirically from depth data or from measured optical characteristics. The former simplifies survey management in many ways and is used in the approach described here.

Data collected over areas off the north-east coast of Australia has been analyzed at the Australian National University (ANU) to study difficulties arising due to the intricacies of the natural environment. Complete details of the project are given in Warne [1978].

The study confirmed the simple form of the relationship between Landsat signal and depth (equation 1) but found that the coefficients in the model vary considerably from place to place in a manner which, at best, is predictable in only a qualitative way. The problem is one of detecting coefficient variations and so determining where further depth measurements are required to calculate new coefficient values.

Equation 1 cannot, therefore, be applied unreservedly to depth calculation. The ANU study has led to a practical approach based on integration of: Landsat imagery of the survey area from several overflights of the satellite; a skilled image interpreter; a suitable system by which he can deal with the Landsat data; and a shipborne survey. For the approach to be economic, the dependence on the ship must be significantly reduced when compared with conventional surveys. (With new developments in airborne depth sensors, the ship may in the future be replaced by an aircraft [Hickman, 1973; Kim et al, 1975].)

Although the digital form of the data - and hence computer analysis - must be used because of the limited useful signal range, the complex nature of the marine environment demands the skill of a human interpreter to supervise the analysis if satisfactory results are to be obtained. Available interactive image analysis systems for remote sensing studies concentrate on multispectral classification and are unsuited to this application. A special purpose analysis system has been developed using interactive image analysis facilities at the ANU and incorporates a variety of software tools developed primarily to aid in hydrographic studies [Warne, 1977].

In principle, the system uses Landsat data to fill in between sparse shipborne soundings. The average number of ship traverses required for a survey is generally reduced by a factor of fifty or more when Landsat imagery is used. The denser the soundings, the more accurate and reliable will be the results and there are circumstances which need a greater density or even a complete shipborne survey.

Savings in survey cost by factors of between two and 20 or so can be realized. Variations can be made in the density of ship soundings, the number of satellite overpasses analyzed, and the extent of ancillary support. There is a fairly direct correspondence between the cost, both in terms of time and money, and the map reliability achieved. Consequently, the authority responsible for any survey can weigh up its own requirements and constraints to arrive at an appropriate balance of reliability and cost.

It is generally accepted that under moderately favourable conditions, Landsat can map depths to approximately 20 metres with an accuracy of ten percent [Byrne and Honey, 1977; Polcyn, 1976; Warne, 1978]. Test surveys conducted at the ANU have shown that degradations likely under normal circumstances are not severe provided an interactive digital approach is used.

Limited spatial resolution causes some shortcomings, most significant of which are isolated rock outcrops which cannot be resolved. Such outcrops must be at least two pixels square if their reflected radiance is to be properly measured by the Landsat detectors, and even larger if radiometric enhancement, with its consequent loss of spatial resolution, is to be applied. There is no way of guaranteeing that the Landsat technique does not miss such outcrops. To reliably detect these features, a supporting technique such as aerial photography is required.

6 MULTISPECTRAL AND TEMPORAL TECHNIQUES

For features above or near the waterline, several of the Landsat MSS spectral bands can be used together to identify the land/reef cover type. Each type of cover has associated with it particular optical characteristics that cause it to reflect different amounts of different wavelengths of light.

This is basically saying that each cover type has associated with it a particular colour, but here the concept of colour is extended to include infrared as well as visible light. The Landsat MSS system effectively samples these reflectance characteristics at four discrete wavelengths producing a set of four values which is referred to as the "signature" of the particular cover type. Once the signature is known, a particular cover can, in principle, be identified anywhere it occurs in a Landsat scene. If signatures are known for all features of interest, each picture point in the Landsat scene can be classified according to its particular type. A number of computer algorithms now exist for performing this function [Williams, 1976]. Once such a classification is done, thematic maps can be produced and areal cover statisticas calculated as required.

Unfortunately, a number of difficulties arise in naturally occurring situations. Ground cover type is not the only factor affecting the light reflected from an area of the earth's surface. The season, meteorological history, and presence and concentration of nutrients are all major factors leading to variations of the spectral characteristics of a particular cover. Each cover type, then, is represented by a range of signatures rather than by a single signature and frequently the ranges from two different types overlap. Some localized variations are averaged out over the area covered by a single sample (80 metres square) of the MSS system, but this finite sample size itself introduces problems in that a sample generally contains a mixture of cover types. Results are, therefore, sometimes more appropriately expressed as proportions of each particular type present. Such an analysis relies, in part, on a priori knowledge of the types of cover likely to be present. Consequently, Landsat analysis of an area such as The Great Barrier Reef is only meaningful with skilled interpretation based on a degree of local knowledge, though the computer analysis techniques already developed for agricultural studies can assist in establishing quantitative results.

Some problems can be overcome using multiple overpasses of the satellite. In the hydrographic mapping case discussed previously, imagery from different overpasses is used to eliminate atmospheric and current-induced disturbances. In the multispectral classification situation, the spectral signature from several overpasses can be combined to give a joint spectral/temporal signature. It has been found that changes in characteristics are frequently more valuable in identifying features than the characteristics themselves. For example, while two species of vegetation may not be distinguishable on the grounds of their "greenness" alone, it frequently happens that the rate of change of "greenness" throughout a growth cycle does make the two types separable.

7 FUTURE DEVELOPMENTS

The next satellite in the Landsat program is Landsat-C due for launch early in 1978. It will differ from its predecessors in the addition of a thermal infrared channel to the MSS and the replacement of the former three channel RBV by a high resolution (40 metres) panchromatic RBV [NASA, 1976]. The thermal infrared detectors will have a resolution element on the earth's surface of 238 metres square, there being one thermal scan for every two lines of the other MSS bands. The thermal detectors will also be switchable to eight possible gain levels.

NASA is upgrading its Landsat processing facilities to increase its throughput by a factor of ten. Data will be processed within 24 to 48 hours as opposed to the present two to three week period. Planimetric corrections will be applied to both digital and photographic data and, where possible, registered data from multiple overpasses will be produced.

Landsat-D's equivalent to the MSS system will probably have six spectral bands [McCloy, 1977]. The additional band will be in the visible blue region of the spectrum and will considerably aid water studies. Other bands are to be be adjusted slightly to provide better discrimination, especially for agricultural studies. Resolution will be improved to thirty metres, but at the cost of reducing satellite altitude, so reducing the range over which data will be receivable by ground stations from approximately 3,800 kilometres to 3,000 kilometres.

Perhaps the most exciting development in the field of oceanographic surveys will be the advent of Seasat-A [Nagler and McCandless, 1975; NASA, 1977] - the first of a series which is especially designed for oceanographic work. Potential applications of Seasat data include:

(i) wave measurement and forecasting;
(ii) monitoring of the transport of chemicals, nutrients and pollutants;
(iii) studying shoreline and estuarine dynamics;
(iv) monitoring tidal behaviour;
(v) studying the dynamics of the coastline and shoals; and
(vi) monitoring beach erosion.

It will carry five sensor systems:

Sensor	Suggested Applications
Compressed Pulse Altimeter	Ocean topography Wave height
Microwave Scatterometer	Wind speed and direction
Synthetic Aperture Imaging Radar	Wavelength spectra Local high resolution images
Microwave Radiometer	All-weather temperature measurement Wind speed Atmospheric path corrections
Visible and Infrared Radiometer	Clear weather temperature measurement Feature identification

Seasat-A will be launched in 1978 and is intended to have a 1-3 year life. It will provide global coverage every 36 hours for all of its detectors except the imaging radar which will have a coverage cycle of 14 days. For the system to reach full capability, giving updated data every 6 hours with complete radar images twice per day, at least 6 satellites will be needed. It is envisaged that such a system will be viable in 1985, however consideration is also being given to launching an interim system of 3 satellites between 1980 and 1983.

In Australia, the utility of Landsat has been limited by long delays in receiving data from the USA and the inability to determine which data is actually collected and processed. Not having suitable data receiving and processing facilities of our own, we have had to depend on on-board tape recorders which are subject to other mission requirements and which have proved the least reliable component of the satellite system. This situation will be rectified in 1979 when Australia's own data receiving and processing facilities become operational. Production surveying with Landsat will then be possible.

8 DEVELOPMENT REQUIREMENTS FOR BARRIER REEF SURVEYS

The Barrier Reef region is unique and so presents unique problems which must be resolved before Landsat can be turned to production monitoring of the area. The most significant development requirements are discussed briefly below.

Cataloguing of characteristics of features of interest must be the first step. This would involve qualitative and quantitative comparison of Landsat imagery with ground truth data concerning vegetation type, nutrients, presence of sand or coral and so on. Ideally, the comparison could be made for a number of overpasses of the satellite so that temporal as well as spectral characteristics could be determined.

Two particular problem areas set a reef survey apart from other applications of Landsat. Considerable radiometric correction of the raw Landsat data is necessary in marine studies and this generally results in a loss of spatial resolution. In the hydrographic mapping situation, considerable loss of resolution can be tolerated but this would not always be permissable in reef studies. On the other hand, in most reef studies the reefs are not submerged to the same depth as the majority of the seabed in hydrographic surveys. This leads to less attenuation of the light and consequently the radiometric defects are less critical. The trade-off between spatial resolution and radiometric quality appropriate for this application has yet to be determined. The second unique problem in reef studies is the mixture of optical media between the object of interest and detector. In some areas there is only the atmosphere, while in others both atmosphere and water are present. Computational algorithms will need modification to cope with this effect.

To obtain the greatest benefit from a research study, both computer analysis and skilled interpretation is necessary, preferably in an integrated manner such as the approach to analysis suggested for hydrographic surveying. The study would need to be interdisciplinary, combining the expertise of those familiar with the reef with skills in the new analysis methods needed for Landsat surveys.

It is difficult to foresee all the problems likely to be encountered in satellite monitoring of The Great Barrier Reef but the potential benefits are enormous especially when Australia's Landsat facilities become fully operational in 1979. To obtain these benefits, considerable prior effort must be committed to identifying and overcoming problem areas.

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A SYSTEMS APPROACH TO THE MANAGEMENT OF A REEF ECOSYSTEM

K.P. Stark and A.B. Pomeroy
Department of Civil & Systems Engineering
James Cook University of North Queensland
Townsville, Queensland, 4811, Australia

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1.0 ABSTRACT

The great Barrier Reef Marine Park Authority has been charged with the responsibility of recommending appropriate controls to ensure optimal management of the Great Barrier Reef, a unique complex ecological system.

Any dynamic living system is subjected to continuous change and man's interaction with it must inevitably affect these changes. Management of the Reef, therefore, implies the establishment of procedures which will allow this interaction to occur in a way which optimises the requirements of users of the system consistent with the needs of conservation and preservation of the system. These management decisions must be taken with a background of inadequate understanding of the complex processes - climatological, hydrodynamic, geological and biological - which describe the system behaviour.

The systems approach offers management a method of attack which attempts to integrate the knowledge and resources available in a manner which can allow an effective macroscopic view of the system for managerial purposes. Planning and management of a reef system must involve a team effort combining an ecological view as well as a critical appraisal of man's goals and expectations.

This approach requires the establishment of an appropriate baseline study, an effective data base, and the development of macroscopic system models consistent with the information available. Flexibility in design is required to ensure that the system description and definition can be modified with the development of scientific understanding. An attempt will be made in the paper to outline an initial system definition and an appropriate methodology to assist early planning and management requirements.

2.0 BACKGROUND

The Great Barrier Reef Marine Park Authority is charged with the definition and planning of Marine Parks with due regard to a number of objects as defined in Section 32(7) of the Act (Ref.1). These objects are:

(a) the conservation of the Great Barrier Reef;
(b) 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;

(c) 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;

(d) the reservation of some areas of the Great Barrier Reef for its appreciation and enjoyment by the public; and

(e) the preservation of some areas of the Great Barrier Reef in its natural state undisturbed by man except for the purposes of scientific research.

This charter can be broadly interpreted as the responsibility for *management* of the Great Barrier Reef where management implies the establishment of an optimal set of controls to ensure that the objectives as defined in the Act are attained.

It is widely recognised by scientists who study some aspects of the Great Barrier Reef that our understanding of the biology and geology of the Reef is quite rudimentary, nevertheless, a management plan must be developed now, to ensure (i) that existing usage is not causing irreparable harm, and (ii) that future usage can be properly co-ordinated and integrated.

In many ways this problem is, at this stage, similar to the management of a 'black-box' system whose properties and behaviour have defied detailed analysis and understanding. In management terms this means *managing under conditions of uncertainty with little or no information.*

It is not possible to explain in detail how the properties of the system will change with time but it is possible to outline a progressive management plan which, with a complementary progressive research programme, will allow a rational utilization of the available resources during a period, whilst, at the same time, a more detailed understanding of the system behaviour is being acquired.

3.0 DESCRIPTION OF SYSTEM

3.1 General

The Great Barrier Reef extends for 1,200 km along the Queensland coast at a distance from the coast which varies from 20 km in the north to 300 km in the south, approximately. The development of the Reef is geologically a comparatively recent occurrence as the first reefs date back some 15,000 years to the last Ice Age (Pleistocene). In this post-glacial period spasmodic sea level changes were associated with aggregations of terraces and ridges along the edge of the continental shelf which involved an easterly movement of sediments conveyed from rivers on the mainland. The first coral deposits most probably moved westerly from reef developments in the Pacific (Ref.2). The geological formation of the Reef varies considerably from north to south.

Reefs north of Cooktown are closer to the coast than elsewhere and tend to form linear reefs along the outer edge of the shelf. This continuous strand of reefs forms a very effective interface between the deep ocean and shallower areas on the shelf. The narrow openings between reefs are characterised by strong currents which assist circulation and the transfer of sediments from the vicinity of reefs.

The shelf between the coast and the outer reefs in the northern region of the Great Barrier Reef, where attention is focussed in this Workshop (latitudes 10° - 16°S), is generally narrower and shallower than corresponding areas to the south. It is marked by many fringing reefs along the coast and a variety of platform reefs. Water levels are less than 35 metres. Navigational charts for the area are comparatively poor with a number of ill-defined areas. The bathymetry of the area is obviously dynamic and complex.

The complexity of reef systems becomes even more evident when the composition of a particular reef is examined and the problem is further compounded when the biota - the living organisms - in a reef community are considered. A number of the papers presented at this Workshop focus attention on these difficulties.

It is appropriate, however, to draw attention here, not only to the magnitude of taxonomic complexity but also to the complexity of interactions between different parts of a reef system. The problems associated with identification of species of coral and their intra-specific variation are outlined by Veron & Pichon in Ref.3 following a study of some tens of thousands of specimens. It is important to stress here that many of these intraspecific variations are closely related to environmental factors.

Further, Pownall (Ref.4) has suggested that some 10 percent of fish species in the world's oceans can be found in the Great Barrier Reef together with a vast array of other animals and plants. Details of these reef inhabitants will be outlined in other papers.

3.2 Definition

In defining the system under study for management purposes it is important to identify the interaction of man with the system - man's usage expectations - and it is also necessary to specify the physical limitations of the system concerned; that is where the system ends and the *system environment* begins. Climate and climatological data must be considered. Very often with other systems, management decisions can be made without consideration of climatic factors but the system under consideration in this Workshop is inextricably dependent on every facet of climatological data.

The system under study has then 3 major sub-systems:

(i) the ecosystem
(ii) the users
(iii) the climate.

The known details of the ECOSYSTEM will be described in other papers but it must be acknowledged that our understanding of the ecosystem is entirely inadequate to allow a definition of ecosystem dynamic behaviour at this stage.

A survey of Users of the Barrier Reef has been undertaken by Domm (Ref.5) under the auspices of the Great Barrier Reef Authority. Briefly, the principal usage types can be classified as :

Professional Fishing	-	Residential, domestic, other
Specialised Fishing	-	e.g. Bêche-de-mer
Recreation	-	Fishing, boating, skin diving, shell collecting
Tourism	-	International, Australian, residential
Research Activities		
Conservation		
Mining Activities	-	Prospecting, drilling, mining
Transportation	-	Major shipping lanes, harbours, other

Indirect usage of the system area can affect the behaviour of the system. Such usage can be classified as pollution.

Pollution	-	River, urban, industrial, farming, shipping effluents, 'oil' spillage.

It must be realised that some of these usage types may not be relevant in any particular management decision.

The CLIMATOLOGICAL sub-system is pertinent, not only in affecting the dynamics of the system, for example, the rate of photosynthesis, wave action and sediment transport, but also, in determining the usage rates such as suitability of weather for fishing, boating or diving. Furthermore, major climatological factors can cause step changes in the pattern of system growth and development. Such occurrences include major cyclones, with enormous wave and storm surge patterns, and floods which penetrate many kilometres with freshwater and silt loads.

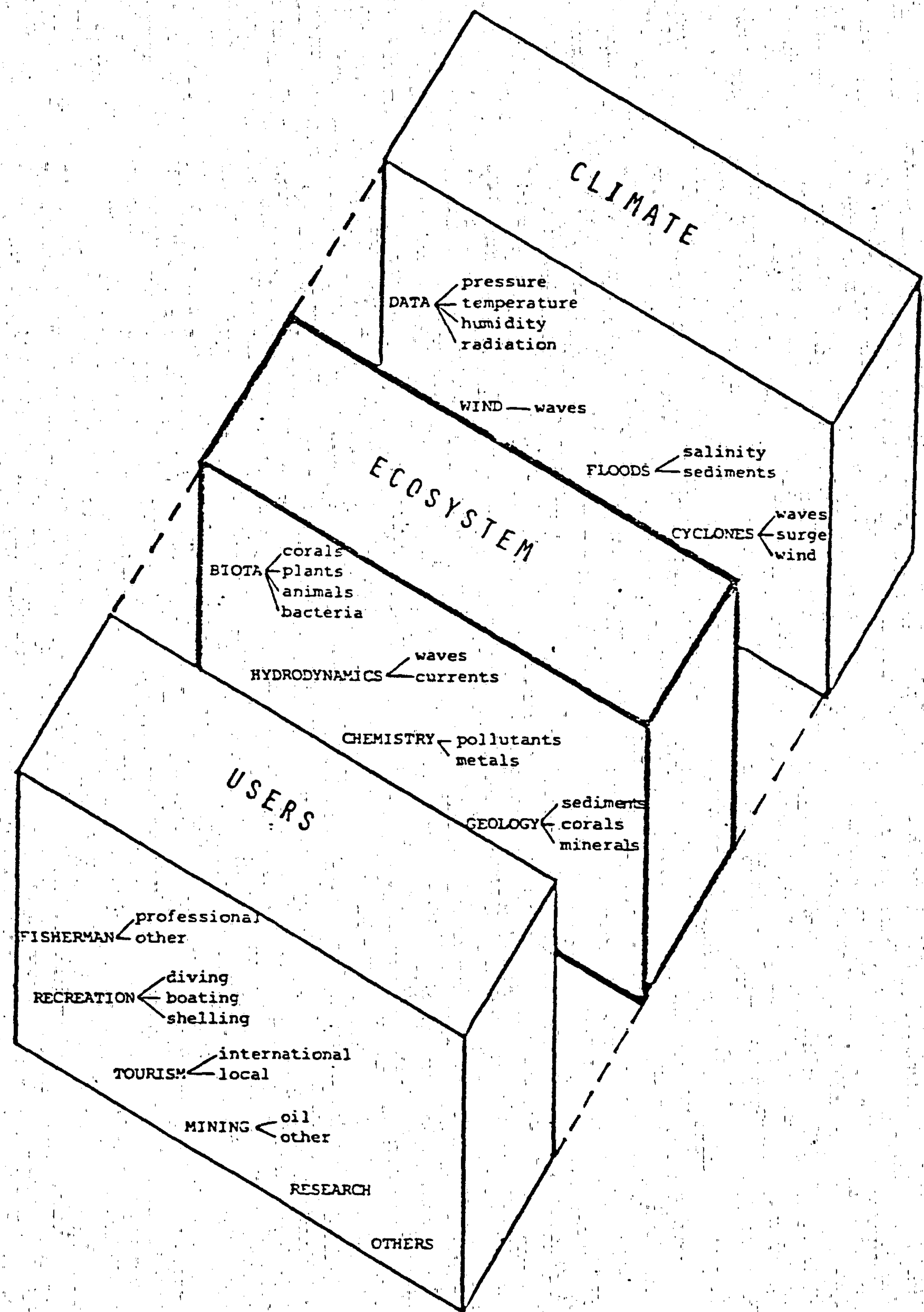

Figure 1 Overview of System Under Study

The major climatological properties of the system can be listed as:

barometric pressure	rainfall	waves
temperature	winds	floods
humidity	tides	cyclones
radiation		storm surges

A diagrammatic representation of the system is given in Figure 1.

It should be obvious that management of the system implies setting rules and policies to guide and control the behaviour of the USERS so that the state of the ecosystem remains at a required quality standard when subjected to the interactions that will occur between and within the 3 sub-systems USERS, ECOSYSTEM and CLIMATE.

4.0 MANAGEMENT OBJECTIVES

Bearing in mind the responsibilities of the Barrier Reef Authority as defined under the Act and as amplified above, the management objectives can be simply stated as - the maintenance of the Reef in an 'optimal viable' state consistent with the maintenance of 'viable' usage patterns for each of the different types of users. Acceptance of this objective suggests a hierarchical goal structure for the management of the system as follows:

(i) Primary Goal - Maintain reef in optimal viable state

(ii) Secondary Goal - Maintain usage functions at viable level

(iii) Decisions - Nominate areas for different usage activities and maximum levels of activity

(iv) Operations - Monitor effects of different usage activities

(v) Management Information - Incorporate in management information system

(vi) Analysis - Evaluate effects on system

(vii) Decisions - Modify policies adopted in step (iii) and continue iteratively.

A diagrammatic representation of this hierarchy of goals is given as Figure 2.

The definition of what constitutes a viable state for the total system, or any part of it, can only be made in terms of the understanding of the system at any particular time. As this understanding grows, a more precise definition should be possible. Broadly, however, the term 'viable state' could be interpreted as one where the existing level of activities could be maintained without appreciable deterioration of the 'quality' of the system, even with the occurrence of very rare or unlikely events.

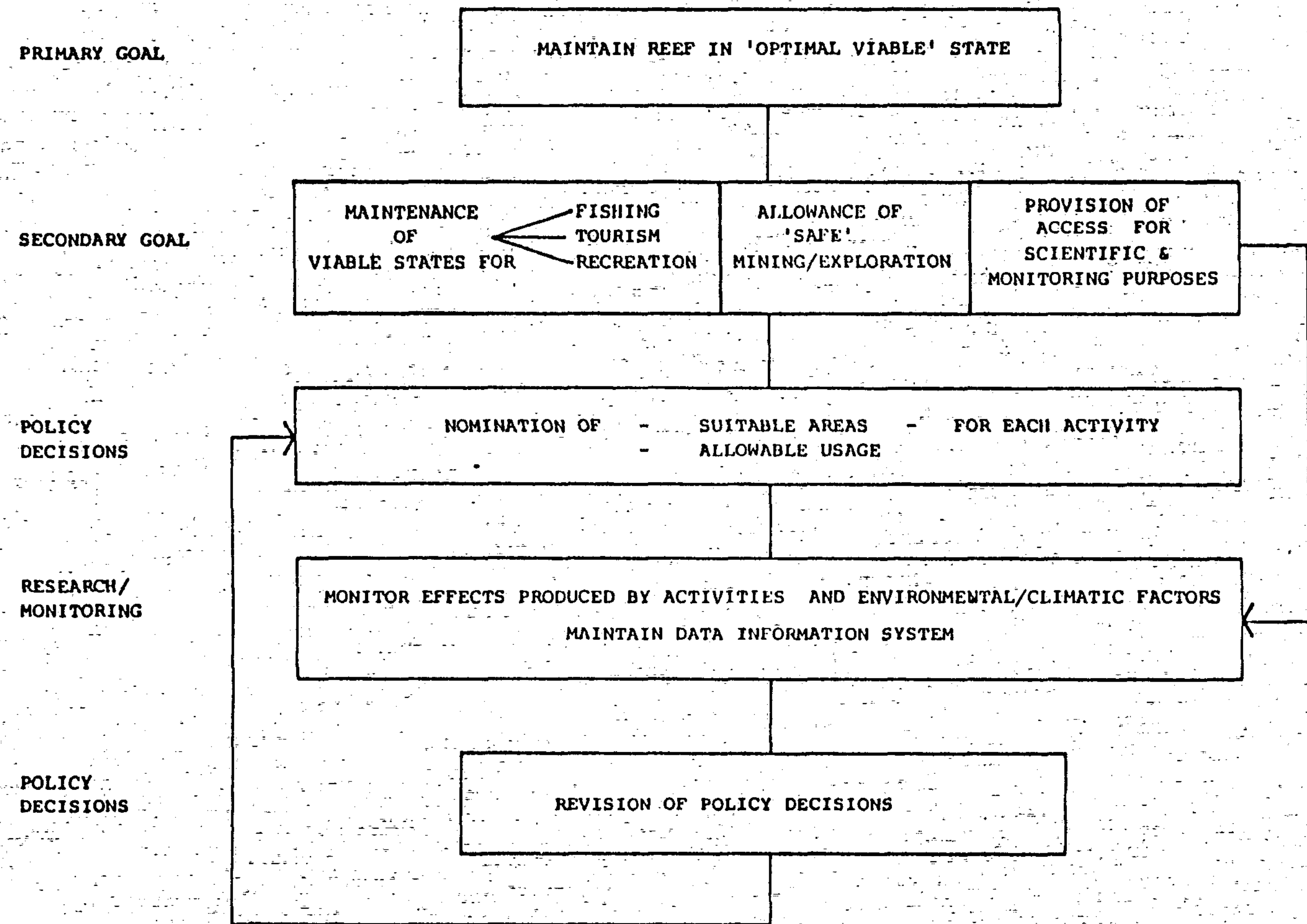

Figure 2 Goal Hierarchy for Management of Reef

Unfortunately, the term 'quality' cannot be given an accurate assessment; however, it will be necessary for management to define certain criteria which can be used as a quality index. Again, this index will be capable of more accurate definition as our knowledge and understanding of the system behaviour is enhanced.

5.0 PROGRESSIVE STEPS IN MANAGEMENT PROGRAM

A simplified view of the management role outlined above is given in systems dynamics terms in Figure 3. Management decisions must be two-pronged, firstly, to *set* the appropriate standards or quality indices which must be maintained to ensure system viability and secondly, to *control* levels of user-activities so that the standards set are not violated. This process requires continuous monitoring of the system within the feedback loop of Figure 3. It is not obvious from Figure 3, however, that the level of decision-making becomes more sophisticated as the information about the system is effectively co-ordinated and utilised. The spectrum of decision cases is illustrated in Figure 4 as ranging from the 'no information stage' to the 'complete information stage'. Slotta et al (Ref.6) identify these 4 classes of decisions in association with the four stages of progression from 'no' to 'complete' information.

Initially the information base for the reef system is so limited that decisions will be based on intuition and subjective judgement. Public participation programs might assist with information but generally such information is not scientifically accurate. Class 4 decisions will, therefore, require a judgement of acceptable quality standards which must necessarily be quite conservative if system 'viability' is to be maintained. It is suggested that broadly defined quality indices should be established for Class 3 and 4 decisions which will allow system degradation to be monitored. Standards set for these decisions should not allow system degradation to exceed some arbitrary limit, say of the order of 10 percent.

The ability to make improved decisions increases as information collected is used effectively. The establishment of a system DATA-BASE will permit this. Such a data-base must be designed so that (i) interaction with the information stored is possible for all researchers and management personnel; (ii) new data can be added progressively as it becomes available; (iii) sparse arrays of data can be efficiently stored; and (iv) interrogation programs can be undertaken with little or no computer background.

The accumulation of information by monitoring and research will also permit the complementary development of operations research, systems engineering and management tools to assist management in improving the class of decision progressively from Class 4 to Class 1.

Complex multidisciplinary problems, such as management of a reef system, are unlikely ever to reach decision Class 1 for which deterministic solutions are available. It is necessary, therefore, to consider some of the methodologies which are appropriate to Class 2 and 3 decisions. These methodologies include the application of statistical methods, cluster analyses, simulation models, decision theory, allocation techniques, models of particular sub-systems and large scale interactive system models.

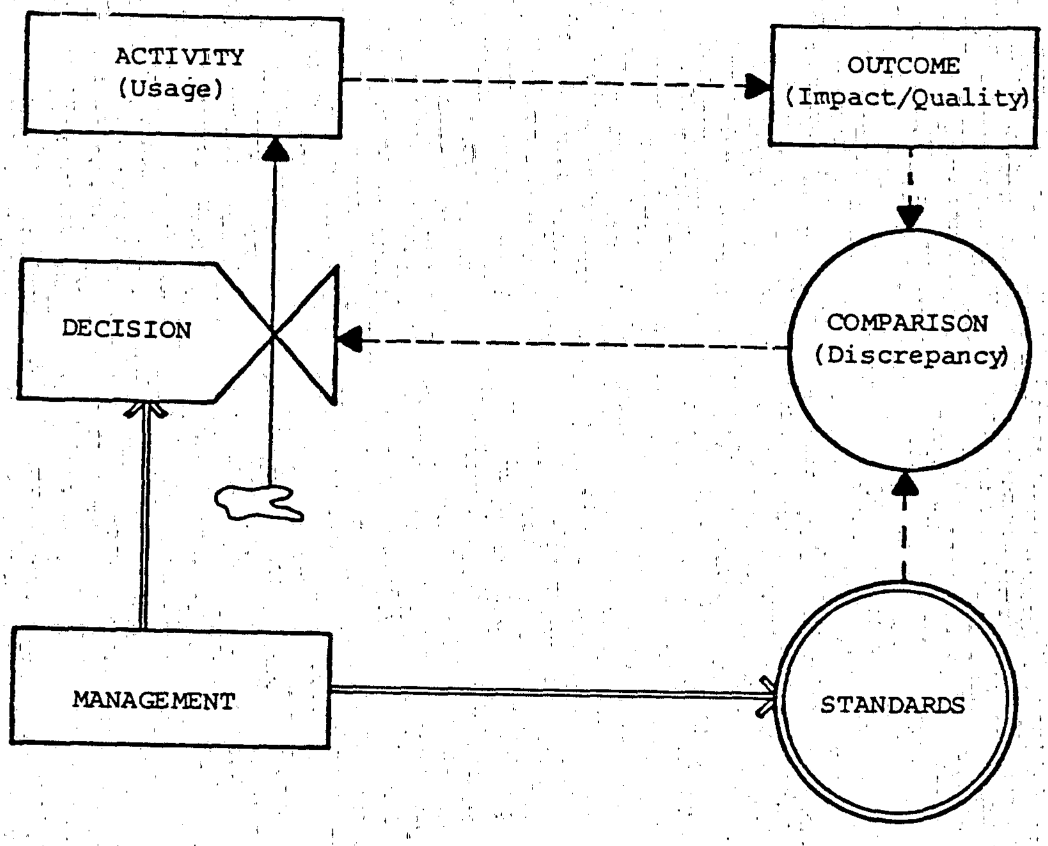

Figure 3 A Simplified Goal-Maintaining System

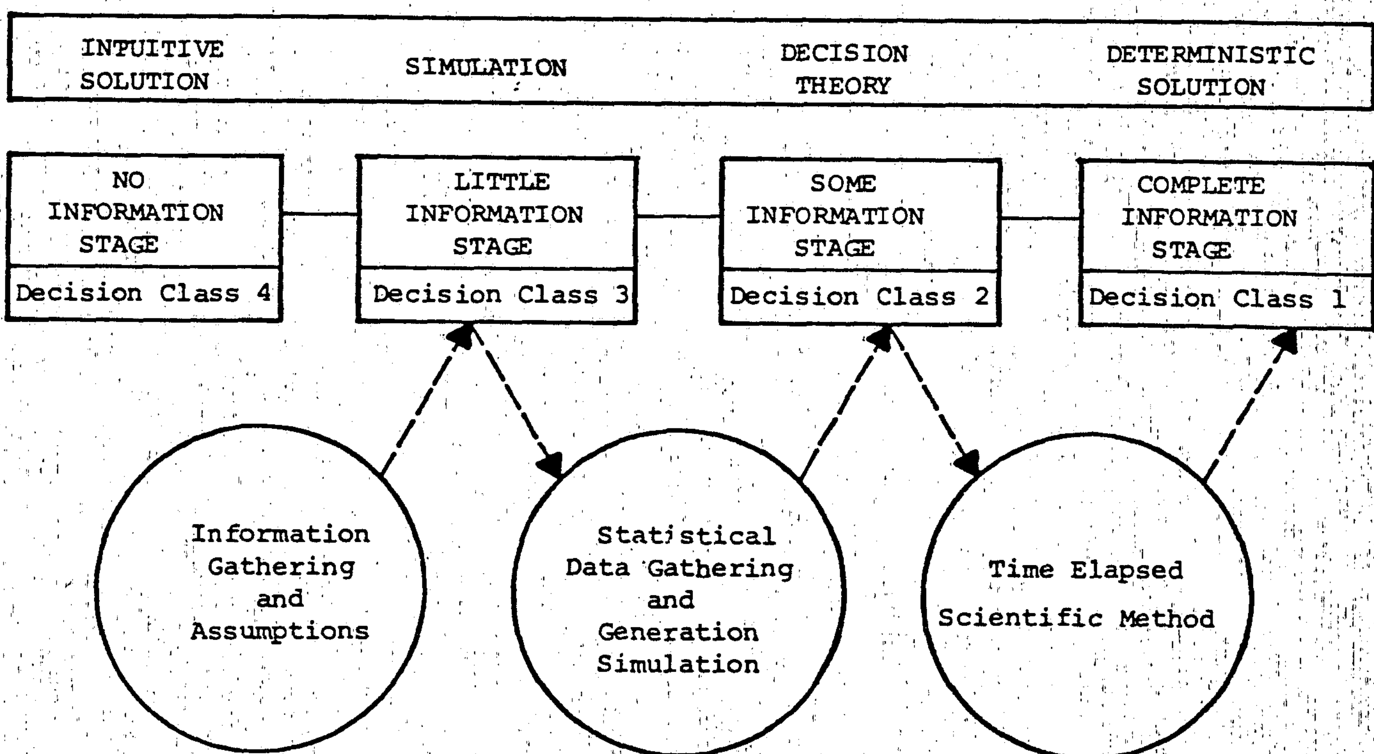

Figure 4 Spectrum of Decision Cases

An effective large scale system model for management purposes would not be feasible until sufficient multidisciplinary information is available from detailed studies of system behaviour. This research will extend over many years during which time a large scale system model should be progressively developed through the stages suggested in Figure 5 (see also Ref. 7,8). During this developmental stage some sub-system models should be available for assisting management decisions (see Section 6).

6.0 INITIAL SIMULATION MODEL (CLASS 3 DECISION)

Although accurate scientific data will not be available for some time, the management role must be performed; furthermore, the information base will be continually expanding. It is recommended, therefore, that a simulation model based, on systems dynamics techniques, be developed to assimilate, and assess the data available at any time and then simulate the behaviour patterns of users and their effects on the ecosystem under the variety of expected climatic conditions.

A broad flow diagram for such a simulation program is given as Figure 6. In this diagram the possibility of simulating weather changes, system dynamics and changing usage patterns is incorporated with the understanding that these simulations will depend on the decision class operative at any particular time.

A simple grid pattern covering the project area is supplied as Figure 7. The square network can be modified as required for different node positions, grid shapes or sizes. Each grid area can be described in terms of all known characteristics which will be obtained from the project data base, updated continuously with research and monitoring data.

Such a simulation program can be developed now, with very rudimentary treatment for some segments. It would, however, enable the assembly of all known data and usage types and would provide a ready indication of areas of conflict, e.g. too many users wanting to use a particular GRID AREA. Stress points within the system could therefore be identified for different usage growth rates and appropriate management criteria simulated to obtain the most effective solution.

Although it is not possible to define all the system program details, some amplification of two major segments - the hydrodynamic model and the ecosystem model, might be appropriate.

6.1 The Hydrodynamic Model

The hydrodynamic model is particularly important in considering the transfer of wind, tide, atmospheric pressure, flood and other effects throughout the system. As an example the use of a hydrodynamic model developed at James Cook (Ref.10) is given in Figure 8 where the currents produced, at one time step in the passage of a cyclone across the project area, are shown. The numerical model that has been developed simulates the pressure and wind fields developed in a cyclone and moves the cyclone in an appropriate path. The hydrodynamic effects are, in turn, simulated by solving the relevant equations for each time step and producing a record of water depths and velocities at every point in the field of study. Figure 8 shows

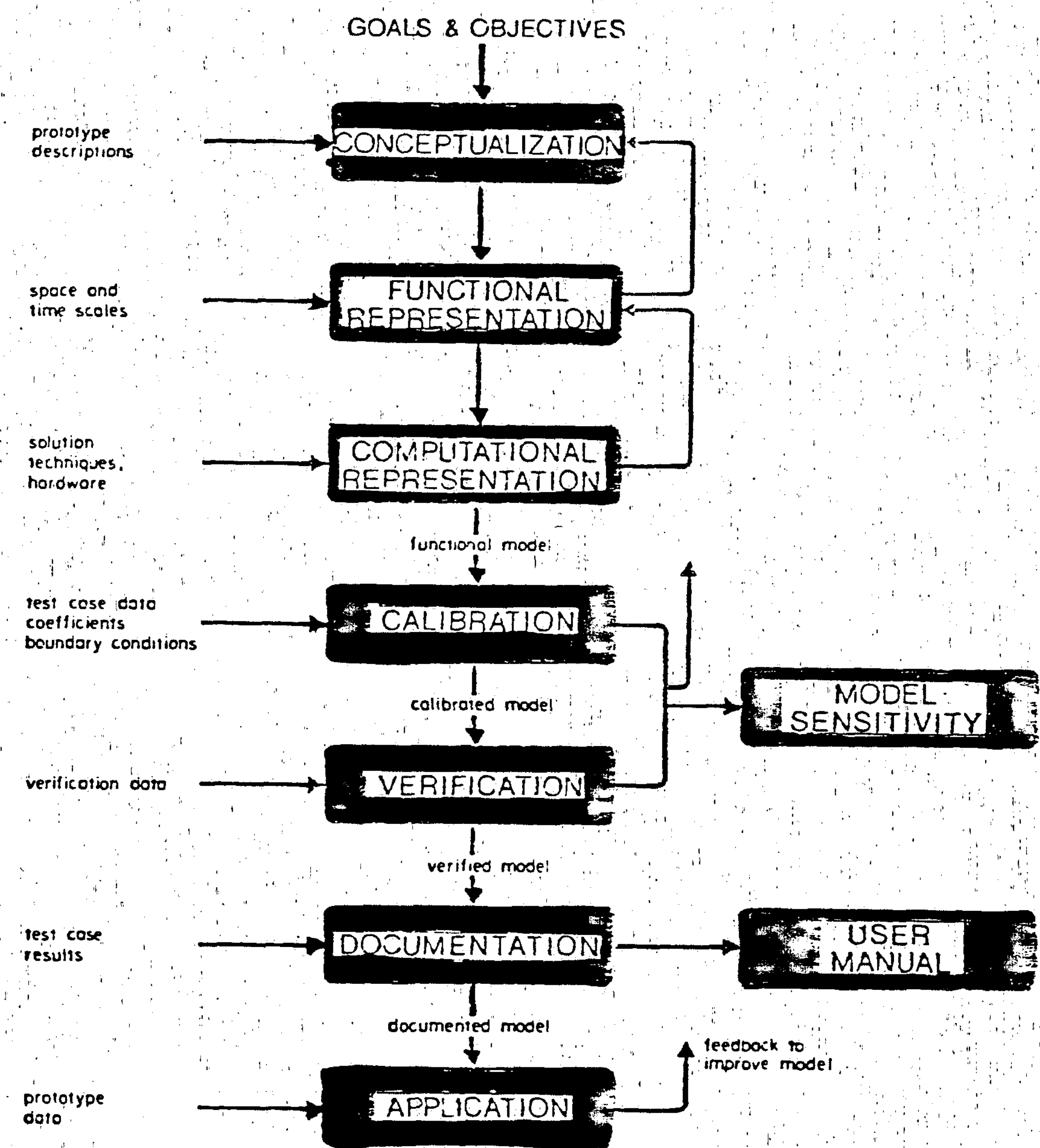

Figure 5 The Processes of Large Scale Mathematical Model Development

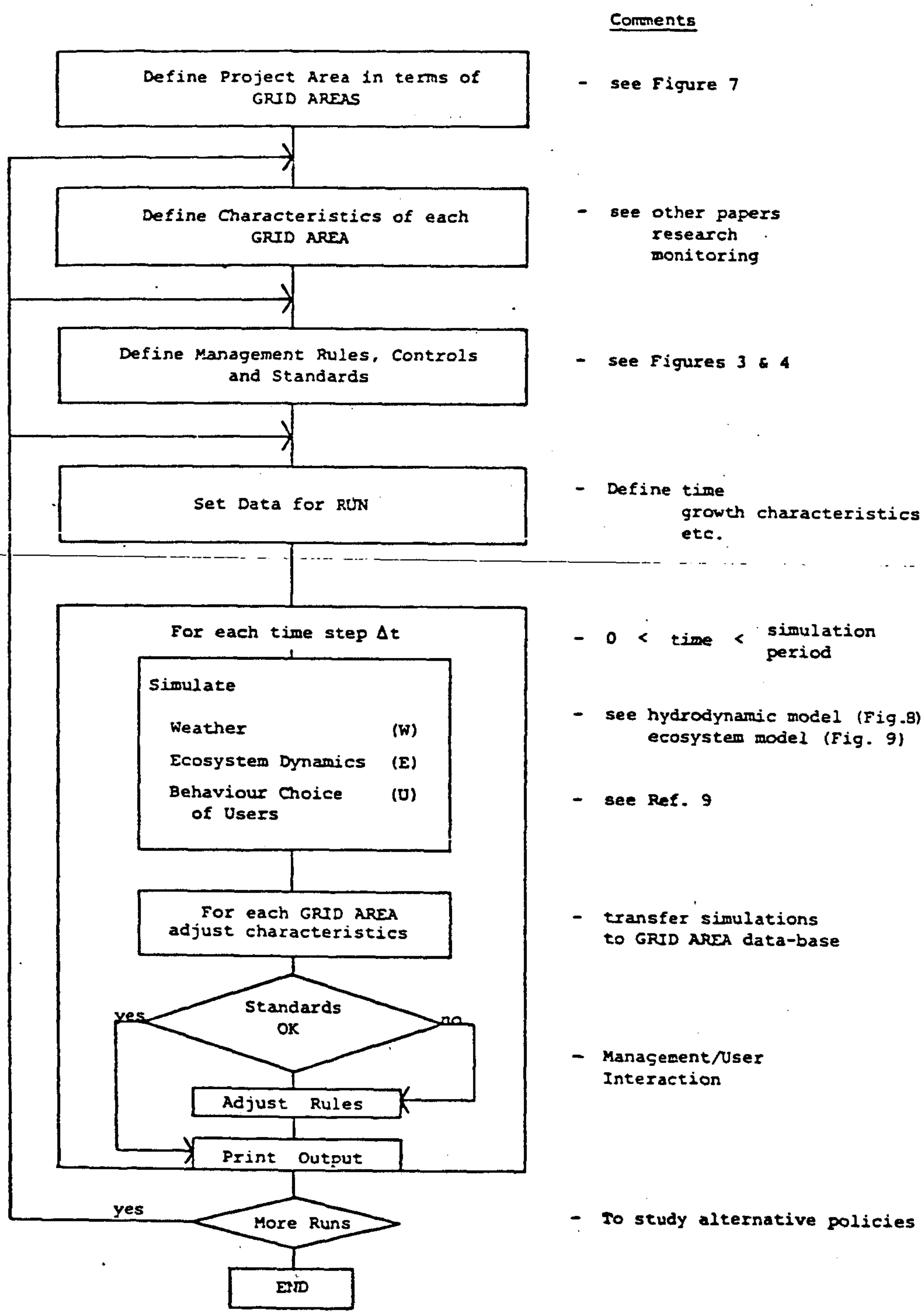

Figure 6 Management Simulation Flow Chart

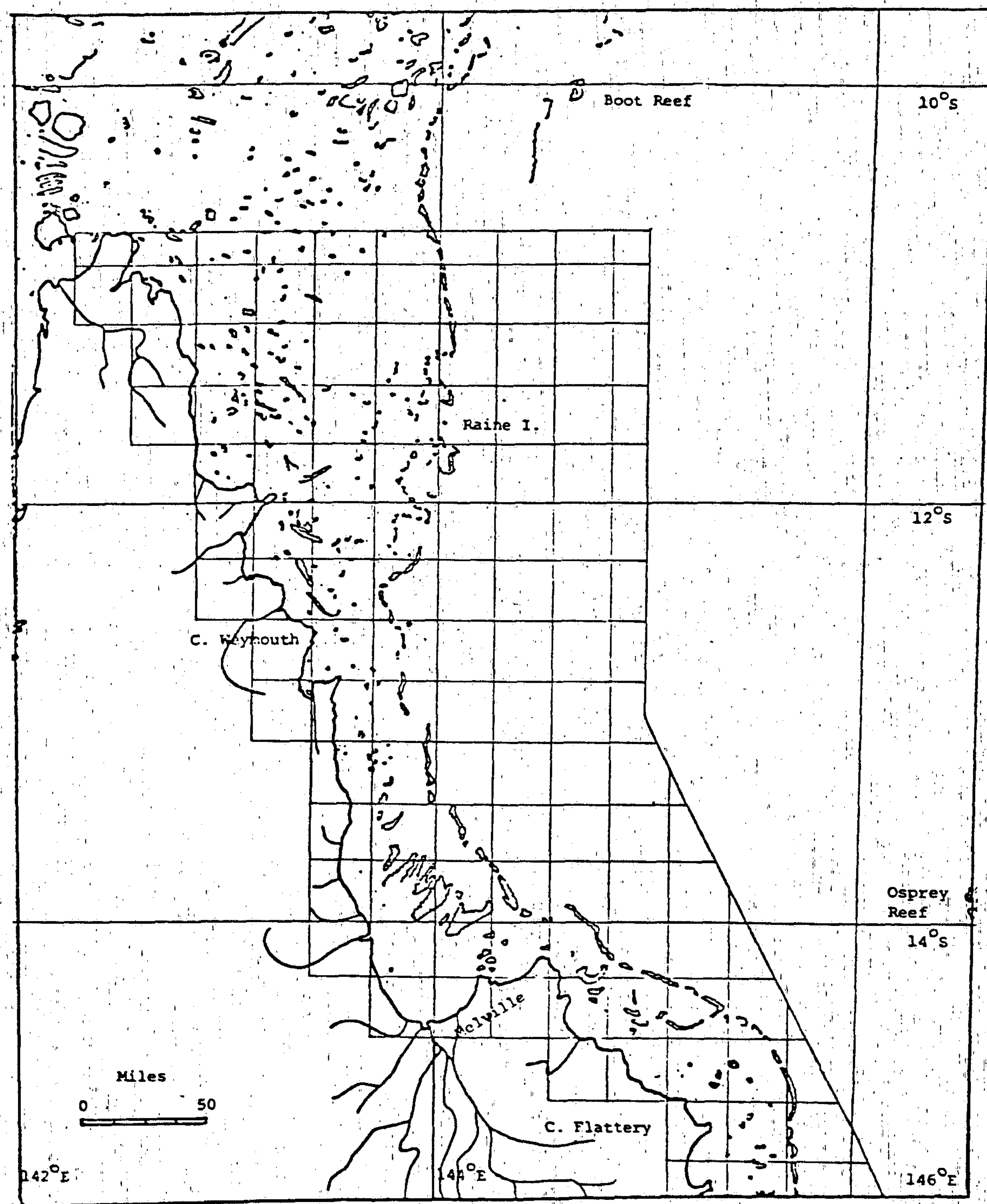

Figure 7 Grid Areas Defined on Great Barrier Reef Region, Northern Area

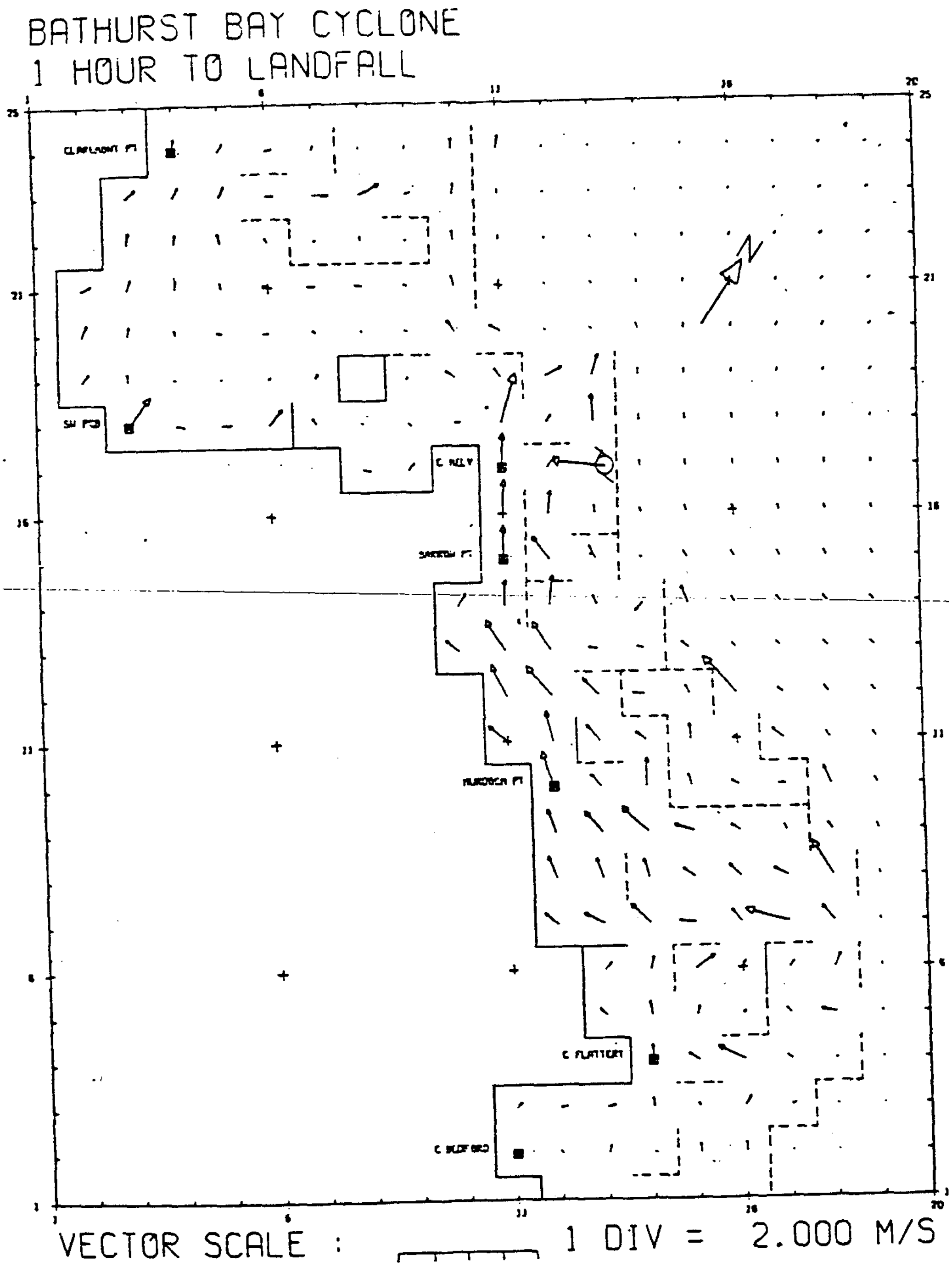

Figure 8 Current Patterns Produced by Hydrodynamic Model

only one of the many plots produced, viz. the velocity field at one hour before the cyclone crosses the coast. The cyclone modelled, in this case, was a very intense one with a central pressure of 914 mb and it has produced some most significant currents particularly in the narrow waterways between reefs. Similar studies can be undertaken to model wave heights and water quality during particular wind and flood histories.

6.2 The Ecosystem Model

Management decisions cannot approach a Class 2 level unless a clear understanding of system dynamics is available. This implies an understanding of the complex biological interactions which exist within species and between species. Population dynamics and food-chain requirements at different trophic levels must be understood to model ecosystem behaviour. It is recognised that even the most elementary ecosystem model is some years away for a complex reef system but it is important to consider the requirements of such a model now. Otherwise much useful data will be lost or ignored whilst emphasis is placed primarily on taxonomic studies. Furthermore, the complexities of many of the interactions will require intensive and prolonged research studies which may be given misguided emphasis in research programmes unless an understanding of their relative importance is considered.

In the *'Three Bays Project'* (Ref.8) an Ecosystem Dynamics Model has been developed to simulate the population dynamics and the level variable interactions for 19 selected level variables as shown in Figure 9. Each variable is defined in terms of the level and rate of change of its biomass as influenced by a number of processes - consumption, birth, death, respiration, faeces, migration, excretion and transfer. Figure 10 describes the general system dynamics equation for each transfer process where the transfer function - f - and the transfer coefficient - k - must be determined from data, experiment or literature.

It should be stressed that the process of model development is complex and long-term and must follow the steps indicated in Figure 5. The *'Three Bays'* Model has been developed as part of a pilot study and is not operational in the sense that it can be used directly in a managerial role. A similar study for a reef system which is even more complex must necessarily be considered as long-term.

7.0 DISCIPLINARY-MULTIDISCIPLINARY-INTERDISCIPLINARY

Scientific training has traditionally involved specialisation with the result that most scientists have developed an understanding of a limited range of paradigms which are pertinent to particular disciplinary problems. Many multidisciplinary projects have tended therefore to degenerate into a number of pertinent disciplinary sub-projects and no attempt has been made to develop multidisciplinary paradigms which are useful in assessment of total system behaviour. Obviously, such multidisciplinary paradigms must recognise the importance of disciplinary paradigms but transcend these by including interdisciplinary behaviour as well within their consideration.

LEVEL J. / VARIABLE I.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 PHYTOPLANKTON			$C_{1,3}$	$C_{1,4}$	$C_{1,5}$	$C_{1,6}$		$C_{1,8}$	$C_{1,9}$		$C_{1,11}$				$D_{1,15}$		$E_{1,17}$		R_1
2 TRICHODESMIUM															$D_{2,15}$		$E_{2,17}$		R_2
3 COPEPODS				$C_{3,4}$	$C_{3,5}$	$C_{3,6}$					$C_{3,11}$				$D_{3,15}$	$F_{3,16}$	$E_{3,17}$	$E_{3,18}$	R_3
4 CRAB LARVAE				$C_{4,4}$			$M_{4,7}$ $C_{4,7}$		$C_{4,9}$		$C_{4,11}$				$D_{4,15}$	$F_{4,16}$	$E_{4,17}$	$E_{4,18}$	R_4
5 MOLLUSC LARVAE							$C_{5,7}$	$M_{5,8}$	$C_{5,9}$		$C_{5,11}$				$D_{5,15}$	$F_{5,16}$	$E_{5,17}$	$E_{5,18}$	R_5
6 POLYCHAETE-L						$C_{6,6}$	$C_{6,7}$		$M_{6,9}$ $C_{6,9}$		$C_{6,11}$				$D_{6,15}$	$F_{6,16}$	$E_{6,17}$	$E_{6,18}$	R_6
7 CRAB				$B_{7,4}$						$C_{7,10}$					$D_{7,15}$	$F_{7,16}$	$E_{7,17}$		R_7
8 MOLLUSC					$B_{8,5}$		$C_{8,7}$			$C_{8,10}$					$D_{8,15}$	$F_{8,16}$			R_8
9 POLYCHAETE						$B_{9,6}$	$C_{9,7}$			$C_{9,10}$					$D_{9,15}$	$F_{9,16}$		$E_{9,18}$	R_9
10 BENTH.F.FISH												$C_{10,12}$			$D_{10,15}$	$F_{10,16}$	$E_{10,17}$		R_{10}
11 PLANK.F.FISH												$C_{11,12}$			$D_{11,15}$	$F_{11,16}$	$E_{11,17}$		R_{11}
12 NEKTON.F.FISH												$C_{12,12}$			$D_{12,15}$	$F_{12,16}$	$E_{12,17}$		R_{12}
13 PEL.MIC.ORG.				$C_{13,4}$	$C_{13,5}$	$C_{13,6}$												$T_{13,18}$	R_{13}
14 PEN.MIC.ORG							$C_{14,7}$	$C_{14,8}$	$C_{14,9}$									$T_{14,18}$	R_{14}
15 SUS.ORG.MAT(1)													$C_{15,13}$	$C_{15,14}$					R_{15}
16 SUS.ORG.MAT(2)													$C_{16,13}$	$C_{15,14}$					$R_{16,17}$
17 DIS.ORG.MAT													$C_{17,13}$	$C_{17,14}$					$C_{17,19}$
18 DIS.NUTRIENTS	$C_{18,1}$	$C_{18,2}$																	
19 SINK																			

C - CONSUMPTION D - DEATH F - FAECES E - EXCRETION

R - RESPIRATION B - BIRTH M - MIGRATION T - TRANSFER

Figure 9 A Matrix Representation of Selected Ecosystem Interactions for the *Three Bays* Study (Ref.7)

THREE BAYS MULTIDISCIPLINARY PROJECT

General Equation

$$\frac{dv_k}{dt} = \sum_{i=1}^{n} k_{ik} \cdot f_{ik} \; (v_i, v_k)$$

$$- \sum_{j=1}^{n} k_{kj} \; f_{kj} \; (v_k, v_j) + \alpha \; P_{sk} \; v_k$$

where v is the biomass of the level variable

k_{ik} is the constant for the transfer function from level variables v_i to v_k (v_k being the level variable being considered at that time).

f_{ik} is the function representing that transfer, the function contains level variables v_i and v_k.

k_{kj} is the constant for the transfer function from level variables v_k to v_j.

f_{kj} is the function representing that transfer.

$\alpha = 1$ when $k = 1, 2$ otherwise $\alpha = 0$

P_{sk} is the photosynthesis pertaining to level variable k.

Figure 10 Biomass Transfer Equation for Systems Dynamics Model

Management of a complex reef ecosystem requires such multi-disciplinary paradigms and expenditure patterns should be programmed with this purpose.

Furthermore, personnel whether directly or indirectly employed should be fitted appropriately into such programs with the realisation that many experts can provide only disciplinary support which must be carefully integrated into the master program.

Management structure must be dynamic to cope with the progressive changes in decision-making roles and the corresponding changes in managerial expertise. In the same way research support should be planned to provide continuous disciplinary and interdisciplinary expertise which is complementary to the changing managerial roles. Research effort should therefore, be focussed on:

(i) baseline studies, data base and information system development;

(ii) fundamental interdisciplinary studies to explain phenomena defined in (i);

(iii) sub-system model development, management oriented studies to assist in model definition; and

(iv) large-scale system models.

It should be stressed, however, that these four aspects of research must occur concurrently with appropriate progressive changes in emphasis, otherwise, it will not be possible to develop efficient interdisciplinary paradigms which should be, of course, the primary aims of the Barrier Reef Authority.

8.0 SUMMARY

The Barrier Reef is a complex ecosystem which is utilised by man for a variety of purposes.

A Management program for the efficient utilisation of the reef must be developed progressively as our understanding of the reef grows.

Some systems engineering methodologies can be adapted to this reef management even when management options are at a rudimentary level.

Baseline studies and the establishment of a managerial information system can be undertaken immediately, while examples of some simulation programs are given. These programs attempt to consider the simultaneous requirements of the Climate, the Ecosystem and the Users (Man).

Progressive management development and a complementary decision-making capability require concurrent establishment of research programs which must emphasise the need for corporate interdisciplinary paradigms. Such paradigms will provide acceptable tools for the management of the complex ecosystems encountered on the Great Barrier Reef.

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MARINE PARK MANAGEMENT PRINCIPLES

R.A. KENCHINGTON

GREAT BARRIER REEF MARINE PARK AUTHORITY

INTRODUCTION

In May 1975 an International Conference on Marine Parks and Reserves was held in Tokyo. A wide ranging paper delivered at the conference by G.C. Ray (1976) reviewed the state of marine park theory and strategy. This paper (Ray, 1976) with the others given before the same Conference (Gare, 1976; Salvat, 1976; Robinson, 1976) provides an excellent introduction to the principles of marine park planning and management.

The Conference passed resolutions which made a powerful case, in the interest of the ecological health of the world for a comprehensive, effective and well monitored system of marine parks and reserves representative of all coastal, longshore and marine ecosystems.

The specific case for coral ecosystem reserves was developed by Johannes (1975) in reviewing the literature on the effects of pollution upon reef communities. He stressed that coral ecosystems were in urgent need of protection on a number of grounds but commented that their case would probably not be given adequate attention in comparison with the more obvious and easily observed threats to terrestrial communities such as the Redwood forests of California.

There was however, and there still is, widespread concern whithin Australia and internationally for the conservation of the Great Barrier Reef. This may be summarised under four headings:

1. Concern that one of the major natural heritage areas of the world should be conserved and preserved for future generations.

2. Concern at locally evident deterioration

3. Concern at the possibility of over exploitation of the renewable resources.

4. Concern at the impact of pollutants.

The passage in 1975 of the Great Barrier Reef Marine Park Act was a consequence of political acceptance of the urgency of this widely expressed concern.

The Great Barrier Reef Marine Park Act provides for the progressive establishment of a Marine Park within an area encompassing the Great Barrier Reef from the level of the tip of Cape York (approximately 10° 41'S) down to latitude 24° 30', beyond the southern extremity of the Reef. The very size of the area places management on an awsomely large scale and blurs the relative clarity of focus which is gained when a large amount of effort is focussed upon the only reefs in a relatively small area, such as the Virgin Islands (Robinson, 1976).

THE BASIS OF MANAGEMENT PLANNING.

1. Major Provisions of the Act:

Section 32(7) of the Great Barrier Reef Marine Park Act provides that:

> In the preparation of the plan, regard shall be had to the following objects:-
>
> (a) the conservation of the Great Barrier Reef;
>
> (b) 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;
>
> (c) 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;
>
> (d) the reservation of some areas of the Great Barrier Reef for its appreciation and enjoyment by the public; and
>
> (e) 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 Authority is thus, in the terminology of Ray (1976) an ecocentric organisation established to achieve ecologically conforming use of the Great Barrier Reef. The Authority is concerned both with the conservation of the Great Barrier Reef and with ensuring a regime of multiple use management which will enable all reasonable demands upon the resources of the Reef to be met without causing damage to the Reef ecosystem.

2. Demands upon the Resource:

Achievement of the goals of the Authority requires consideration of user demands and natural impacts, many of which are in actual or potential conflict with each other. Categories may be listed:

1. Indirect - Impacts not specifically related to the existence of the Reef
   - Shipping lanes
   - Discharge of effluents

2. Direct non-extractive - no material taken from the reef but there may be indirect impact from waste disposal
   - Visual/photographic recreation
   - Visual/photographic tourism
   - Film making
   - Scientific survey studies

3. Direct extractive - exploiting the renewable resources of the Reef
   - Professional line fishing
   - Professional trawling
   - Professional shell collecting
   - Professional aquarium fish collecting
   - Professional spear fishing
   - Professional coral collection
   - Professional boat charter for amateur line fishing
   - Professional boat charter for amateur spear fishing
   - Professional charter for amateur shell collecting
   - Professional chartering for amateur fishing
   - Professional chartering for amateur shell collecting
   - Amateur line fishing
   - Amateur spear fishing
   - Amateur shell collection
   - Amateur aquarium fish collection
   - Amateur coral collection
   - Scientific experimental research

4. Destructive - catastrophic destructive events of natural or man induced origin
   - Shipwrecks, physical impact
   - Shipwrecks, spillage of pollutant cargo
   - Explosions
   - Severe storms

3. Available information:

For the development of a comprehensive management plan there are three categories of information which should be regarded as pre-requisite:

1. An inventory of the resources of the Reef

2. An understanding of the direct impact of each form of usage upon the Reef and upon the resource exploited

3. A basal understanding of the reef ecosystem which will enable the interactive effects of individual and multiple usage to be predicted.

In none of these categories does the available information surpass rudimentary levels. It is unlikely that the situation, particularly as regards the second and third categories of information will be much changed within the next decade. Ecocentric management will thus require to proceed on a basis of cautious empiricism. A major programme of monitoring to assess the effectiveness of management plans will be of the utmost importance.

THE PLANNING PROCESS

1. Provisions of the Act.

The Great Barrier Reef Marine Park Act provides for planning of the Marine Park to be essentially a two stage process.

Section 31 provides for the declaration of sections of the Marine Park. A declared area becomes subject to any general regulations which may exist under the Act and, under Section 38, operations for the recovery of minerals are prohibited except for the purpose of research or investigations relevant to the establishment care and development of the Marine Park or for scientific research approved by the Authority. Beyond these provisions the act of declaration has no effect on the usage of the area.

Section 32 provides for the preparation of a zoning or management plan for a declared area. The Authority is required to give public notice of intention to prepare a zoning plan and to invite representations inconnection with the plan.

Once prepared the plan is subject to review following scrutiny by the public, the Minister and the Parliament.

The stages in the planning process may be listed:

- Selection of area
- Review of available information on the area
- Field survey of the resources of the area
- Study of the pattern of usage of the area
- Study of the economic and social importance of reef usage in the area in both the local and national context.
- Development of zoning plan
- Public scrutiny of zoning plan
- Ministerial approval of zoning plan
- Parliamentary approval of zoning plan
- Gazettal of plan and announcement of date of effect

2. Selection of area

There are two major options in determining the order of priority for considering areas for declaration. The first is to select areas in which access is easy, local stresses are evident and some information is available. The second is to select areas which are remote, and apparently little used in order to conserve them in a pristine condition.

In recommending the reefs and shoals of the Capricorn Ridge for declaration as the first section of the Great Barrier Reef the Authority selected the first or 'reaction to stress' option.

The second or 'anticipatory' option is philosophically attractive since in attempting to institute management planning and controlled use before stresses are apparent it is truly an operation of conservation of a pristine environment in anticipation of human activity. The practical difficulty lies in the paucity of information on such areas.

3. Review of available information

In preparing for the declaration of the first section of the Marine Park the Authority received a report from the Great Barrier Reef Committee in which the published literature on the history and the scientific knowledge of the area was reviewed.

Another report detailing the activities and interests of the fishing industry was prepared jointly by the Commonwealth Department of Primary Industries and the Queensland Commercial Fishermen's Organisation.

The Authority expects to receive similar reports on areas being considered in the future. A contract has recently been signed with the Great Barrier Reef Committee commissioning reports reviewing the historical and scientific literature on sections of the Great Barrier Reef. The fishing industry organisations have undertaken to prepare reports on their interests in particular areas and the Authority will continue its policy of inviting submissions from interested parties.

In the case of isolated, remote areas however, there is little published information, either because there has been little formal study of such areas or, because such work as has been conducted is so recent that it has yet to be published. The northern section of the Great Barrier Reef is such an area and it is for this reason that the Authority decided to hold a Workshop to review the current state of knowledge of the area and to consider whether it should properly be considered for early 'anticipatory' declaration as a near pristine area.

4. Field Studies

It became apparent early in consideration of the reefs and shoals of the Capricorn ridge that, despite their heavy usage there is effectively no widespread understanding of the distribution of resources of the area. Intensive scientific research has been concentrated on very small areas with little indication of the representativity of such areas.

Although the statistics which are available on fishing and collecting activities yield some information on the gross quantities of material taken there is no information on the age/size structure of the exploited populations and thus there is no basis for relating fishing or collecting effort to sustainable yield.

There is thus a need for the Authority to obtain over significant proportions of areas under consideration for declaration and zoning data which describes the resources of the reefs both as a basis for planning and as a baseline data set against which information gathered in monitoring Park areas can be assessed.

The problem of obtaining information on the state of coral reefs over large areas arose during studies of the extent of Crown of Thorns starfish populations on the Great Barrier Reef (Pearson and Garrett, 1976; Kenchington and Morton, 1976; Kenchington in press). A joint study has resulted in the development of a survey methodology which will enable the topography and coral cover of reefs to be recorded and some indication of major coral community types to be obtained (Done, Kenchington, Pearson and Garrett, in preparation). The method permits broad scale reconnaissance of reefs and can be used in conjunction with more detailed study of representative sites to build up resource maps of the corals of coral reefs.

The problem of obtaining information about the status of fish populations is being investigated. Goedon (in press) has developed a technique for surveying the standing crop of commercially important fish in near reef areas and the Authority hope that it will be possible to apply this technique in its assessment of reefs. Authority staff have embarked on a study in an attempt to devise a methodology for assessing and comparing populations of the smaller non-commercial reef fish.

CONSIDERATION OF SOCIAL FACTORS IN REEF USAGE

Robinson (1976) provides a broad discussion of many of the salient social and economic factors which must be considered in Marine Park Planning.

However in view of the size of the Great Barrier Reef, the remoteness of most of the Great Barrier Reef and the widely held but generally undocumented claims of over exploitation of the renewable resources of the Great Barrier Reef, a number of factors claim special mention.

1. Requirements of the Act

The Great Barrier Reef Marine Park Act requires the Authority to plan with the objective of regulating of activities that exploit the resources of the Great Barrier Reef so as to minimize the effect of those activities on the Great Barrier Reef. Achievement of this objective will require a sophisticated understanding of the social and economic factors relating to reef usage.

2. Local and National issues

The Great Barrier Reef is held to be a national and international resource of major significance. It has been proposed for listing for inclusion on the Register of the National Estate. Robinson (1976) has noted that the interests of local and non local users of environmentally significant areas tend to differ, and has indicated to environmental planners the need for caution in seeking a balance of local and national interests.

The size of the Great Barrier Reef and its general remoteness make it probable that formal policing of regulations will be severely limited. Thus, even more than is usual in environmental planning, it is necessary to consider that success will depend very largely on the extent on the ability of the Authority to convince local interests of the long term benefits and importance of any management plans involving regulation of traditional patterns of resource exploitation.

3. Social dependence on the Resource

Robinson (1976) noted that the chief difference between locan and non-local users of environmentally significant areas lies in the greater emphasis in extractive activities by local users and a greater interest in educational and interpretive material by visitors. There is no hard data for the Great Barrier Reef but the same situation probably applies. In terms of man days per year it is probably true that reef usage for the purposes of observation through observatories, glass bottomed boats, snorkel and SCUBA and reef usage for the purpose of collection or recreational fishing are approximately equal. However, in keeping with Robinson's (1976) comments observational use is dominated by single-occasion visitors whilst extraactive use is dominated by locals who visit the reef several times each year.

CONSIDERATION OF ECONOMIC FACTORS IN REEF USAGE

1. The Fishing Industry

The most economically important resource of the Great Barrier Reef under present conditions is the fish stock. Trawled species, such as Prawns and Scallops form the basis of a commercial fishery. Migratory pelagic fish, such as mackerel are fished by commercial fishermen with some fishing activity by amateur fishermen. The situation in connection with the demersal reef fish stocks is very complex with involvement by both professional and recreational fishermen and a considerable economic interest in the activity of amateur fishermen on the part of the tourist industry and charter boat operators.

The extent of the interests of the commercial fishing industry (fishermen, processors and marketers) have to be carefully weighed against the extent of commercial dependence of recreational fishing by the tourist industry, charter boat operators and suppliers of fishing tackle, bait boats and boating equipment. Here the early success of the Authority's planning will depend not only on its ability to convince local interests of the long term benefits of management but also that it is sensitive to the needs of parties whose interests in the Reef are modified as a consequence of management.

2. The Tourist Industry

Despite the fact that the Great Barrier Reef is Australia's best known natural feature, few tourists are able to see the Great Barrier Reef. Accessibility is a major problem since the Reef lies between 20 and 100 km off the coast of Queensland and the intervening waters are rough under South Easterly wind conditions which prevail throughout the winter tourist season and subject to cyclonic storms during the summer.

The tourist industry is small and fragmented. The majority of effort is concentrated on coastal islands remote from the Great Barrier Reef but possessing fringing reefs. There are three island resorts on the Great Barrier Reef itself.

In the field of boat charter, the majority of effort is expended on general charter to fishing parties and there are few boats equipped for tourist diving. Most local diving groups have their own equipment are able to use such general charter boats but for visiting tourists this option is not available.

Growth of the tourist industry is likely to be the most significant change in the economic structure of reef usage.

CURRENT PLANNING OBJECTIVES OF THE GREAT BARRIER REEF MARINE PARK AUTHORITY

1. Establishment of baseline data collection methods which will enable reef types and usage patterns to be identified.

2. Development of zoning plans which set aside representative areas of the coral ecosystems of the Great Barrier Reef for preservation and study.

3. Creation of acceptable zones within which reasonable use of the Great Barrier Reef can take place. This will involve segregation of incompatible activities.

4. Creation of single purpose usage zones for the study of the impact of types of usage.

5. Close co-operation with the fishing industry and amateur fishing interests to achieve an understanding of the population biology and distribution of the principal commercial reef fish species.

6. Development of interpretive and educational material concerning the Great Barrier Reef. This will include the development of visual material and field facilities such as snorkel trails and documented SCUBA dive locations to promote ecologically conforming recreational and tourist use of the Great Barrier Reef.

7. The development of data collection and monitoring techniques, many of which can be used by students and dedicated amateurs. This program has the dual aim of increasing the scope of management data collection and of achieving active user involvement in reef management.

8. Promotion of co-ordinated research programmes on the Great Barrier Reef and maintaining close liaison with research management to achieve the maximum possible direction of research effort towards topics of interest in the development of reef management technique.

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DISCUSSION SESSION IV

SURVEILLANCE AND MANAGEMENT

CHAIRMAN: DR. J. ALLEN

H. Jitts: My question is addressed to Professor Stark. You said that the aim of it all was to find some way of maintaining an optimal viable system, and then turned round and told us that the viable system was dynamic, that it was changing, and that what is today is not what was yesterday, and will not be what is tomorrow, and then talked about aiming at an optimal viable system. I was wondering if perhaps we are not getting confused here. How can you maintain an optimal viable system that does not exist? How can you aim your whole management system at an optimal viable system, when we cannot define it and I do not think we ever will be able to define it. I think this really brings me to what I think we should be putting our minds. We talk too much about conserving the Barrier Reef as if it is a thing, a solid object that we have to stop the wind from eroding. It is not that at all, it is a dynamic system. What we really mean when we speak of conserving the Barrier Reef, is to stop mankind from spoiling it, and I think that is what we should be looking at - the impact of man on the system, rather than trying to define the system and preventing the system from changing.

K.P. Stark: If we define maintenance of an optimal system, it does not have to be a static concept. You must accept that it is going to be dynamic; there is a difficulty in that what you view today and tomorrow as being the objective might well be different. I tried to make that point by looking at the different stages in the process of management from the "no information" stage to the "complete information" stage (see Fig. 4) which we will never reach with this particular type of system, and I think to some extent that is what you were saying - we will never reach that end.

I also made the point that when we are exercising controls within our role as managers, the only controls we can exercise are those on the users, but we have to have some objective at the back of our minds when we are setting such controls.

It is important however, when you are looking at the setting up of your management information system, that you realise that the information is coming from trained people with scientific backgrounds who will define something within their particular discipline, and their area of expertise, but when they start treading outside that area they are very wary and frequently will not make a statement, even though they probably have the most informed opinion about the effect of that part of the system on the rest. The role of management is to squeeze that additional information out of the experts, because management must look at the total problem. So managers are trained in a different way, and frequently much of what they do might be called the worst end of decision making involving intuition or - more appropriately for managers - good management. The aim of the Great Barrier Reef Marine Park Authority in its management role is to bring these management and scientific approaches together and to reach the best decision on whatever controls are necessary.

J. Farrands: Professor Stark, with regard to your term "optimal viable state" in your talk, perhaps you could explain how an "optimal viable state" differs from an "optimal state" or a "viable state".

K.P. Stark: The terminology "optimal viable state" refers to the primary goal in the hierachy of goals defined in Figure 2. The use of viable ensures that the objective function is defined as a dynamic, i.e. time-dependent relation. Broadly, a "viable state" is one in which the "quality" of the system is maintained even with the occurrence of rare or unlikely events. The terms "optimal state" implies that, for a given set of users of the system, the best (optimal) set of levels of usage is that which produces the optimal level of the objective function which must be defined in terms of specified indicators of system behaviour. Obviously our definition of objective function will depend on our understanding of the system at any particular time.

J. Bunt: I think there is a point that is worth making here and that is that models tend to develop an air of infallibility about them. They have a sort of artificial authority that sometimes exceeds their intrinsic value, and I think we have to remember that they are subject to fallibility, and regardless of the quality or quantity of information incorporated, an inappropriate model will provide inappropriate answers.

K.P. Stark: I agree. Models should be treated in the same way as advice from experts. They are all fallible.

G.A. Horridge: Since satellite pictures do not provide the resolution necessary for surveillance, for example to identify different boats, I seriously question the point of obtaining the vast volumes of satellite or air reconnaisance information what we do not have the surface craft to back the information and arrest the intruders.

R.A. Kenchington: There are two orders of magnitude differences between the cost of using aircraft as opposed to satellite surveillance. I was advocating satellites for management surveillance, as a sort of condition-surveillance and not as day to day policing system, and therefore I must disagree with you. I think we do need the sort of gross information they can provide.

One of the classic issues of course is the Acanthaster story. If you were able with the satellite to pick up large areas of algae cover which followed an Acanthaster infestation, I think this is the sort of information that a body managing a reef should have at its fingertips. If you pick up something abnormal then you can send someone there, otherwise its an intuitive decision resulting in inspection and nothing else.

K.P. Stark: Once the satellite is up I do not believe the costs are anywhere as much as we might think. We built a satellite antenna at James Cook University which now receives information from the Geostationery Meteorological Satellite (GMS)(as distinct from Landsat Satellite). This GMS is up above New Guinea and we could get pictures from it every hour if we wished. It is certainly possible to resolve down to the level of algal bloom, oil slicks, or cloud cover in quite a lot of detail. You cannot get down to the stage of pin-pointing one Taiwanese vessel or a shell collector.

D. Hopley: Mr. Kenchington in his presentation of Dr. Warne's paper suggested that the near infra-red radiation was useful only to differentiate between land and sea. In fact living corals, when exposed, have a very high reflectance of near infra-red radiation, which means that they stand out very clearly and this is particularly so in aerial photography. Our problems now result from low water penetration; below say 15-20 cms the corals do not stand out at all on near infra-red films. Our problem in terms of satellite surveillance is that there is yet to be any satellite photography or sensing which has been carried out at absolute low water. This only picks out the living coral on the reef flats, but in most cases this is the area of coral which tourists see. It is the area of coral on which, if there is going to be any impact on the Reef from tourists, we are likely to see it here first.

J. Farrands: Mr. Kenchington, have you any satellite images compared with aerial photographs of particular reefs? Do we have this ground truth information?

R.A. Kenchington: I have some for Tideway, but I am not happy with my ground truth information. I have considerable ground truth information from last May's survey of the south-east reefs and reasonable satellite imagery, but I had only an old aerial photograph of that particular area, so the answer is no, not really.

J.T. Woods: Mr. Chairman, although we may be able to make decisions to take care of tourism, fishing, shipping and mining (amending the Act a little as we go), how do we move into this uncertain area of looking after a dynamic reef system to take care of what happens when a major cyclone moves in as has been recorded at Bathurst Bay 70 odd years ago, or when that clump of reef east of Cape Direction, starts sliding quietly one morning into the abyssal depths of the Coral Sea bed.

P. Saenger: My question is almost inevitable. Mr. Kenchington has said in his talk that the regulations have to be acceptable to the user groups. In running through the priorities of the management programmes, one was impact of individual users. A comment was made that it is very difficult to involve the user in assessing these impacts, and I just wish to ask why?

R.A. Kenchington: I agree that it could be done. I was looking particularly at the problem of organisation of some of the amateur groups. It may not be possible to get the depth and length of continuous records taken at particular sites which I think one needs. With an organised body like the fishing industry, it may not be so difficult. We really need to find out something about standing crops and the stocks of say, coral trout. The fishing industry is an organised body and carries out research programmes of the nature required.

N. Haysom: I would like to make a comment. Management is a mixture of art and science and the proportions of the mixture very often depend upon how much time you have before you make a managerial decision. If I can revert back to the beche-de-mer decision, we did take a number of factors into consideration. We did have some data in the sense that we knew what the annual catches were in years past and had a crude estimate of how much was landed, because we knew the number of boats operating in each year. We did not have any information on precisely where those beche-de-mer were found. Here was a fishery which in the past existed for a very long period of time and in an apparently very stable condition, so perhaps it could do so again. We had to take sociological factors into consideration - we wanted to keep them away from places like Lizard Island, Princess

Charlotte Bay, the region of the Queensland coast between say Port Douglas and Tully, where there are a lot of people and a lot of users of the Reef, and the Reef is close to the coast. The decision to limit the fishery to four units was to avoid a monopoly but at the same time avoid overcrowding the fishery.

Chairman: Professor Stark expressed in his paper the view that the Great Barrier Reef Marine Park Authority is charged with the responsibility of recommending appropriate controls to ensure optimal management of the Reef. There seems to be a need to identify a clearer set of definitions of the objectives. Then, one has to distinguish between the principal objectives and the sub-objectives and the priorities which will be given to them before one can think about how to achieve these objectives. This will require attention to the form and style of organisation and management, to information relevant to the objectives, and to the managerial tasks relevant particularly to the processes of decision making. But having reached that stage, there is still the problem of implementation. All of this has to be done in a cost-effective way within a framework of inevitably constrained resources.

I will now close this particular session and express on your behalf our thanks to the three speakers.

SESSION V: IDENTIFICATION OF GAPS IN KNOWLEDGE AND ESTABLISHMENT OF PRIORITY PROGRAMMES FOR RESEARCH

DISCUSSION SESSION V - IDENTIFICATION OF GAPS IN KNOWLEDGE AND ESTABLISHMENT OF PRIORITY PROGRAMMES FOR RESEARCH

CHAIRMAN: PROFESSOR K.J.C. BACK

Chairman: I invite Dr Mather to present the report of her group.

P. Mather: Our group found that primarily we needed a definition of "optimal" and we decided that this depends on man's perception of the system. It therefore relates to our beneficial use of the system. It was also agreed that the research we recommended as having a priority need, has to be based on clearly stated hypotheses that are related to the management objectives. We therefore thought that one of the prime necessities was a survey of the current use and expectations of use of the area and an assessment of its impact, and a projection of the likely impact of potential users.

We then moved on to what we regarded as the priority scientific work that would be needed for management:

1) We were all agreed that hydrographic studies supplemented by near surface infra-red photography are essential to provide data on which to plan programmes relevant to management and investigation.

2) Hydrological investigations are a necessary preliminary to understanding the biology and geology of the area, including the sedimentation and lithification processes. Such hydrological studies would assist in the management of the area in relation to coastal or terrestrial uses on the mainland, and in relation to uses in the area itself. It would also help to provide an understanding of the inter-relationships between reefs. We would suggest in order to give priorities that it be directed in the first instance to key areas of the coast likely to suffer change, but we recognise that it would be impossible to restrict the study to those key areas. We are concerned that hydrological studies should be related to the composition of and the major current flows and the transport of sediments and chemicals.

3) In the geological field, we believe that the first research effort should be in relation to sedimentation and lithification processes. We think these are the basic necessities for understanding a healthy coral reef.

4) We were not able to explore fully what we thought were the priorities in biological research because of the complexity of the problem and the short time that we had defeated us. Thank you.

Chairman: Thank you Dr. Mather. Professor Michael Pitman will now present the report for his group.

M. Pitman: Baseline data: We recognised the need to collect basic information involving reef hydrodynamics and for a survey to identify reefs, so that all objects of rarity and importance like shipwrecks, archaeological sites, bird breeding areas etc. could be stored on a data bank system and be retrievable.

Monitoring human impact: Perhaps we can provide for the general public, log books for the collection of recreational fishing data. Projected land use and the relationship of reef use to land use should be studied.

Biological resources: Concerning both reef and non-reef biological resources, we felt that survey and distribution studies seem to us to be a priority at the moment in terms of variability and population dynamics. We also felt the need for physiological and biochemical studies of individual organisms. A number of particular topics were suggested, such as studying the biology of what we call fragile major species, e.g. marlin, turtle, crocodile, dugong and oceanic nesting birds. Surveys too can relate to effects of human activity, the effects of fishing on the Reef etc. We felt that the information (models) gathered from studies in the southern part of the Reef should be extended to the northern section to see if we are talking about the same system. Population dynamics especially of microfauna and plankton seemed to be an area requiring some research.

Geomorphology: A comparison of geomorphological models involving nutrient cycling, sedimentology and the origins of reefs was suggested, again to make sure that ideas developed for the Capricorn Group applied to reef development in the north.

Monitoring systems: It was suggested that an essential development was the encouragement of new observation systems, the involvement of physicists to examine the possibilities of using infra-red photography, ultra violet light, underwater technology, ultrasonics and radar, and the extent to which these techniques could be used in surveying.

Areas of special concern: Some general topics came out of the discussion. One was a concern about Raine Island; I need not say anymore about that. Concern was expressed about research logistics; do we need a research station in Torres Strait, or is all this going to be done by expeditions? How is it going to be funded? We cannot provide answers, but I think the Authority needs to consider the questions. We thought it important that there should be encouragement of research activity. Much of the work we heard yesterday has been from people who have been following their line of interests and who are producing a lot of valuable data. An important point was the delineation of scientific and reservation areas. This should obviously be done very soon, and we felt it is a matter of high priority.

Finally a general point, the need to encourage specific research projects rather than a general idea of concern, on the basis that if you encourage a specific research project you are likely to get answers from it, whereas if you have a general area of concern, you just spend money on it. Thank you.

Chairman: Thank you Professor Pitman. Dr. John Farrands will report on the findings of his group.

J. Farrands: The highest priority on which we found consensus was mapping the area and naming or numbering the reefs. The mapping should be complete and there should be underwater mapping as far as possible using satellite techniques.

The next issue in this class was the measurement of water flow, which is clearly important. It is enormously complex because of the currents which are turbulent and wind driven, and although the tidal diary seems to be sufficient for the fishermen present in our team, it is clearly inadequate for the biologists. We thought that it would be impossible to produce a complete study of water flow but efforts could be directed initially towards areas where it is relevant to the particular biological research.

We felt that the biological data would never be complete, but at least it should begin to comprehend aspects like plankton movements and seabird population impacts which we have not considered here.

We felt that there should be a survey of the reef users, including scientists, and an assessment of the damage they are doing to the reef. We suggest that there should be more inter-disciplinary studies, particularly on the energy flow in the reef.

In view of the magnitude of the problem considering the geographical extent of the reef, the group felt that there should be a nomination or areas of points of outstanding scientific, aesthetic and social features and interest should be concentrated on these areas.

We discussed the estimation of the size of reservation areas referred to by the last group, but we did not reach a useful consensus because of uncertainty about the interaction of the reservation area with the rest of the ecosystem.

But I think a significant number of us did agree with the previous group in this matter. We stopped at that point because to begin to delineate more details of research topics would involve us in questions of priority which we could not resolve.

Chairman: Thank you Dr. Farrands. Dr. Connell is substituting for Dr. Saunders and will report on his behalf.

D.W. Connell: Our discussion group makes no claim to having developed a co-ordinated and cohesive report on research needs. It is clear however that the northern sector of the Reef has been little studied and that there is a great lack of information of all kinds. In our rather hurried discussion we had little time to fully develop our ideas and establish a firm rationale for research priorities. Nevertheless our ideas represent an immediate expression of opinion on research needs which can serve as a basis for further development with the reports from other groups.

Initially our group discussed whether research needs should be related to the overall development of scientific knowledge or the specific needs required by the Authority to effectively manage this northern sector of the Reef. We decided the major focus for identifying research needs should be related to management problems and the activities of man, in other words the latter alternative. We discussed the various impacts that man had on this sector of the reef and divided them basically into the following groups:

1. Tourism: The development of tourist resorts, the visitation of tourists to reef areas for diving, boating and reef walking activities were considered to be in the early stages of development.

2. Fishing: In this category we included commercial and recreational fishing and also the illegal poaching activities of foreign fishing vessels. In addition professional shell collecting could be included in this category.

3. Shipping: This includes development of shipping channels, harbours and associated works.

4. Pollution: Under this heading we considered such things as a possible spillage of noxious cargoes being carried by vessels through the Reef, pollution from resorts, and pollution from mainland sources.

5. Coastal Development: Here we were concerned with the development on the mainland coasts as well as development of the coasts on the islands.

6. Mining: Although mining is prohibited by the Great Barrier Reef Marine Park Act in areas declared part of the marine park, mining could occur in other areas.

Within all these various individual activities on the Reef we can identify three basic impacts.

(1) Introduction of pollutants.

(2) Physical damage.

(3) Extraction of species.

After this initial discussion of impacts on the area, we now turned our discussion towards identification of research needs. Overall we can see two areas of major interest. The first is the lack of basic data which would be needed by an research programme so that it could function effectively. The second was an assessment of the specific management areas which were believed to require early investigation. These areas are outlined separately below:

BASIC DATA:

1. Charting and Mapping: The need for an accurate set of charts together with satellite and aerial photograph material was felt to be basic to all research. Somewhat related to this it was felt there was a need for a standard referencing system for all of the reefs and islands in the whole area of the Great Barrier Reef. The group was not entirely agreed but the Standard Metric Grid might be useful in the regard.

2. Data Bank: Some members of the group suggested the need for a computer based data bank system to allow easy access to all data available on the Reef. However one member expressed concern that such systems could become an end in themselves and a great deal of wasted effort could be made in developing the system rather than providing for reef information needs.

3. Social and Economic Data: The group generally felt there was a need for data on current visitor usage and projected usage in the future. In addition there was seen a need for basic information on the fishing industry; such facts as catch size, return to fisherman, species types and other aspects were considered important.

4. Baseline Studies and Gross Survey: The group felt this was one of the most important immediate basic data requirements for the northern sector. It was agreed that monumental studies of the northern reef ecosystem would be an inappropriate use of scarce resources at this stage but what was needed was a survey in which major factors were identified. Techniques such

as the use of aerial photography and satellite information could help identify such major features as sea bird and turtle rookeries and other major features.

In order to manage the reef, the opinion was expressed that there was a need to measure the "health" of the reef, to assess in fact, the success or otherwise of the various management options being exercised. In order to do this there is a need for baseline studies to be carried out. Once again the group felt that such baseline studies should not develop into major undertakings in theoretical research but should be concerned with the development of an understanding of reef ecosystems as related to the major usage factors identified.

SPECIFIC AREAS FOR RESEARCH

The group now turned its attention to more specific aspects of reef management which were in need of early investigation. Within this category we were generally agreed there were three aspects which needed to be considered. We recognised that given more time other areas could have been identified which possibly may have been of equal or greater interest.

1. Fishing: The group saw the management of fishing in the area as being an important management problem. In addition to commercial and recreational fishing there was a need to investigate the impact of illegal foreign fishing in the area.

2. Pollution from Shipping: We were aware that a substantial volume of shipping is using the various reef shipping channels at this time. Some ships are believed to carry cargoes of noxious chemicals while large cargo vessels are claimed to carry quantities of fuel oil up to 10,000 tonnes. The group felt there was a need to quantify the volume of various products passing through reef waters and investigate the impact of any materials accidentally or purposely discharged into those waters on the Reef ecosystem.

3. Effect of Tourism: We discussed the effect of tourism on the northern sector of the Reef and agreed that at this stage this is comparatively low. However the opinion was expressed that a study of the effect of the tourist industry at Lizard Island was important for two reasons: firstly, it would provide information which would be of value for the management of the tourist industry at Lizard Island; and secondly, it would provide information which could be used for the management of the rest of the reef as it may give indications of the effect of tourism on a pristine reef area.

It is interesting to note that the group felt that at this stage pollution from mainland sources was not a research area that required early investigation. Thank you Mr. Chairman.

Chairman: Thank you Dr. Connell. The final group was led by Dr. John Bunt.

J. Bunt: Our group was primarily concerned to identify areas of interest rather than become too specific. A number of specifics have emerged in any case in the course of the discussion just now, and what I am saying is not necessarily a priority listing.

We felt that there should be an attempt by a suitable group to decide on the limits of the study area, and how it might be zoned for study, because there are a number of factors that are involved in that consideration.

As our discussions proceeded, we zeroed in on the fact that we are looking at a system which is vulnerable to human use, human impact and that in terms of immediacy, this deserved the highest priority. There are two types of events involved - a catastrophic type of event, and a set of events very diffuse in time and space. Thus we felt there might be some merit in setting up task groups to consider likely impacts in the areas talked about already. These task groups might be in a position to call into operation the logistics and the expertise to investigate either as a matter of urgency or over extended periods.

It was suggested that a great deal could be gained from examining inputs and outputs of reefs (symptomology) to give some indication of what the system is doing, e.g. examining productivity, levels of nitrogen fixation, amounts of dissolved organics. One of the group indicated that there are quite specific techniques that enable one to reconstruct the character of a reef perhaps for the preceding 50 or 100 years.

Another area requiring close examination is the biological connection between reefs.

The final area that we considered is a long term project, which I have called resource monitoring, involving mapping and bathymetry. It would extend to cover biological resources to provide some indication of the biological character of the reef areas and the adjacent coast.

The climate and the character of the water masses, their physical and chemical properties should be examined and of course the geology of the entire system should be examined.

We discussed looking at specific things like the population dynamics of individual species, but the options are extensive and we really feel that the Authority should invite groups to investigate those types of details.

Chairman: Thank you Dr. Bunt. I will now close this session and thank on your behalf the Chairmen of the various sessions.

SESSION V1: CRITERIA AND CATEGORIES FOR ZONING AND METHODS OF REGULATION

DISCUSSION SESSION VI - CRITERIA AND CATEGORIES FOR ZONING AND METHODS OF REGULATION

CHAIRMAN: PROFESSOR K.P. STARK

Chairman: This session has been concerned with the criteria and categories for zoning and the methods of regulating those zones, and the first speaker will be Professor Oliver.

J. Oliver: I will try quickly to deal with the views of our group. First of all we started with the problem of what criteria we were going to use for zoning - the purpose of zoning - and the general view was that we were concerned with a "use" problem, we were attempting to be "eco-protective". In the light of that emphasis we established four zones of decreasing need of protection, correlating protection and impact. Where the dangers of impact were major, our protection needs became high. We moved towards other zones where although the impact dangers could be high, their seriousness was considered perhaps to be less and the degree or type of control was similarly adjusted.

We started then with a zone of maximum protection, where we were seeking to ensure that there was no disturbance of what our group members termed the naturally evolving ecosystem. We were conscious of the fact that the use of the term preservation has built into it a series of problems, and our main concern here was to maintain for posterity the natural environment in a state where it was least disturbed, which of course does not mean that preservation is the whole answer.

Secondly, we had a zone of controlled protection where we agreed that there was a need for minimal disturbance to take place. The basis of that disturbance was in terms of scientific enquiry. It was recommended here that there should be protection of the natural ecosystem to prevent deterioration but some access for specifically names groups and for fully identified purposes might be permitted.

We would continue through this spectrum of control to regulate for zones which have specific purposes where we felt we were dealing with renewable resources. In fragile areas that were thought only able to absorb limited disturbance, the impact should be limited to prevent any long term non-reversible destruction to occur.

We had two sub-headings in this category: recreational activity and commercial fishing. There was some debate as to whether the adjective "commercial" should be added to fishing because we recognised that there were forms of recreational fishing which could take on a similar sort of degree of impact to commercial fishing.

We then moved into a fourth zone of controlled exploitation more likely to apply to non-renewable resources, where in fact any sort of utilisation and development of those resources had an inevitable one-way and destructive effect. The purpose of the control here was to ensure that the degree of exploitation, the amount of non-reversible use, was kept by the control down to the very minimum, so that its impact would not disturb the natural ecosystem to a critical degree.

The fifth zone protects the rights of agreed or accepted special groups. There was a point made that there were traditional aboriginal rights which extended over some parts of the Great Barrier Reef.

We then went on quickly to look at the problem of regulation. It was agreed first of all that to achieve regulation, an educational programme was necessary to explain to people the whole purpose of the Marine Park, the purpose of the zones, and to identify the people likely to be affected when regulation and control was involved. With regard to regulation and control, clearly some positive form of approval or licensing becomes necessary for those groups who were identified as having an interest in extractive activities on the Reef. This was recognised to be a big problem with large numbers of relatively passive users whose impact is individually small, and whose activities would be very difficult to police. Policing by rangers or inspectors would be necessary to lend impact to what could otherwise become just paper regulations. Finally, we felt it necessary to draw to the attention of the Authority that through the Act, legal powers could be given to various official personnel and this would clearly form part of a regulating procedure.

Chairman: Thank you Professor Oliver. The next leader is Professor Horridge.

G.A. Horridge: As we understand it, areas that are zoned would lose State jurisdiction, which at present extends to three miles from low water mark. When these areas are zoned the State legislation is over-ruled by Commonwealth legislation. This is probably the most important factor to bear in mind. Zones must be flexible, and hopefully they must combine several different usages. There follows a list of some of the reasons for creating zones. These headings could be zone types or they could also be to some extent criteria: most of them are obvious.

(a) The zone outside the Reef is part of the designated area. There it might be necessary to put restrictions on ships cleaning oil tanks in the ocean, although it is not within the Reef zone. This may come under the existing regulations.

(b) There must be shipping lanes. There is already designated air space.

(c) It is hoped that there could be wilderness areas where no-one is allowed access.

(d) Recreation uses are varied, and in those areas it will be necessary to have detailed by-laws. A contribution to the success of recreational facilities is that positive provision is made for people. This concentrates the people so that it limits the impact on other regions which may be of a more fragile nature. The provision of barbecue sites in parks is an example.

(e) Commercial activities include either fishing, mining or marine farming. These are clearly zones for special purposes.

(f) We also recognised the traditional aboriginals and Torres Strait Islanders, but did not identify any particular rights for them.

Surveillance and control, in the view of this group, is best obtained by education and by enlisting the sympathy and support of the public. However, it is necessary to have wardens as well as police. It was agreed that these forces must operate by boat, from Thursday Island and Cairns. All parties involved in surveillance should report to Marine Operations Centre in Canberra, which should remain the central clearing house as a National System is developed.

Finally the public should clearly understand who has jurisdiction and what laws apply to the area.

Chairman: Thank you Professor Horridge, and now Mr. Hegerl.

E. Hegerl: We started off by assuming there was a need for some wilderness areas which would be areas of maximum protection. Wilderness areas would be the places of difficult access which are at present little used, but it was recognised that there are inshore areas at present under use and we should also preserve representative samples of these. It was agreed that in areas of maximum protection or wilderness areas, there would be no destructive interference with the environment, except for monitoring of the biota.

Our next category was research areas, and we had two sub-categories there. It was resolved that research activities and areas could be divided into two main groupings - extractive/manipulative and purely non-manipulative. Research involving manipulation would only be permitted in certain areas, through the issue of permits by the Authority. The research areas should be representative of both inner- reefs and outer barrier reefs. We saw a need for the protection of historic sites both Aboriginal and European.

Recreational areas, another category, would be representative of as much of the Reef as possible. In some areas amateur fisheries would be permitted. It was agreed that around tourist resorts, fishing activities might have certain restrictions. It was thought that the Authority might wish to regulate spearfishing or amateur fishing, and also that the Authority might wish to rotate the zoning areas.

The final category for the lack of a better term, we called "open areas". We mainly saw these as buffer areas for the places of great protection. It was very important though that the "open areas" be large enough to sustain commercial fisheries. In the "open areas" the existing use of living resources would be permitted. We briefly looked at the problems of surveillance, using perhaps satellite techniques or dirigibles, in fact any number of possibilities existed and this remains a technical problem that needed considerable investigation. Thank you, Mr. Chairman.

Chairman: Thank you Mr. Hegerl. The next leader is Dr. Smith.

D. Smith: Just briefly we had decided in our committee to recommend the establishment of four zones.

The first one we described as totally restricted; the criteria here would include fringe park reserves representing reef ecosystems, but also perhaps more particularly, zone types of what might contain unique or endangered species, or sites used by certain species during the breeding season, like Raine Island. Entry to these areas would be restricted by permit, and only non-destructive research would be allowed.

The second type of zone we defined was also classed as restricted, but would be characterised by being more easily accessible areas. They might be established to employ as buffers for zone type 1, contain representative reef types and the usage permitted would be manipulative research, educational uses and what I would call non-destructive recreation like snorkelling and photgraphy. Here again entry would be by permit and a ranger would be necessary to control any undesirable activity.

The third type of zone we listed as recreational again would probably be characterised by greater accessibility than some of the other areas. It would allow recreation, including the extraction of species, sport fishing, spear fishing and also resort construction. It was suggested minimisation of damage to this area be accomplished in part again by ranger protection. Also there might be the construction of walk-ways, swim-ways etc.

The fourth type of zone we defined as commercial. The commercial areas would include those of minimal ecological significance, where shipping areas, harbours and mining activities might occur. Under recommended controls, we suggested establishment of shipping lanes to minimise probability of accident.

For the last type of area we defined fishing type five, and that simply means all areas other than areas one and two.

There were some comments that were made that I want to pass on. The committee was concerned over the uncertainty as to the control within the reef flat area and that questions of jurisdiction should be cleared up as it is not possible to protect the Reef without protecting the area above low tide. It was also suggested that the Authority might investigate the possibility of preservation of some of the estuarine areas adjacent to the northern part of the Reef in particular.

Other than this, suffice to say, I believe our conclusions were similar to those reached before. Thank you Mr. Chairman.

<u>Chairman:</u> Thank you Dr. Smith. Dr. Milward is the next Chairman.

N.E. Milward: The work group agreed that the central objective in regard to the use of this area was as a national heritage and also a world heritage. The group recognised that this part of the Reef is closest to the wilderness state, an area that has received least attention or interference by man, and this is one important reason for adopting this philosophy of preventing change, if this can be achieved.

Secondly it has centres of particular significance, like the bird rookeries, turtle nesting sites, as well as having a very high diversity of both plant and animal life. Perhaps it acts as a natural reservoir for supplying organisms to the southern part of the Reef.

It is recommended that research programmes or research activities to be carried out in the area, are brought to the attention of the Great Barrier Reef Marine Park Authority so that the Authority can provide a data bank facility for information coming out of the programmes, and possibly get in a co-ordinating capacity.

One of the final points considered by the sub-group was an issue which had been raised earlier in the workshop, and this was in relation to the proposals for the beche-de-mer fishery. The group was concerned over the proposals for the re-establishment of the beche-de-mer industry. These appear to be contrary to the aims of good management, and hence the protection and utilisation of the area. The fact that decisions of a political nature have been taken based on outdated information, and with little recent reliable information, highlights the need for investigative programmes and management planning.

I would like to finish with a comment made by one of the members. It is recognised that the area is presently used in various ways, and that it could possibly be utilised in other ways in the future. Traffic through the area, shipping lanes, recreational extraction by the amateur fishermen and shell collectors, and non-extractive recreation are perhaps activities that should be catered for in any zoning plan. We feel, however, that before actually defining zones to provide for each of these activities, a great deal more information is required on which to base any reasonable proposals. Obviously if we are going to obtain this information, additional research programmes have to be developed. We feel that even with the existing knowledge, it should be possible to draw up a list of areas which would be recognised as important for carrying out this research and for providing the information on which to draw up the zoning and regulatory procedures.

It is suggested that perhaps, if it can be done within the terms of the Act, a temporary moratorium should be placed on these areas so that other developments do not take place which might conflict with the research programmes. It was also agreed that consideration should be given to a moratorium being imposed on the whole area to prevent further development in the way of utilisation or tourist activities, until a specifically based management programme is available. As one member of the group said "You should not crack a diamond until you really appreciate its full value", a truism which we should keep in mind when thinking about the Reef. Thank you.

Chairman: Thank you Dr. Milward. I would just make the comment that I thought I stressed this morning, that you will never have full information. I think there is a danger therefore from the viewpoint of conservationists, that if it is always that nothing be done, then the decisions will be made as political decisions, and there are bigger dangers inherent in that.

J.T. Baker: I think it would be wise if we could say in respect to rezoning, (in answer to Mr. Hegerl's comment) Section V of the Act, 37(1) which I think is important, says that subject to sub-section (3), the Authority may at any time amend the zoning plan, and the zoning plan that was in existence remains until the new one comes over, so that the Authority can in fact put up a zoning plan and amend it progressively and rotate on a three year basis if desired. The exception being that if the Authority declares a special zone, then the Governor General has to be involved in changing that. But so long as you do not nominate a special zone, the Authority can rezone it any time.

Chairman: I think the concept of incorporating some dynamics into an original zoning plan is important; for example, the plan may incorporate a three year rotation of specified usage types, which as you suggested is both possible and desirable.

I would like to thank the speakers of this Session for their contribution.

SESSION V111: DEVELOPMENT OF GUIDELINES TO ASSIST THE AUTHORITY IN DECLARING AND ZONING A MARINE PARK IN THE AREA

DISCUSSION SESSION VII - DEVELOPMENT OF GUIDELINES TO ASSIST THE AUTHORITY IN DECLARING AND ZONING A MARINE PARK IN THE AREA

CHAIRMAN: MR. H.J. HIGGS

Chairman: We come to the final session now, the development of guidelines to assist the Authority in preparing and zoning of the Marine Park. From the viewpoint of members of the Authority this is of vital importance and so we may hear the Chairmen's summary of Session V starting with Professor Back.

K.J.C. Back Mr. Chairman, ladies and gentlemen. I will attempt to bring together points raised by the different groups upon which there is some agreement, and hope that as a result of the group reports and of this summary, research priorities will emerge which will assist the Authority in developing guidelines for the declaration and zoning of marine parks in the area. When speaking on park management priorities this morning, Mr. Kenchington identified three main categories of information required by the Authority - resource inventory, impact management, information and monitoring programmes. He suggested that scientific research might deal with:

(i) fragility, stability and reef dynamics;

(ii) past history of the Reef and the effect of human usage;

(iii) stress indicators.

(iv) the determination of the inter-dependence of reefs and the critical minimal size of a reef.

The group discussions just reported have indeed dealt with many of the categories of information and research highlighted by Mr. Kenchington, and I shall endeavour to list those of common concern.

Firstly, there is a need for precise definition of terms. For instance, what do we mean by "ecosystem"? Dr. Mather stressed that the term "optimal" is man's definition in terms of his perception. Again, what do we mean by a "reef area"?

Secondly all groups agreed on the need for basic data, data which must be systematically co-ordinated, be stored and be retrievable. Under this heading was included the mapping, naming and adequate description of all reefs in the area. The importance of modern satellite technology was stressed. Evidence was presented of vast gaps in our knowledge of the biology of the reef system. Associated with this, particularly in regard to the history of the Reef, was the need for study of reef geology and sedimentation.

Thirdly, most groups attempted to identify priority research programmes and it was a common view that priority should be given to protection of rare phenomena, fragile environmental species and areas of special importance. In regard to the latter, not all species can be identified at present but those we know about deserve special and urgent attention. Raine Island is a case in point.

Fourthly, there was agreement on the need for studies which dealt with the marine environment, especially studies on hydrodynamics and hydrology, not only within the reef area, but between the reefs and the mainland and between the reefs and the islands, with special reference to currents, the moving of solutes and micro-organisms and, of course, sedimentation.

Fifthly, there was the question of 'usage'. This includes the assessment of the impact on the reef system of disturbance factors, especially factors relating to human activities such as fishing, tourism and recreation, scientific activity, and the usage of the reef by aborigines both in the past and present. Disturbance factors also include land based effluents, such as industrial and agricultural wastes, urban wastes, and of course, oil spills. Other disturbance factors discussed were natural hazards (cyclones, earthquakes), and biological phenomena such as predation by crown-of-thorns starfish. Reference was made to the health of the reef and methods of determining the general level of healthy reef activity and the indicators which might be monitored.

Finally, a most important matter was raised by Professor Pitman's group, namely, the management and logistics of reef research. Do we need a research station in the Torres Straits or will research be done by way of expeditions? How will the research be funded and co-ordinated? This whole question deserves full and detailed consideration by all those associated with research on the Great Barrier Reef. Thank you Mr Chairman.

<u>K.P. Stark</u>: Mr Chairman, ladies and gentlemen. Most groups raised the question "should the zoning regulations that we consider here apply to all the Great Barrier Reef or merely to the northern section?" Most groups adopted the principle that they would look at the general question

for the whole of the Great Barrier Reef Region, but with specific reference to the northern region where appropriate. A problem arose because a number of groups considered that the northern region was a particularly special part of the whole Region. This point was highlighted by Dr Milward's group which suggested that it might be appropriate to place a moratorium on the whole northern area until further research development could be undertaken. This might appear to be an extreme viewpoint, but the merit of it is there, and I believe it was considered by the other groups also because of the special features of the northern region. Fundamentally, it is a zone with unique features of pristine character where it might be possible to apply maximum protection with little disturbance of the naturally evolving ecosystem. This then is the first zone classification and the most restrictive. It could be applied perhaps where access is already difficult. Other groups suggested that we would also need this particular zone type where we have some special species or merely to ensure that at least part of the Reef is retained in a way that could allow the monitoring of changes occurring elsewhere.

The second type of zone was labelled by some groups as a restricted zone in the sense that access would require some form of license. Perhaps it would be a zone where research activities or educational facilities without extraction of species except for particular research projects could occur. This zone then could be labelled a 'research' or 'restricted' zone in which there would be controlled protection, but not as restrictive as required in the first zone.

The third type of zone could be called a recreational zone in which there would be limited extractive activities such as fishing or shell collecting, controlled perhaps by a Marine Park Ranger.

The fourth category of a commercial zone would allow such activities as shipping, harbours, definition of transportation routes and tourist facilities.

The fifth zone, a fishing zone, it was suggested could apply to all areas except the first two types which were specifically restricted.

The final zone type recommended is self-explanatory and related to 'special groups'. This zone would protect the rights of special groups such as Aborigines and even historical European sites.

I would like to comment on a couple of points that came from the Chairmens' summaries. There was a general feeling that controls might best be exercised by educating people to understand why zoning is necessary so that they would appreciate the regulations and the need to protect the Reef. It was suggested that the definition of zone is itself an educational exercise which could help people to understand the need to control the utilization of the Reef. Apart from the patrol-boat rangers, aircraft flights, satellites, the issuing of permits and other surveillance techniques, the importance of the educational aspect of such control should not be overlooked.

There were two suggestions that the Act might not quite cover the whole of the requirement of zoning; one was the need for the Barrier Reef Authority to study ways to implement what you might call dynamic planning to allow zoning plans to have some kind of time scale or some method of adjustment.

There was another suggestion that the entire ecosystem is not included under one jurisdictional body. For example, the mangroves, rivers and estuaries are still within the overall system of the Reef but not included in the definition of the Great Barrier Reef Region under the Act. Maybe some attention should be given to this, particularly if we are looking at special areas where complete restriction of activity is envisaged. Islands also are not within the framework of this Act, but are controlled by other Acts and to some extent by different Governments and there is a need for careful liaison and co-ordination by the Authority if what we have been talking about in the last two days is to be achieved. Lastly, it was suggested that the Authority should undertake the role of co-ordination of all the data that applies to the Barrier Reef Region. With that, Mr. Chairman, it would be best to leave the rest of the framework of that session to discussion.

Chairman: Thank you very much Professor Stark. I would like to take a few minutes of questions or comments on Sessions V and VI if anyone wishes to make them.

B. Goldman: I would like just to make two comments, firstly on what Professor Stark said with regard to a data base. It might be sensible if we could consider the establishment of a reference and scientific data base co-ordinated through the Great Barrier Reef Marine Park Authority in Townsville where one could have a computer based system of all literature relevant to works done on the Reef, and perhaps species inventories for ecological programmes might also be appropriate. The Great Barrier Reef Marine Park Authority could act as this informational unit and a clearing house for scientific research.

Secondly is the concept of a biotic corridor across the Reef. In other places, like Africa for instance, it has been obvious that if one destroys a migratory path of some species, then you severely influence its population. The problem here would be to delineate a zone on a reef and expect that to remain as a unit. The extension of this argument is that we should be aware of the fact that we cannot allow any destructive influence to create a wedge right across the Reef which might act as a biotic barrier.

Chairman: Any comment on that?

K.P. Stark: Well just briefly, we suggested "shipping ways" should be defined as particular zone types and what you are saying is we should have "turtle ways" to protect biotic corridors of turtles and so on.

B. Goldman: No.

Chairman: We need to seek some form of clarification on what people were saying about zones. It seems to me that an important part of this study is to discover what is the smallest viable zone, or at least what is the range of area necessary to protect the "wilderness zone", or "fishery zone" - Dr. Mather?

P. Mather: I would like to start off Mr. Chairman by very thoroughly agreeing with Dr. Goldman - I think he is absolutely right about biotic corridors. I would recall discussion (that followed Professor Talbot's paper) in regard to the probable route by which you get interconnection between reefs, and that is the floating larvae. No matter what the use of a particular reef (as long as you have viable populations on intervening reefs), the biotic corridor will probably be preserved. This is what is meant by biotic corridor.

I would also like to comment on the term fragility that has been mentioned by several groups. There has been much debate as to whether the Great Barrier Reef is fragile or not, and yet I feel that the only true fragility that has been identified to date has been confined to a few vertebrate species like the dugong and whales. This does not meant that there is not a very complex fragility (as Dr. Bunt reminded us). This ecological fragility - if it exists - is not understood. It is very relevant and central to modern ecological theory. The Authority will need to assume for the present that the system is fragile and maintain the environment in such a condition so that the habitats and their biota might continue to survive.

Finally I would like to point out that there was a consensus that knowledge on the chemical processes of sedimentation and lithification have a high priority of research.

F. Talbot: Firstly, we have talked a lot about ecosystems and management when we do not really know anything about the ecosystems. I would remind you that we are really like a group of intelligent chimpanzees looking at a Rolls Royce jet engine and we should not really talk of management.

Secondly it seems throughout that we are still bringing terrestrial concepts to a marine area. We are talking of zoning, and thinking in our minds of circumscribed areas as we have been forced to on land. I am a little concerned that maybe we are handling a system which is so broad that we are dealing with an area extending from the bottom end of the Great Barrier Reef right through into the central west Pacific. Perhaps we should not be thinking so much in terms of circumscribing areas, but in terms of looking at the whole area and trying to keep it healthy.

N. Webb: I would just like to comment on Session VI. We were asked to examine and we did so in this sequence, criteria and categories for zoning and then went on to methods of regulation. I do not object to that sequence. I just want to suggest that at some stage though in the process of addressing these considerations, we run that through backwards and start with the administrative problems and the enforcement problems going backwards through to the criteria and objectives.

J. Oliver: I feel that the Authority is thinking of a dynamic approach in management terms, and that much of the discussion of gaps in information tends to have rather a static viewpoint in terms of processes, in terms of distributions, variability and the dynamism of the natural environment. I have a specific personal orientation here in a concern for climatic change, and it seems to me that much of the crystallisation into zones, the crystallisation of distributions, perhaps the study of processes, is in danger of being undertaken in a static rather than a dynamic situation.

J. Bunt: If I might add a word or two here as this is a little bit of one of my hobby horses. There is the symptomology of a reef where you have a "body" and it has a "pulse" a "heart beat" and a "temperature", and these are the results of the inputs. In terms of a reef these are the resource transformations and the products; it is spelt out in our discussions and it should not get buried, for this is perhaps more critical in terms of our monitoring than anything else we can do.

Chairman: Thank you Dr. Bunt, and here we must conclude this specific discussion on Sessions V and VI.

THE END